Appropriate architecture for southern Sudan
design and construction method for the Solid House Foundation

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Appropriate Architecture for Southern Sudan
Design and Construction Method for the Solid House Foundation

Willem Doreleijers
Appropriate Architecture for Southern Sudan
Design and Construction Method for the Solid House Foundation

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Framework for the study

Introduction

Part A
- SHF vision

Part B
- Rumbek, Southern Sudan

Part C
- Project examples & guidelines

Research

Results

Design
- Designing
- Check applicability
- Conclusions
- Further research

Forms, Functions, Execution, Lifespan
- Results: Models (Guides)
- Pilot Building

Implementation

Part D
Summary

This report presents a research (Parts A, B & C) and a design development and proposal (Parts D & E) for a habitat project of the Solid House Foundation (SHF) in Rumbek, Southern Sudan. The framework on the left shows the structure of the project and the report.

The principal research question for this thesis is:

What could be an appropriate self-help building design and building method for a habitat project in Rumbek, based on the vision of SHF?

Part A The Solid House Foundation
The vision of SHF supports dome building as well as any other alternative building method. However, an alternative building method adapted to a local situation would lead to more self-help building promotion, better cultural acceptance and less energy loss in extensive construction supervision and training.

Part B Rumbek
Literature research, extensive interviewing, workshops and observations in Rumbek are the sources for the presented information that may concern anybody who is active in the field of habitat in Southern Sudan. A selection of the facts will be used for design development of housing. The main conclusion is that the design should be focused at the Dinka in Rumbek, who strongly desire for a more durable/modern way of building instead of their fast decaying traditional huts called tukuls.

Part C Appropriate Building
To respond well to the climate of Rumbek, stimulation of shadow and cross ventilation are essential.

Throughout the research a list of factors is developed for assessment of comparable examples of projects for habitat in developing countries. The ten factors are: Affordability, Cradle to cradle, Environment response, Demand driven, Participation, Capacity building, Social acceptance for the long term, High quality, Cooperation with local parties and Technical acceptance for the long term. The comparing of examples has led to some important decisions.

Part D Design Development
The results from parts A, B & C lead to the following design question:

What could be an appropriate design for a self-help house in Rumbek, if it should be affordable, durable, environment responsive and both social and technical acceptable for a long term?

Part E Final Results
SHF domes should preferably be built as facility buildings, sanitation in the case of Rumbek. Because of the exorbitant prices of cement and rebar, it would be recommended to start a research and development process for ferrocement dome structures - which use less cement and almost no rebar. Considering domes (for housing) in Rumbek, adaptations for the climate response as well as the social cultural acceptance deserve some special attention.
The final proposal as an alternative for the SHF dome for Rumbek consists mainly of Compressed Stabilized Earth Blocks (CSEBs), Compressed Earth Blocks (CEBs) for interior walls, Concrete Blocks (CBs) for the plinth and wooden trusses to support a roof of iron sheets.

The images on the left show the proposed model.

Answering the design question

Affordable durability:
Use CSEBs and CEBs. CSEBs are termite resistant and the production of CSEBs is likely to generate income.

Environment response:
Use CBs for a waterproof plinth and a large roof are the good hat and the shoes for the house. The steel roof supports rainwater harvesting. The single banked structure stimulates cross ventilation.

Social acceptance:
By using results from the field research (Part B) and involving the voice of the Dinka, the design is adapted to their social cultural background.

Technical acceptance:
Masonry is a way of building within the tradition of the Dinka and trusses with iron sheets are increasingly applied as more modern/durable ways of building.

So why not choosing for the dome concept or just building the way they already do in Rumbek? That would be because the proposed house is:
- as durable as the dome is;
- less expensive than the dome, but some more expensive than a ‘modern house’ in Rumbek. However, aesthetics and other advantages will be decisive;
- responding well to the climate (a little better than the very comfortable local tukul);
- responding to some explicit wishes of the Dinka;
- adapted as much as possible to the local (Dinka) ways of building.
INTRODUCTION
Preface & Acknowledgement

Ever since I first saw the extreme contrasts between rich and poor in Mexico City I intended to do something with it. Mexico was a study trip in my second year at the university with a group of students from the same faculty. We were guided into the slums by Roel van Rooij from Homeplan, who was helping with executing small (imported) houses for the poor communities there. Roel later asked the whole group about their interest in an architecture study which is focused more on its social role in a society with much inequalities. I let him know that I was interested, but since nobody ever responded to him, a general interest to bring this theme to more people’s attention seems to be non-existent. So I was making my own plan. This thesis is the result of it.

Within the architecture study there are many specializations. The specialization ‘architectural design’ is by far the most popular one. To me, designing a building means to take into account the surroundings and the people. For us Europeans it is most interesting to train ourselves in designing modern buildings with modern techniques. The more advanced the design, the more expensive it becomes, is a conclusion from many architects. So there is a challenge in making a good design for low cost. Doing so, I think one of the lead motives to design for, is the social significance involving peoples’ wishes. Then why not think about designing for a country outside Europe, for people who are not trained to design like us, dwell in self made sheds and aren’t living, but surviving? Of course, when you want to work in Europe it is more fruitful to focus on luxury and advanced building designs. But if just a small division of all architecture students used their (joint) effort to contribute to the field of social design in underdeveloped places in the world, it would make a huge difference. This coverage is silently screaming for more professional-practical and scientific attention for habitat in developing countries.

Before starting this project, I got in contact with the Solid House Foundation. The director Wim Stroecken was happy to have me doing a graduation project for his young and growing foundation. I was happy to start a project that would actually be of practical value. To make the project as realistic as it needs to be, a trip to the location was necessary. I don’t know how to express my gratitude for the support that was given to make this trip possible. Not only the trip was great, but also the hospitality that I encounter every time I enter the office in Utrecht. I will never forget it and hope to continue delivering contributions in the future. I am also very grateful for the support from Richina de Jong, Berthe Schoonman and everyone from the architects think tank of the SHF.

Furthermore, my gratitude is for Tomas Viguurs, who supervised me in Rumbek. His critical and constructive view on the research setup, his experience in the field and learning me how to work more efficiently while executing research were of great value.

My gratitude goes to Peter Erkelens, who supervised the whole project and kept giving me positive energy. I thank Arno Pronk who first got me in touch with the Solid House Foundation. He started a research project and involved me in it. The results from these students were a very pleasant start of my project.

I am grateful for the extensive input that I got from René Dierlez, who shared his expertise in building in tropical areas - including Southern Sudan. I want to thank Mathiang Angotc, for sharing his personal background as ex-inhabitant of Rumbek. More gratitude goes to Karak Mayik, who was willing to use her time to comment my ideas about housing and allowed Tomas and I to work in her office.

I want to thank Marieke, who kept supporting me during the whole project. Her patience and helpfulness gave me much strength. More gratitude goes to my parents, my friends and everyone else I didn’t mention by name.

Willem Dorleijers
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First MDG scheme

(Political) Action against world poverty:

**The Millennium Development Goals (MDGs):**
1. Eradicate extreme poverty and hunger
2. Achieve universal primary education
3. Promote gender equality and empower women
4. Reduce child mortality
5. Improve maternal health
6. Combat HIV/AIDS, malaria, and other diseases

7. Ensure environmental sustainability
8. Develop a global partnership for development

[http://www.un.org/millenniumgoals/]
Chapter 0
General Introduction

1 Theme & Definitions
An important motivation for this thesis is the urge to apply architecture and building technology with a strong emphasis on the social aspects: building for people who need shelter as a primary basic need.

Focusing on the effect of building (within habitat projects) on the standard of living, the purpose is not building itself, but a long run socio economic development. An important purpose is to stimulate and motivate people to think more about their future and less about their primary needs. Thinking about the future involves the development of local economy, education, health care, etc. In short: the long run development of a healthy habitat with a dedicated community.

Definition of the theme:
The development of a building design for a habitat project (in Southern Sudan) with the purpose to stimulate a durable development. Construction is one of the many means to carry out a habitat project.

The Solid House Foundation (SHF) from Utrecht, the Netherlands, realizes habitat projects with the same purpose as mentioned above. This Dutch NGO offered their contribution to this master's thesis. The vision of SHF, as it is received as a very valuable one, will be the basis for the research and development for a building design and a building method to be implemented in Sudan. SHF offered their guidance for this project, because the focus of the result will be one that is useful for the current SHF project under development in Rumbek, Southern Sudan.

For better understanding of this report a short introduction of the most important vocabulary:

Appropriate architecture
Building based on local conditions and needs.

Habitat
Apart from the built environment for living, habitat is strongly related to culture, education, health, safety, community spirit, socio economics and more. Habitat is a certain definition of society with an emphasis on the (built) environment.

Building method
A particular building process that leads to a certain form. A specific building method could be well-defined by a step by step manual.

Long run development/sustainable development
The continuous increase of the quality of life and wellness, taking into account the future generations. This definition will be discussed in §1.1.1.

2 Social significance
The theme is a definition of social significance. With habitat projects like SHF develops them, a worldwide problem is partially solved: poverty. There is an explosive growth of the part of the world population that is living in underdeveloped areas with a low standard of living.

The scheme on the left makes clear what this thesis is part of, according to the Millennium Development Goals. The Millennium Development Goals (MDGs) were developed out of the eight chapters of the United Nations Millennium Declaration, signed in September 2000.
Second MDG scheme

**Fight against world poverty:**

**MDG's**
1. Uitbanning van extreme armoede
2. Alle kinderen naar de basisschool
3. Vrouwen en mannen gelijk
4. Minder kindersterfte
5. Minder moedersterfte
6. Bestrijding diverse ziektes

**7) Ensure environmental sustainability**
8. Werelwdjijd partnerschap voor ontwikkeling

**Other aspects**
(infrastructure, safety, facilities, energy, living comfort)
The first scheme shows that an organization like SHF is contributing to the fight against world poverty, but only for a small part of the total goals. However, taking a closer look at what a habitat project really signifies - at least the way SHF promotes it - there is much more involved.

The MDGs related to what SHF does as a habitat organization:
- Goal 1, 4, 5 & 6: the development of a better living environment is inevitably concerning poverty, the health situation and thus the death rate.
- Goal 2: education and building of schools is a substantial part of a habitat project.
- Goal 3: extensive consultation with women, as they are the heads of the households, is an important focus of a habitat project according to SHF.
- Goal 8: Local partnerships and good connections with organizations in the same work field are a prerequisite for successful projects according to SHF.

Conclusion thus is that the first scheme does not show the true relations between the aspects of habitat projects related to the millennium development goals. The second scheme - on the left - shows a more justified image of the relation between the subject of this master's thesis and the fight against world poverty.

The reason for showing not only the true meaning of habitat, but first the official and political version, is to bring the phenomenon of habitat into the spotlight of development work with a very high value for beneficiaries. Habitat projects are often not directly recognized as substantial help with a positive effect on the future, because the results of habitat development are hard to measure. Much harder to measure than the construction of pumps, treated people at emergency hospitals and distributed bags of rice.

3 Scientific relevance
This thesis is written for the specialization 'Lifespan' within the field of Building Technology. The sustainability and therefore the lifespan of the built environment will be approached in two ways:
- The design of an environment responsible house model;
- The new housing model will be aiming at the support of the local economy and thus further development of an independent habitat.

The design will be a search for a better alternative for the current building designs and methods in Southern Sudan. The eventual results will also be of value for the SHF, as they requested to add a second building method to their portfolio while at the same time evaluating their dome concept for the location of Rumbek.

For the local research in Rumbek a question list has been developed with the purpose to be useable for habitat research all over the world. A consortium called EVOHOME, founded at a Red Cross symposium in Eindhoven, intends to use and possibly further develop this list/guide for the local research. See Annex 2 for more information about EVOHOME.

An interesting issue for mapping - setting up a professional information network - is the current lack of practical and useful information for housing projects in developing countries. Many organizations in the same field do not have the means or the time to share their knowledge. Within this report some projects will be discussed along a measuring instrument which may be useful for both future initiatives and future evaluations of habitat projects in developing countries.
Logo SHF
.4 Principal research question and sub-questions

.4.1 Conceptual model

.4.2 Objective -within the research-
To develop a self-help house model for a habitat project of the SHF, based on local conditions and needs.

.4.3 Principal research question
What could be an appropriate self-help building method and building design for a habitat project in a developing country?

Prerequisites
I: Based on the vision of SHF.
Apart from the vision which will be explained in the chapter on the SHF, the research part about examples will aim at further development of SHF's vision.

II: Based on the local conditions and needs of/appropriate for Rumbek, Southern Sudan.
A local research mission in Rumbek will be an inevitable step to gain answers to the principal research question. Preliminary research pointed out that social acceptation related to the local conditions and needs are most important for any successful development. The only way to properly chart the local situation is to visit and analyze for this specific purpose.

Sub-questions
Part (A): What does SHF do and what are the prerequisites for their actions?
A1. What is the vision of SHF?
A2. What projects has SHF been doing and what are the results?
A3. What building method does SHF use?

Part (B): What should we know from Rumbek, Southern Sudan?
B1. How can the environment of Rumbek be described when analyzing the demographic, economic, social-cultural, technological, ecological and political aspects? (déstep)
B2. What actors are involved with habitat development in Rumbek?
B3. What aspects of the built environment of Rumbek should be considered valuable for development of a habitat project?

Part (C): What can be learned from examples in the field of habitat for developing countries?
C1. How should a building respond to the climate of Rumbek?
C2. What are the most important aspects to consider for habitat projects according to experts/expats from the field?
C3. Which results from other projects might be useful for application within a new habitat?

.5 Desired Results
Goal: a building method and design, further developed by SHF in a partnership with local stakeholders and beneficiaries. The aesthetic and functional design will be a case study explicitly interpreted as one (or a few) of the possible options for reconstruction and development.

SHF wishes to continue and implement her policy and vision on habitat programmes, while continuously broadening her perspective. In this report some examples from experts and projects from other organizations contribute to an evaluation of the vision of SHF.
INTRODUCTION

Framework for the study

Introduction

Part A

SHF vision

Part B

Rumbek, Southern Sudan

Part C

Project examples & guidelines

Research

Results

Designing

Forms, Functions, Execution, Lifespan

Check applicability

Conclusions

Results: Models (Guides)

Further research

Pilot Building

Implementation
The input for the research will focus on Rumbek. The possibilities and impossibilities of the local situation, geophysical and climate conditions determine the technical solutions. Example of results may be the possible use of certain materials. Furthermore there should be an exploration of socio-economic and cultural aspects and preferences of the local community. Adaptations of SHF to the local situation guarantee the applicability and desirability of the project.

The intentional pilot project resulting from this study will form an example to the local inhabitants as well as local builders in the vicinity of the pilot project. The envisaged effect of this trial should be an appreciation of the designed building method, which should be faster to construct, cheaper, culture respecting and replicable for (assisted) self-help housing.

The best suited building design and building method will be presented in the form of a series of images of execution steps. Like the one that is visualized here for the dome building concept of SHF. Simple drawings and scale models are important for a correct transfer of the developed idea.

.6 Organization of the report

.6.1 Project framework
The three parts that represent the sub-questions in §.4 are the fundamental subjects for this thesis. The framework visualizes their input (Parts A, B & C) for the eventual designing process. Within the phase of the design a constant cycle of looking back, thinking forward and gaining feedback from relevant sources will be very important.

The result, a building method and design, will be used in the implementation phase which goes beyond this master's thesis, but certainly is a near future goal. The final model will then be discussed with local parties and will be built if all circumstances allow so. At the same time a new research will be started up, continuing at the point where this report ends.

.6.2 Chapter sequence

Chapter 0 General introduction.
Introduces the research idea, objective and method to be followed.

Every chapter of the parts A, B & C is introduced with a repetition of the relevant sub-questions from §.4 in a grey box.

Part A - SHF
Chapter 1 SHF.
Introduces and examines SHF. The basis of this project is their vision. But some comments about how to realize -parts of- that vision are necessary and form a basis to develop a new idea.

Part B - Rumbek
Chapter 2 Rumbek: Factors & Actors.
This chapter is a start up of the exploration in Rumbek. It includes some literature study and additional field research information. The conclusions are not all of value for the designing process, but are foremost of interest for SHF and possibly other initiators in Rumbek.

Chapter 3 Rumbek: Built Environment.
This chapter contains the main research results from the local research mission in Rumbek. The information in this chapter is quite extensive and should be narrowed down for part D. However this chapter presents all the information because it contains references for further research and development.

Part C - Appropriate building
Chapter 4 Climate Response.
About possible solutions for a climatologically responsive and thus comfortable building for specifically Rumbek.

Chapter 5 Projects for Developing Countries.
Here a number of example projects within the field of habitat are
The human eyes and brain connection:
compared. Therefore an instrument to make a justified comparison is developed. The conclusions are valuable for SHF and for shaping the right vision to start designing.

Part D - Design Development
Chapter 6 Design Suggestions.
This chapter contains the design vision and a new and more specific principal (design) research question. A strategy is presented as a direct answer and a foundation for the final results.

Part E - Final Results
Chapter 7 Domes in Rumbek.
Using the same vision from chapter 6, this chapter recommends SHF if and how to construct domes in Rumbek.

Chapter 8 Final Design.
The final proposal -as an alternative for the SHF dome- is presented and explained.

Chapter 9 Final Conclusions.
This is where the dome and the proposed model within this report are compared for the situation in Rumbek. Furthermore the recommendations for further research are presented.

.6.3 Lay-out
The report is designed to be orderly, most of all concerning the combination of text and images. To realize that, the pictures are almost always situated on the left and text on the right. This idea is based on the way the eyes send their information to the two different brain parts. See picture on the left! To confirm the rule, sometimes exceptions are necessary. That will be the case when pictures are inevitably related to text but take more space than the text. The pictures will not be numbered, but will be titled. A list of all pictures therefore will not be necessary, because the pictures are always related to the text and form a parallel story.

.6.4 Appendix
The report before you has an extensive background. That is why the appendix is an important accompanying bookwork. The first Annex contains the process and reflection of the author (in Dutch). This report shows the core of the project and is kept as slim as possible. The contents are thus somewhat shifted towards the annexes. This enables a clear overview for the reader with two hard copies.

.7 Literature
Recommended literature for introduction to the subject.
- Website of the SHF: http://www.solidhouse.nl
- Website Habitat for Humanity: http://www.habitatforhumanity.org.uk
- Website of the UN: http://www.un.org/millenniumgoals
- Dierkx, R.J, 2002, Cool Schools For Hot Suburbs, models for affordable and environmentally responsive schools in Nairobi, Kenya, Faculteit Bouwkunde TU/e (proefschrift, bouwstenen nr. 67)
Part A:
THE SOLID HOUSE FOUNDATION
Chapter 1

SHF

What does SHF do and what are the prerequisites for their actions?

A1. What is the vision of SHF?
A2. What projects has SHF been doing and what are the results?
A3. What building method does SHF use?

"Solid House Foundation's (SHF) objective is to create social housing, education and permanent infrastructure for low income groups in developing countries, providing safe housing which has a positive effect on the health of people. By involving the target community actively in the projects, SHF also generates economic activity and stability and contributes to the quality of communal life." [SHF, 2005]

SHF is a relatively young and small organization, founded in November 2003. Their purpose is to develop and realize durable housing for low income groups in developing countries. A purpose that contributes to the world housing problem.

SHF so far only built domes, called SolidHouses. This does not mean that building domes is a focus of SHF. Nor does it imply that building is seen as the main activity. It is about the whole process entailed in the activity of building. About an integrated approach. That's about teaching the target group how to build, stimulating local economy, making financial plans, community building, improving health, safety and so on. They aim at adopting a competitive position towards local systems.

1.1 Vision

Developing a durable solution for social housing has to be viewed upon as a very broad business. A key issue concerning this, is Social Engagement. In this case social means a demanding target group, participating, taking responsibilities concerning organization and finance. But it also means that the target group executes the work that has to be done. SHF does not wish to show their performance by means of realized buildings, but above all the quality of knowledge transfer is important. It's about improving the peoples' ability to live (capacity building) and their dependence.

Above all, a mobilization of a community is very important, by means of building durable and solid houses for the future. The broad mission of mobilizing a community involves subjects like housing, education, economic development, health, safety and community creation/education. Thus, by involving the target group as the very active body of the project, there are two goals to be accomplished: the technical goal (create shelter) and the social goal (improve skills and stimulate mobilization of a community)

The vision of SHF can be summarized as follows point by point:

1. Durable solution
2. Cost effective; affordable for the target group
3. Participative approach
4. Improvement of community spirit (capacity building)
5. High quality living environment
6. Improvement of independence and responsibility
7. Demand driven projects
8. Cooperation with professional local parties
9. Ecological and social responsible

The requisites for a SHF project can be summarized exactly according to the summary of their vision stated above. The description in §1.1.1 about the attitude of SHF towards sustainability is an important ingredient for a critical point of view.

1.1.1 Hypotheses towards long run development

One of the requisites for SHF projects is the durable solution. Nowadays everything has to be durable/sustainable and slowly people are misusing
The three legs of 'Sustainable Development'
these words to make a profit. The significance of the word 'sustainable' has become too broad. That is a reason to replace the word by 'long run development'. This is also a very broad subject and therefore has to be defined. This definition will be described in this paragraph, according to the vision of SHF.

The approach of SHF towards a sustainable development.
The main question is: how would SHF most ideally stimulate/contribute to a sustainable development in a developing country?

A main rule for SHF activities:
With their efforts SHF wishes to contribute to adequate, context sensitive, functional and accepted habitat and livelihood solutions with an enduring impact (for several generations, say 80-100 years).
[W. Stroecken, 2007]

This greater picture consists of three main fields of interest: Technical, Social and Economic sustainability. These are the three legs of the tripod. If one leg does not function, neither will the tripod.

How does SHF make sure every leg of the tripod is supportive? In developing countries, there is lot of difficulty in forecasting or guaranteeing existence of certain elements of one of these three fields in the long run. In fact nothing can be guaranteed. This is why organizations like SHF organize activities to maximize the likeliness of arriving at a sustainable impact through cooperation with credible and capable locally embedded partners. The most important parties are the beneficiaries themselves.

On the one hand, the assessment of feasibility of sustainable development needs some experience. On the other hand the likeliness can be supported by a local network. When social and economic circumstances are supposed to be stable and/or growing, only then the time has come to work on technical sustainable solutions.

Another factor is Ecology. This factor may play a role in the three main aspects. For example when sand for construction is obtained from e.g. a neighbouring village -instead of 100 km away because the sand quality is different- it has positive effect on local economy and on social relations with the village.

Since SHF is a young organization, it can until now not be said if any project realized was a sustainable one. An important factor for the near future is the evaluation method. SHF only intends to evaluate rather than intervene when errors are noticed in completed projects. This strategy is focused on learning and at the same time not making people dependent on activities of SHF. Independency is also a form of sustainability.

1.2 SHF Projects
SHF has currently completed two projects, has two projects running and has two projects under development. One of the latest developments is the research and starting up of a project in Rumbek, Southern Sudan.

The first project for SHF was the building of eight small and two large domes for young families in El Alto, Bolivia. They were built by 28 'shoe-shine boys' from the neighbouring city La Paz who were trained by SHF in cooperation with the Bolivian building company IAA. The first two domes were built on the IAA terrain to experiment and to have show models. IAA offered seven of the 28 boys a permanent contract.

A project called Guaguazu is starting up, concerning 12 villages which are connected with a factory that extracts materials from a local fruit. Because the factory is being professionalized, the workers will earn much more and may become able to get involved in an innovative micro financing system for housing.

In Kenya, about 20 kilometers from Nairobi, SHF built two domes together with NACHU (National Cooperative Housing Union). NACHU supports habitat and housing initiatives and executes social housing programs. The
Part A: THE SOLID HOUSE FOUNDATION

01 - ditch for the foundation
02 - more concrete
03 - reinforcement on the tamped concrete
04 - installations
05 - strip for the balloon
06 - balloon under the strip
07 - making the balloon airtight
08 - ready to go
09 - applying rebar
10 - attaching rebar

SHF building method in 28 steps
two domes function as meeting places and are housing small enterprises. The goal is to get people acquainted with the concept of the SolidHouses and experience a dome from the outside as well as the inside.

A second project which is still running in Kenya is the development and pilot construction of an ablution dome, connected to a girl school. The ablution block will be executed with a bio digester, minimizing the environmental impact. SHF works together with WASTE and practical Action, both parties having experience in the field of appropriate technologies.

A new project starting up is called ECO TACT, which is about building 1000 toilet blocks for 1000 schools in Kenya.

In east Sri Lanka SHF has been re-constructing a village called Inspector Eastham since May 2005. This new village will be housing about 56 Tamil families who lost their homes after the Tsunami and civil war which is still going on. SHF works together with the local Sewalanka Foundation and the local Community Based Organization (CBO). Together they founded the sub-division Solid House Foundation Lanka, SHFL. At this moment SHF is retreating because most goals have been achieved. In chapter 5 this project will be subject of a short analysis.

This research aims at the development of an SHF project in Rumbek. The project started with a Fact Finding Mission together with UN Habitat in March 2007. The intention of the project is to start with a pilot of sanitation domes, expand to more areas and eventually start a habitat program.

1.3 SHF Building method

SHF's concrete domes, or 'SolidHouses', are constructed with pneumatic formwork. This concept originates in Texas, where the Monolithic Dome Institute (MDI) trains people to build their own dome.

The pneumatic formwork is produced by BingFo in the Netherlands and transported to the location. Other materials are purchased locally. After the reinforced concrete foundation ring and floor have hardened, the formwork is fastened to the foundation. The formwork is inflated using blower fans (and a generator). Rebar (diameter 10 mm) are tied around the balloon in meridional and circumferential direction, resulting in a framework of maximum 25 cm spacing.

The vertical rebar embedded in the foundation ring are attached to the steel reinforcing of the dome itself.

Pieces of plywood or board are used to make the formwork for window and door openings. Additional rebar is added. Concrete is applied in two layers of about 3 to 4 cm each, applying the next layer when the concrete is hard to the touch. The layers can be hand applied or 'flipped' on by using a small mason trowel.

After the exterior concrete has cured enough to stand, the formwork is deflated and removed. Usually the concrete will be strong enough in 24 hours after the last coat. The exposed rebar on the inside of the dome are brushed and then coated with a layer of about 1,5 cm of concrete.

The inside should be coated with plaster. The outside should be coated with an elastomeric coating to help with solar reflectance and to protect against possible leaks from hair line cracks. The domes are hemispheres, some elevated on a cylinder of one meter. The hemispheres have a diameter of 6, 9 or 12 meter.

On the left a sequence of pictures starts and continues on the following pages, to show the building method of SHF in 28 steps.

1.4 Criticism on SolidHouses

SHF realizes they need more than one possible offer for a building project. An expansion of their portfolio is one of the reasons for the support they granted for this graduation project. Speaking with people on the university about this thesis, some of the fellow students seem to know SHF. A critical view upon the building of domes used to be and still is their first reaction. After getting acquainted with (members of) SHF it should be
admitted that the critical view on the building of domes hasn’t changed a lot, but much appreciation has risen for the philosophy behind the visual results (concrete domes) of SHF. Apart from this appreciation it is important to find out where the criticism on the dome buildings of SHF has its roots. To give shape to the critics on dome building, the next paragraphs contain arguments for the choice to support SHF by generating other building methods for which this thesis might be of practical use.

1.4.1 Pilot Project Nayan Utaya in El Alto, Bolivia
The first project of SHF was completed in 2004. It took place in Bolivia, where a group of young ’shoeshine boys’ completed 8 homes in El Alto.

Problems experienced in Bolivia had mainly to do with the air pressure of the formwork. Problems with the concrete quality occurred due to the extreme climatic circumstances, which resulted in extra coating material, an increase in shell thickness from 8 to 10 cm and an increase in rebar diameter of 8 to 10 mm. In the evaluation report the importance of the right mix and the treatment during setting of the concrete are stressed. Also requirements for the coverage of the rebar is given: a minimum of 2.5 cm on the outside and 1.5 cm on the inside.

The putting on of the concrete mix on the balloon is hard work and not easy, because of the coarseness of the material. There is a lot of lifting involved to get the concrete higher and higher to the top. The balloon doesn’t support people standing on it, but this still happens because of the very awkward body movements needed for applying the concrete mix. The thickness of the mix is necessary for not directly sliding of the balloon, but the result is not as prescribed in the manual (which should be layer by layer). When the dome has dried, one can see the variable thickness, rebar still visible, electricity cables and even a small stroke of the sunlight coming through. A second layer -the plastering- should cover all these imperfections.

Speaking of quick self-help building, the method of dome building is not smoothly applicable. It’s hard work, complicated and technically troublesome for laymen. With a lot of guidance and training one may become experienced enough for independent building of SolidHouse domes.

Anneke added some remarks concerning the balloon. She doubts the current balloon (with/without bottom, a possible valve, foot pump) and the necessary massive foundation. In short, she wishes simplification of some forms and of the whole building process/method. Of course, experiencing the building of a pilot model doesn’t mean experiencing a smooth process. It is a trial and its purpose is to improve future activities.
One of the first SHF domes in Sri Lanka
The report argues the tension between the form and building site. In an urban situation the needs (water, Electra, materials) can be satisfied, but the form is less defensible ((vertical) expansion). In a rural site there is a lack of needs, but the form could be more appropriate.

Speaking of the dome form, this may seem a good modern connection with the round African huts, but Anneke suggests not to make this link too easy. She bases this on the fast changing of housing forms in yet developed countries and notices this possible linking as a conclusion drawn too fast. There's more in a culture than just what you see, so an extensive research about the social cultural situation is inevitable.

1.4.3 Carli Hammer’s thesis reflection

Carli Hammer graduated with her report “Optimization of dome housing in Sri Lanka” for her master degree of civil engineering in the end of 2006. This report is linked with hers, as it continues to search for improvement of the building concepts that SHF applies within her projects. In her conclusions Carli argues the dome concept from a technical point of view:

“The strength of a dome is that it can enclose a large space with little material, facilitating a flexible lay-out of the plan as no bearing inner walls are necessary. In the current Solid Houses in Sri Lanka however, inner walls are made of heavy bricks and their placement is not even flexible as it need to support the first floor. One of the main problems after the construction of the dome has finished, is the partition of the inner space in a practical way, while at the same time creating supports for the first floor. Walls are sometimes built up to the roof, which requires a lot of building material while these walls are not necessary from a structural point of view. In other words, if brick walls are desired to divide the inner space up to the roof, why not use them to carry a roof? The ring tension and -pressure forces make a dome shell very strong. Openings however weaken the shell as the ring forces need to be diverted. In Sri Lanka inhabitants wish to have as many openings as possible in their homes.”

Concluding some of the main strengths of a dome shell are undone by the way it is now used. Why then construct domes when they are adapted to resemble a standard home as much as possible?

The SHF is aware of this contrast and would rather use light materials indoors to allow for future changes in the dome’s function, creating sustainable shelters. However, community building is at least as important for the SHF as ‘dome building’. Consequently if the inhabitants propose brick walls for the first dome this is not overruled. The change of the domes into a more sustainable practical solution should therefore be approached very delicately and be stretched over a number of ‘test-domes’.

Let’s suggest to use the shell only for the roof. This not only solves the problem of the anchorage of the inflatable formwork but also facilitates openings in the walls without weakening the shell. Yet the plan is still circular and partition walls will be made though they do not carry the roof. What is then the advantage compared to a house with a rectangular floor plan and a roof made of elements such as corrugated plates? And do these advantages outweigh the advantage of a rectangular floor plan?

A dome can resist earthquakes and survive other extreme climatic circumstances such as tornados. However as the shell is very exposed to the weather circumstances throughout the year, material use is very restricted. More important, the walls are not protected against direct sunlight, which is a disadvantage in a tropical climate such as Sri Lanka’s. Besides, for the construction of a house with brick walls and an overhanging roof of corrugated plates no formwork, nor electricity is needed. (…)

Yet it is likely to emphasize that one should not blindly press upon the application of domes for housing purposes. Care should be taken not to push people to live in an adapted dome while they would actually prefer a ‘normal’ house, which might even be cheaper and easier in construction as well. The Solid House Foundation is conscious of this issue, and therefore discusses the concept extensively with future inhabitants to be certain to provide them with a house.

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1 However, an elephant attack without any damage to the dome shell proved the strength of the dome with openings.
A graph to show the possible amount of energy that can be used for other on site activities than construction.

Note: The final target is the eventual improved living situation of the target community with good future perspectives.
that is according to their needs and wishes. At the same time this explains the apparent discrepancy mentioned above.

1.4.4 Conclusions
The critics from the technical point of view are very true. These critics are valuable arguments to develop a new building technology. On the other hand, for many technical problems are many solutions. Therefore advice about how to make the dome concept appropriate for SHF in Southern Sudan is presented in chapter 7.

The main reason for SHF to argue their use of the dome construction method, has nothing to do with the dome itself. It has to do with the process of institutionalizing a building design and method. SHF is concerned about the TOTAL process of improving lives of a community. Building technology is a means to achieve so. It is an input in the very beginning of the process of a habitat project. The objective of this thesis is about that beginning. To consider the whole process of a habitat project would be too much to take into account. The challenge of dealing with the technical input for the beginning of a habitat project is to get the building process started as smooth as possible. For dome building it is now known that people need to be trained quite well, as it is an unknown technique to many traditional cultures. To make this training less intensive by introducing easier techniques, much effort will be available for other operations within the same project. See the graph for a visual explanation.

An extra focus within SHFs vision for this project is that a building method should be introduced clearly as a self-help system. SHF may be building a number of the eventually proposed model in cooperation with a local community. But ideally any other community in the vicinity of these new houses should be able to copy it without needing any extensive training. For optimized dome construction people certainly need to be well trained.
Part B:
RUMBEK
The most important different tribes of Sudan in 1961
Chapter 2
Factors & Actors in Rumbek

What should we know from Rumbek, Southern Sudan?

B1. How can the environment of Rumbek be described when analyzing the demographic, economic, social-cultural, technological, ecological and political aspects? (destep)

B2. What actors are involved with habitat development in Rumbek?

In this chapter a combination of literature study and the local research results are presented. The model used to obtain answers for the fieldwork: Local Research Questions can be found in Annex 3.

2.1 Factors
In the following paragraphs which reveal facts about Rumbek, the ‘destep’ analysis methodology was used. This method was chosen, because it prevents from forgetting relevant matters and thus guarantees an exploration from A to Z. Destep is a method well known in the area of marketing and communication sciences and is short for the factors of importance for acquaintance of a geographical area: Demography, Economy, Social culture, Technology, Ecology and Politics.

2.1.1 Demography
About the people in Southern Sudan only estimates may give still an incomplete image of the demographical situation. Sudan has always been a shattered country looking at ethnical diversity. Southern Sudan always was and still is the most diverse part of the country.

In 2005 less than half of the original population lives in Southern Sudan, the rest is in the north or in neighbouring countries as an IDP. Right now they are returning. Numbers are varying from hundreds till tens of thousands. There is no clarity about these numbers at all, because of ongoing irregularities at most of the borders. When IDP’s come back to the ground they were born, they may find other people living there. This will be a difficult issue for the authorities to deal with in the near future.

How many people now live in Rumbek is unclear. But people do know about the approximate divisions between ethnical groups. The dominant cultural group are the Dinka forming 90% of the population. It is the largest tribe of Sudan, with about 2 million. The Dinka are leading the Southern Sudanese army, the SPLM. The Dinka people will be the same as ‘the people’ in the rest of the report, considering their vast majority in Rumbek and their specific culture.

Rumbek used to be a commercial urban centre for the Dinka and had more than 50.000 inhabitants (around the year 2000). Because of the civil war many people fled and have been very slowly coming back since 2005. Authorities of Lakes State now predict Rumbek to become a city of about 70.000 inhabitants. In the masterplan of the local authorities this number means that the urban area is to expand about 3-4 times its current size. The density of the whole area therefore will increase.

2.1.2 Economy
With fertile black clay soils, Rumbek’s dominant production system is agriculture. Although crops are of primary importance, livestock forms the main source of cash income for most of the inhabitants of Rumbek. Of the livestock the cows are most important, they are currently not only worth about 400$ a piece, but are the cornerstone of Dinka society. Sometimes a clan owns up to thousands of cows. The cash value of cows is inferior to the amount of cows owned. This is the biggest hindrance to the economic development of the Dinka.

In Dinka society men work and women take care of the men and the house. Women obviously do the hardest work as they take care of the whole family, fetch water, carry building materials, prepare food, etc. The men take care of the cows, often miles away from where they live.
Money and status

A Dinka man with his two wives
Many men work for the army, but also jobs at the market and new coming organizations are becoming important. Nowadays a smaller group of men work for authorities. Construction workers are mostly 'imported'.

Rumbek depends on agriculture in its rural areas, the region depends on import as well because of a lack of agricultural activities. Thus import is very important. Because import is very difficult (looting, corruption, very bad infrastructure, long term flooding), imported products are very expensive. Another reason why goods in Rumbek are very expensive is the influence of the UN (& the international community). Since 2005 UN started hiring local people as drivers. As they paid their drivers much too high wages for the local standards, the prices in the market went up.

Building materials are very expensive because they need to be imported. All materials in fact are very expensive because even the local material prices depend on seasonal influences. Furthermore prices vary per buyer, per month, per borderline (tax), per seller, and so on. [Anson Kowero, SSL]

In 2005, after a 20 year period of stagnation, the luxury goods such as mobile phones have reached Rumbek. People are now forgetting their true needs and start riding motorbikes, calling mobile, spending lots of money for their status. While they buy fuel or airtime which they can hardly pay for, the men forget the women back home with for example sick but possibly curable children.

Building good houses is next to owning cows, a means of showing status. Therefore building activities are an important economic activity. One of the very few reasons to sell a cow is to build a house (a tukul).

Only a very small amount of people with management capacities are present in Rumbek, virtually always educated in Kampala or Nairobi. Those are mostly the ones that do business, e.g. run a bar or a shop, or are involved in a commercial company, the government or humanitarian organizations. Not only businessmen, but also craftsmen are trained abroad. The local craftsmen are not capable of building larger or different constructions than their tukuls. For example a contractor from Kampala in Uganda works on the basis of a contract for the handing over of one construction project.

2.1.3 Social-cultural
The religion of the Dinka is Christianity. Also animism is still present, but catholic churches are dominating. There are some divisions of the Christian belief, but all are based on the bible. The religion is a very strong part of the culture. It is visible on rooftops of some proud house owners.

Livestock, especially the cows, are most important in the Dinka culture. Cows provide the most of the income of the families. Dinka family names are derived from their prettiest cows. Cows give necessary milk and meat and without cows a man cannot get married.

The main language is the Dinka language and the second official language is English. Education and thus learning English which is considered very important by the Dinka, is believed as most important to get a good job. Youngsters are willing to learn a lot for their living, especially now there is peace. This does unfortunately not mean they neglect the cattle, but a salary is a type of supplement for the income generated with herding.

Marriage is the highest social level in Dinka society. A good woman may cost up to 250 cows. Only after marriage one may have kids. Daughters are good for the collection of cows for the family etcetera. A Dinka may marry more than one woman. The more wives, the higher the social level and status. Newlyweds always build their own house and each wife gets her own tukul/room.

Dinka are organized in clans, blood related groups. Newlyweds start to live on the ground of either one or the other clan, marriage never happens inside a clan. Several (about 8) clans together are organized as so
A Dinka showing his certificate of achievement for (Hydraform) masonry, enabling him to build houses under contract for other families
called “sections”, a few sections together are a “payam”. Think of a payam as a number of villages. [Zacharia]

In general the Dinka are fast learning, proud, often not hard working and short-tempered people. Among NGO’s in Rumbek it is commonly known that Dinka drag each other -especially (white) people with money to court for every little thing. Dinka like to profit from any situation. Therefore it would be wise to have at least one Dinka working within an organization, because of good interaction with other Dinka, to prevent misunderstanding and to obtain a stable contact. [F.M.Deng]

2.1.4 Technology

In Southern Sudan there is a clear lack of advanced technologies. Traditions overrule industrial development, because people have never had the means nor the knowledge to start up any industry. The main reason is the lack of contact with more advanced -industrial- cultures, because of the enduring civil war. When first arriving to Juba -the capital of South Sudan- the only technology that is visible is carried out by the international community, humanitarian organizations. For example, the very first hardened roads are now being constructed by Chinese workers. The rest of the roads in the whole of Southern Sudan consist of murrum, a type of gravel, but mostly the roads are not more than dusty tracks.

2.1.4.1 Skills for construction

About 5% of people in Rumbek have some useful construction skills, most of them are from Kenya or Uganda. Because these workers are often based in their original country, they need a place to stay and to eat. For Dinka workers (mostly doing less difficult work) this is the same, because projects are often far away from their homes, while the infrastructure is underdeveloped.

In Rumbek town there are:
- ± 1000 masons (mostly Ugandan)
- ± 100 carpenters (mostly Kenyan)
- very few plumbers

Many Dinka are familiar with masonry, because building with mud blocks is a regular construction method. Building with bricks therefore is much more of a challenge. When for example larger blocks are used the skills are better utilized. Building with wood and bamboo is normal for Dinka, but the coarseness of the building technology shows that working in straight lines is unusual and apparently not easy to teach the Dinka well. A lack of skills to build larger constructions is clearly a problem. When seeing structures built by ‘amateurs’, one can see the ironsheet is dented, slantwise assembled on the construction. Ironsheets is another material they are not used to build with, because of a lack of tools and knowledge.

On the other hand Dinka are observed as very fast learners in the practical field, according to the Norwegian Refugee Council (NRC), which has been building many schools in Rumbek County partly together with the Dinka people.

2.1.4.2 Appropriate technologies

Technologies adapted to the situation of Rumbek, like solar energy panels (there is a present lack and need for electricity, only people who can afford a generator have electricity), rainwater or waste water harvesting systems (water for construction, for cooking and for drinking is becoming scarce for the dry part of the year), compressed earth block production or water purification systems, are technically non-existent. Only very few organizations make use of solar energy panels within their compounds. Also very few projects have been built with compressed and stabilized earth blocks.

Either one of these simple and easily executable appropriate technologies could provide a substantial change in the standard of living. Even a very simple product for the impregnation of wood, mud and thatching grass to repel termites could introduce huge changes. The change an appropriate technology would cause is true, because of a severe lack of electricity, (drinking)water and affordable durable quality housing.
Climate charts for Rumbek, based on:
Rumbek, Sudan; Latitude: 6.48N Longitude: 9.42E Altitude: 420m
The sampling period for this data covers 30 years from 1961 to 1990
Currently the only common present (appropriate) technologies are: traditional construction techniques for tukuls and compounds, clay block production, oil production, fired brick production, charcoal production and very little (quite bad) bike or car repairing. These are all traditional and low-tech technologies.

2.1.5 Ecology
The distinction of Southern Sudan with the rest of Sudan goes deep. Especially the extreme South and the Southwest, they resemble areas in Uganda and the Congo Basin. Southern Sudan has a different climate than the North, but also different soils, vegetation, population, agriculture and somehow farming.

Rumbek County lies in the so-called ‘western flood plains’ that span most of the Bahr el Ghazal region. The plains are prone to seasonal flooding during the May to October rainy season, with the lowest-lying areas (deltas) usually flooded by river water for up to four months of the year. For Rumbek the road connection with the South, necessary for all import, is cut off during one to three months a year.

2.1.5.1 Climate
The biggest difference between North and South Sudan is the climate. The South has a rainy season, while the North hardly receives any rain. The rainy season is longer than elsewhere, particularly in the South. Average annual temperatures are lower than those at most other stations in the country, but because the humidity is usually high, the climate is generally disagreeably hot. Climate graphs are from 1990, while right now in 2008 the effect of climate change is becoming a reality, also in Rumbek. A description of the current climate in Rumbek:
Rain starts in May and ends in November. During the rainy period the temperature rises to a maximum of 45 degrees in August. The night temperatures are about 10 to 15 degrees lower than the day temperatures, dropping to a minimum of 20 degrees. The dry season has some colder nights, with temperatures dropping to a minimum of 10 degrees in the months of December and January. (Even though this year the temperatures at night were much higher: 20 to 25 degrees) In March the night temperatures rise up to 30-35 degrees, the only month of the year when most people sleep outside. The day temperatures in the dry season rise up to 50 degrees.

See the chart of average rainfall and temperature & the chart of average sunshine and humidity on the left.

2.1.5.2 Land use
The Dinka are proud of their cattle and seem to ignore the importance of agriculture. Some families practice agriculture, but on a self-sufficiency level and not more. Many people in Rumbek think it is far too difficult to grow a few crops on their land. The supply of water is a main reason not to start, even though there are only 4 to 5 dry months a year. During the rainy season people don’t need to invest much time in growing crops, they also get it from the wild. Most people in Rumbek depend on the food supply of the market. Other families keep land outside the urban area. If they have enough land, they will sell some crops on the market. The people in Rumbek also depend on other goods from the market, such as clothes, bicycles, (fire)wood, charcoal and building materials.

The availability of building materials is a major problem in Rumbek, especially since the year 2005, when the rebuilding of many facilities started to take place. Those facilities are being built with the regular concrete, bricks, (hard)wooden frames, trusses and the necessary steel. That is the only way people want to have a durable building constructed so far. All those materials need to be imported from Uganda or Kenya. The only materials that are locally producible and available are bamboo (not used in modern structures), hardwood and fired bricks. Also local riversand, pisand and laterite rock for concrete is available. A problem with the fired bricks is the immense use of local trees for the burning process. Deforestation is becoming a realistic danger, especially in and around urban areas.
Part B: RUMBEK

Trash is a common item in the streets of Rumbek

Fetching water in jerrycans
The local production of charcoal contributes to this phenomenon.

2.1.5.3 Water and danger
There is a shortage of good water in Rumbek. Many diseases are spread through low quality water. Rumbek has many water points, but in the dry season much water is needed and many wells are dry. There are no water tanks with collected water from the rainy season. The water tanks that are present are used for professional construction projects. The first level of ground water is becoming more and more polluted. The pollution was heavy during the war, when bodies were thrown in wells, but it is restarting with an increasing pile of garbage (together with garbage and wrecks from the war) on the topsoil layer. Batteries and other harmful chemical goods are simply thrown on the land and leaking into it. It is only a matter of time for the water to become dangerously polluted.

Besides chemical danger, there is more danger for the health of the Southern Sudanese. Wildlife. Termites eat the tukuls, mosquitoes transfer malaria, scorpions wander at night, rats and bats live inside the tukuls, snakes enter compounds in the rainy season and hyenas hunt at night. Before the war there used to be lions, which attacked people at night. A reason why the original (rural) tukul was and sometimes still is built on poles. It is so far unsure if there are still lions or not.

2.1.6 Politics

2.1.6.1 Governing (South) Sudan
Currently the Sudan People Liberation Movement (SPLM) is governing South Sudan, forming the young and inexperienced GoSS (Government of South Sudan). The SPLM is the administrative arm of the SPLA, the Sudan People Liberation Army. Rumbek is the administrative centre for the SPLA. It was the SPLA/M which fought the North of Sudan and co-signed the CPA, the Comprehensive Peace Agreement in 2005 to stop the civil war. In 2011 there will be a referendum about the independence of South Sudan. Despite the CPA, there are still clashes between clans and Northern and Southern armies at the borderline, where the oil of Sudan is located. There is not much trust in a peaceful division of the Sudan, people in the South are still ready to fight. Which means that there still is no security for a stable situation. A reason for many Southerners not to invest too many in permanent structures.

2.1.6.2 Land ownership
Slowly the authorities are dividing land of urban centers into plots on a rigid grid, which will be sold and written in a register of deeds. The procedure and the outcomes of this urban policy are questionable. More about this issue in § 3.1.3.
MoPI (Ministry of Physical Infrastructure) of Lakes State requested an expat for long term urban development in July 2006. UNHABITAT first reacted positively, but never got back to MoPI for their request. UNHABITAT does a scoping mission in Jan-Feb 2008, an assessment of SS urban development. They want to fill knowledge gaps within urban governing. This mission is purely set up to identify the capacity needs of the local governments for towns in SS. In March 2008 results of this mission will be discussed and then concretized. UNHABITAT intends to send an expat who then trains people from the local government. But previous training programs seem to have little effect until now, according to the DG of MoPI.
A Dinka in Den Haag

A Dinka in Rumbek

Without titles

Dinka people
personal supporters of the program SHF wants to start up. Unfortunately the power of the SS authorities is limited because of certain contracts with the UN.

2.2.2 UN
The UN has many bodies. It is securing the CPA, mapping the security situation of SS and supporting to development as well as supporting NGO's. However their effective development role remains limited. The UN partly spoilt the local economies, uses more energy than the whole population of Sudan, and builds not with the people but builds for them, not considering long run effects. Beneficiaries may become dependent this way. The UN was the first reason for the SHF to get involved in Rumbek. UNHabitat invited the SHF to do a Fact Finding mission. The many bodies of the UN should provide many services, but their actual response is very low. A large part of UN personnel in Southern Sudan is proved to be incapable of doing the work they should deliver. Unfortunately, SHF has been experiencing these facts as the UN won't answer the request that SHF was encouraged to submit (encouraged by UN personnel in Southern Sudan themselves).

2.2.3 NGO's
Many NGO's were active in Rumbek, in many fields. During the civil war there was much emergency help. Very few NGO's however supported the construction of permanent structures. Some schools were built, most by UNICEF, but yet not sufficiently. The NGO's which focus on starting up sustainable development left soon after they came. There are some good reasons for these types of NGO's to leave the area of Rumbek. Next to the insecure situation it is the most expensive state of SS and the Dinka are very difficult to handle. The introduction of SHF therefore was received as very positive. The previous experiences of other NGO's are good examples for SHF to learn from.

2.2.4 People
Because of their overwhelming majority in Rumbek, the Dinka will be the same as “the people” for this thesis.

To get to know the Dinka, two Sudanese Refugees, now living in Den Haag, NL were interviewed. Mathiang was an inhabitant of Rumbek until 2002. The interview is included in Annex 4. Another action to get fully acquainted with the Dinka in Rumbek was the development of a series of appropriate icons to use for a smoother communication with less educated people. The icons as well as the translations from Mathiang are added in Annex 5. During the field research these icons seemed quite unnecessary, because many Dinka men were able to help me with translations from English to Dinka.

Dinka are available to act, learn and work for own good. They are willing, but have an opinion that is incredibly strong. Maybe stronger than other cultures in DC's, because SS has been standing still due to war for 40 years and even before that they were hardly in touch with any western culture, which now is their great example.

For about 70% of the people goes that the language level is very low: no or very basic English. The skills to make or understand an abstract drawing are limited; this is true for at least the inhabitants without education. Speaking of education, it is considered as most important in Rumbek. There are many schools and churches to support education. Some people, educated only in secondary school in Rumbek, seem to be educated quite well, making a better living than other Rumbek inhabitants who didn't get the chance to be educated properly (a war effect). A conclusion for this point is that there is a good capacity within Dinka groups in Rumbek, to build up a better level of abstraction.

2.2.5 Target groups
Women groups are willing to work hard. Because many men are part of the SPLA, they are not very stationary and travel a lot within the border-
Tents in Rumbek which serve as 'hotel rooms'
lines. As a result women organize independent groups, taking care of their own development. This group could be a valuable one for the SHF, considering a possible cooperation with the Women for Women International group, which already works with women groups in Rumbek.

Churches have a strong network and have an own budget for development work. Despite the groups which are directly mobilized by the church, the church masters form an important link to most social groupings in any community.

Any community is willing to have some young men trained for construction, but with sufficient additional education provided. Also some payment is necessary, and one has to beware of the greediness/hostility of the Dinka.

For communication towards the builders it is important to make drawings understandable. One way to do that is find a local contractor who then steers the other staff to build it the proposed way. The other way to do it is find as many creative ways as possible to make a concept clear, by means of realistic pictures, real-time models or models on scale.

To obtain the right people, one should contact an existing social and active organization, as described. The next step is to find trainers, or are people from a chosen group ready to be trained to train others?

2.2.6 Construction related companies
In and around Rumbek there are many active local contractors. They are profiting from the new situation of peace by building up the permanent structures for people but also for commercial organizations. The commercial world is thus stimulated by the rebuilding activities. Bigger organizations from abroad provide accommodation for humanitarian aid workers and incoming businessmen. They don't build enormous hotels, but rent tents, based on a concrete slab with sewer system, a double 'roof', electricity, and etcetera.

The many commercial construction related companies from abroad are a main cause for the one-sided example of the western way of building.

2.2.7 Neighbouring countries
Many educated people and trained workers come from Kenya and Uganda. Also Dinka who can afford it and long for a proper education often go to their neighbours. Some people from these countries act as expats, working for humanitarian organizations. But most come to Southern Sudan to do business. That business is varying from road construction to the selling of toilet paper.
It is important to be aware of the dependence of Southern Sudan on their neighbours, as the regime in the North of Sudan still doesn't care for the people of the South.

2.3 Factors & Actors
with value for (re)building in Rumbek
This paragraph summarizes the bare facts from the text in this chapter. This list of facts may be interesting for any organization which is active in the area of Rumbek or more general Southern Sudan. In part D, a few of these facts will be used to develop a building method and design.

Demography
• The dominant cultural group for this thesis are the Dinka.
• Rumbek may become a city of about 70.000 inhabitants while it now probably has less than 15.000. An urban masterplan has been approved for this expansion.

Economy
• The amount of cows imply the level of status of a Dinka, which is why they forget the importance of agriculture and investment in other business than cows only. But for the construction of a house people are ready to make a sacrifice because a good house shows status as well.
• Everything that is not produced in Rumbek is expensive, because import is heavily influenced by the rainy season and a weak infrastructure. Furthermore prices for imported goods vary a lot due to many different circumstances. For Rumbek the road connection with the South, necessary for all import, is totally cut off for one to three months a year due to the rain.

Social-cultural
• Marriage is the highest status in the Christian Dinka society. A man pays cows (dowry) to the family of the new wife. A Dinka preferably marries more than one woman for his social level. Newlyweds always build their own house and each wife gets her own tukul/room.

Technology
• Most Dinka seem to be no good in modern construction, but Dinka are observed as very fast learners in the practical field. Foreign contractors are recommended to train the Dinka.
• Technical solutions for the situation of Rumbek like solar energy panels, rainwater or waste water harvesting systems or water purification systems can easily be implemented and will surely have a positive effect on the standard of living.

The severe lack of affordable durable and quality housing may be solved by large scale implementation of locally produced Compressed Stabilized Earth Blocks. (see §3.2.4)

Ecology
• Roughly, Rumbek has half a year of drought and half a year with plenty of rain. The whole year the temperature remains high, therefore the climate is dual: Hot and dry as well as hot and humid. However the humidity is high for more than half a year. Good ventilation and protection from the sun are advisable during the whole year.
• The building of tukuls and the growing production of fired bricks in and around urban areas like Rumbek, are becoming a danger for the local natural environment. Deforestation is a true danger if burnt bricks are going to become a standard for modern housing.
• The first level of ground water in Rumbek is becoming more and more polluted due to dumping of (industrial) garbage and pit latrines.
• Biological dangers for the Dinka and their tukuls are termites, mosquitoes and hyenas among others. In rural areas a solution for larger wild animals like hyenas was building a tukul on poles. For storage of food this was also done to protect from animals like rats.

Politics
• The political situation is still unstable which is why many Southerners don't invest too much in permanent structures.
• A masterplan of an expanded Rumbek has been approved. Roads are under construction many tukuls are being swept away. GoSS has the power to have Rumbek built according to their urban masterplan; a grid of plots.

NGO's
• Previous experiences of other NGO's in Rumbek are examples which should be considered seriously, also in the phase of design.

People
• The western way of building currently is the great example for the Dinka. They do not care about the disadvantages, as status is their dearest wish. It would be best to aim for the good learning capacity within Dinka groups in Rumbek, to build up their understanding. Presentation of ideas for housing should therefore be adapted to a lower level of abstraction.
• A group of women would be a good choice as a target community, so a construction method should not be too heavy to execute. Young men from the community may reinforce. To train the Dinka for construction would be a smart step towards independency, because currently many workers come from neighbouring countries.
2.4 Literature

Next to own experience and results from interviews in the field, a quantity of sources are recommended to get acquainted with the situation in Rumbek. The first recommendation is a novel, which creates a sharp image of the life of a Dinka in times of civil war in Southern Sudan.


- Beurden, Jos van, 2006, *Sudan*, KIT Publishers (landenreeks)


- http://www.succese.org/blog/statistics


Part B: RUMBEK

A rural site in Southern Sudan

A huge Mango tree which serves as a meeting point

Bamboo fencing

A private shop on the edge of a fenced compound
Chapter 3
Rumbek: Built Environment

What should we know from Rumbek, Southern Sudan?

B3. What aspects of the built environment of Rumbek should be considered valuable for development of a habitat project?

This chapter has the core information for further implementation of this thesis. The used Local Research Questions are recorded in Annex 3. This question list contains a basis for finding answers to sub-question B3 and it was the basis for the interviews and observations in Rumbek.

3.1 Urban structure
In the previous chapter (§2.1.6.2) the urban policy was mentioned shortly. The local authorities in Rumbek, governing the whole of Lakes State, an area as big as Belgium, exist since 2005, the year of the CPA. The signing of the CPA signified that the North accepted the South as a temporary independent part of Sudan for the first time in history. A lot of new governing functions had to be filled in by Southerners which were inexperienced in the field of policy, because the Northern regime never acknowledged the people from the South as capable of governmental work. The MoPI (Ministry of Physical Infrastructure) is the newborn ministry that is now dealing with urban issues. From the start the minister and his director general (DG) are aware of the present lack of knowledge about urban development. Despite their requests for assistance (towards the UN) they are still acting with a few inexperienced inspectors for land and survey.

This section will not be treated extensively, because it may distract from the main purpose; to develop a building method and design. For a design the current urban and rural situations will serve as a context. However there is a remarkable development going on in the field of urban plan-ning in Rumbek and it will shortly be discussed together with its effect on housing. The development of urban planning in Rumbek deserves an explicit recommendation for further investigation.

3.1.1 Daily needs
In both a rural situation and an urban situation an infrastructure is based on the connection of households to several facilities which embody the needs of the people. In Southern Sudan a main need is (drinking) water. Many habitations grow when a water point is available. The infrastructure in Rumbek is therefore often based on wells and pumps. The urban centre in Rumbek however has many water points and therefore its infrastructure has changed to make more different services reachable. New needs are becoming more and more important since modern services have become available after the CPA. Needs like:

- electricity;
- more types of shops;
- bars or pubs;
- higher education or training centers;
- paid jobs.

These needs should be considered for the development of an urban structure on a larger scale as well as a smaller scale.

3.1.2 Original system of land division and survey
Land is traditionally owned by families, clans. The Kings or Chiefs of clans used to decide on everything that had an impact on their environment. So did they on the division of their land. People from other clans are often permitted to live within another one. Land may be sold to them, with permission of the chief.

The borders between clans were never drawn on maps, but some remarkable trees are known as marking points for borderlines. Thus trees originally are important landmarks for the Dinka.

This is the ancient Dinka system, allowing settlements to grow like the population does. It results in a cellular pattern connected with footpaths.
A sketch of the two types of urban structure in Rumbek, suggesting the importance of landmarks - which are the trees in rural areas - in new urban settlements.

A picture of the urban plan that was approved for re-division of Rumbek.
From above it looks like a type of nerve system, a dense network connecting all compounds/dwellings, leaving many open spaces in between the paths.

The land is now still owned by clans, there is no land division or legal ownership in the largest parts of Rumbek. The land is thus most likely encroached - it has become a good of clans that have been living there.

### 3.1.3 Current new system of land division and survey

The urban situation that is now under development and under construction (the roads), is a rectangular grid. See the picture of the urban plan. Within the wide roads, the created sections are filled with rectangular plots for people to build a fence and tukuls inside. A rectangular compound so to say, as they are being built more and more since the end of the civil war. This rectangular grid is the wish of the ministry and the Dinka in Rumbek town as well.

The MoPl and Rumbek county officials are now implement their urban plan, mainly involving construction of new roads. Rumbek has four districts, divided by the main crossing roads in blue on the picture. All four districts are being surveyed and re-divided. The land on which people live will remain theirs with new borders, some have to move more than others. The people won't have to buy their piece of land, because over time they are owning it already. The local government generally respects that, since only a few people have the means to buy land and the officials are Dinka themselves. Because space has to be calculated for facilities or services, some people have to move to other parts of town.

The new procedure to obtain land is to deliver a request with a description (and drawings) of what is going to be build. The department of land survey & housing will then make an estimate. MoPl finally approves, after which the requester receives a title deed and pays according to the class of land. There are 3 classes of land: (The plots are all approximately 500 USD a piece)

- Class 1, a plot of 40 by 50 meters, most remote from centre;
- Class 2, a plot of 30 by 40 meters;
- Class 3, a plot of 20 by 30 meters, most downtown.
  [MoPl Lakes State]

Another upcoming type of plot is the plot for business purpose, mostly in the form of a shop. There are two types of shops. One is an individual shop, for which land has to be bought from MoPl and a permission has to be paid for. Plots are 6*7 m or 8*7 m. The other type of shop is one on the edge of a compound. These shops are private shops, no laws are operational for permission or prohibition of them because they are located on legally owned land of a household. [Mozes Mapur, Rumbek county office]

### 3.1.3.1 Effects on housing

The current system for re-division of Rumbek results in the fact that many people are not sure if their house -newly built or old- will remain erect. That is a reason for many people not to invest energy in building a new house or maintaining an older one. The uncertainty of the people raises doubts about the righteousness of the urban plan.

Traditional Dinka compounds are not protected with a fence. Sometimes a fence is used to protect gardens from animals. Since the western world (in the form of international humanitarian organizations) came to Rumbek, the Dinka got used to compounds protected with fences. As the western society is a modern one and Dinka want to develop their country into a modern one, the Dinka want to copy the 'modern' way of building. One result is the building of more rectangular fenced compounds. The fences are becoming important for privacy reasons but furthermore for protection of valuable goods.

The copying of rectangular compound building is now leading to urban plans with a rectangular grid, creating orthogonal and wide roads for heavy traffic. A structure that is completely the opposite of the way of living in rural areas, where a fine network of crooked paths settles the -mainly pedestrian- traffic. An important area of attention for new housing development, as it should be oriented on its context.
The urban proposal for a neighbourhood in Rumbek
3.1.3.2 Urban proposal
To start up a discussion with MoPI in Rumbek, some members of the architects think tank of SHF and I developed a draft plan of a part of Rumbek. Ronald Fukken and myself worked out the draft in October 2007 to make it presentable and based it on a few good reasons. We based our plan on:
- present sizes of compounds in the centre of Rumbek
- present routes
- present houses and compounds
See the plan on the left.
Basically a new urban plan was fitted in an existing urban situation, respecting most of what is currently there, as far as Google Earth is up to date. It is a way to develop an urban area, but takes much effort. Much more effort than creating a grid and cutting out the larger facilities. The local inspectors were interested to see the sketch, but weren’t able to leave useful comments or motivate their wish to create a strict grid in Rumbek.

The big contrast between current urban structure and the rural structure is an indicator of the doubtful developments in Rumbek centre. The original cultural background is ignored. However people seem to agree with the land division into strict plots, because it ends argues about ‘which part belongs to who’ and provides some privacy in the overcrowded centre. Also cars and other vehicles are becoming more important, for which is little space yet.
To develop a plan with more attention to the cultural background, it would be recommended to leave some houses, existing facilities, trees or other communal heritages alone. If standard plots are desired, then it would take some effort to adapt the geometry to its surroundings. But it would be the recommended solution if a more subtle re-organization of the urban centre of Rumbek should take place. The urban proposal as presented is an example of this approach.

3.2 Architecture
3.2.1 Introduction
NGO’s & construction projects
Before the CPA (2005), there were almost no NGO’s building any structures, because investment in permanent structures was risky. (In 2002 there were 47 NGO’s active in Rumbek county!) A reason why Dinka don’t have too much trust in (construction) NGO’s and like exploiting them. On top of that the incredible high costs of the region, among others due to harsh conditions for import of (building) materials, make it hard for an NGO to stay in the area of Rumbek. NRC (Norwegian Refugee Council) solves these problems by using as many local sources as possible.
Projects in Rumbek of interest:
A sketch of the compound of a well doing family in Rumbek center
1. UNICEF schools, 7 copies of a design (R. Dierkx) have been built in Lakes State, 2007-2008. One of these schools is analyzed shortly in annex 6.

2. NRC – several schools. I visited one school under construction near Rumbek, for analysis see annex 6.

Residential construction
Building of tukuls is only done in the dry season. Preferably every year the grass of the roof will be replaced. Sometimes after two years. All of it depends on the money and time available. In the dry season, when clay is smeared onto the bamboo interweaved walls, a lack of water may be the reason to just leave the walls unfinished.

Tukuls are not considered as permanent houses.

Costs of a tukul
This issue is hard to describe, speaking of traditional construction. The Dinka may take up to three months to build a tukul. They don’t count their hours as time is not an issue. Maintenance, decoration and building slabs is done by women, if they have time for it next to taking care of the whole family.

To start with the most expensive material, a 1.5 m radius tukul needs 15 up to 20 bundles of grass, depending on the quality demands. One bundle may cost up to 10 USD.

The adobe doesn’t cost anything, the black cotton soil is everywhere (in the rainy season the slickest earth to ever walk or ride in). The stones are preferably made in the rainy season, because they need plenty of water.

Next examples are given costs of tukuls built by a local contractor:

1. One 4 by 4 tukul, consisting of traditional materials (bamboo, wooden poles, palmera wood, grass, mud-blocks) costs ±1000 USD (300 USD labour, 500 materials, plus variable costs).

2. A modern tukul, 6 by 10 meters, with a cement floor, burnt bricks, bamboo and an iron sheet roof with grass on top, costs up to 8000 USD.

3.2.2 Functionality

This paragraph provides a description of all encountered functional aspects of a Dinka house. These aspects should be looked at when designing a new form of housing. Some functions are very important, others may be disputed since a new design often introduces changes. The following aspects of a Dinka house are conclusions from field work in Rumbek, carried out in January and February 2008. The F-numbers are ordered from important to less important.

F1.
Definition of a Dinka house: a compound filled with several huts, tukuls, representing different rooms with different functions. The most common set up of a compound: Two or more tukuls with closed walls and small windows for sleeping and one tukul with semi open walls for sitting (especially in the rainy season). The always round (or hexagonal) semi open tukul is often also used for storage and cooking when it rains. Cooking normally happens outside. Another item for storage and drying items is a table-like construction, called a käit. The käit is often close to the semi open tukul and the cooking place.

F2.
Distances between tukuls:
Man and wife’s sleeping tukuls are built close to each other.
Kids, a bit further away and visitors even further (thus privacy is important).
Store (for hollowware and more) close to man’s tukul, because the man is responsible for guarding personal belongings.
Kitchen is built separate, because of fire danger. The kitchen is a luxury building, it is of the least priority, because hollowware is also put in the living space, or sleeping tukuls.

F3.
The semi open tukul which is often the most flammable one and cooking sometimes is done inside, is put at a distance with the sleeping tukuls.
A rectangular sleeping tukul

A round semi open tukul

A rectangular sleeping tukul with a clay slab

A tukul on poles with a henhouse on the right
along the direction of the wind. The reason is to prevent other tukuls from catching fire when the semi open tukul catches fire.

F4.
Order to build tukuls on a compound:
1 - for the man himself,
2 - for the wives everyone a separate tukul,
3 - children,
4 - visitors,
5 - storage, on poles,
6 - kitchen.

F5.
A shower is put as far away as possible from the kitchen.

F6.
In the middle of a compound people never place tukuls, only if a compound is to be divided into two parts.

F7.
Unmarried girls preferably sleep together in a separate tukul. They are important for the income of a family, so they are often taken care of and kept away from boys.

F8.
A porch mostly is located at the east side, to have shadow in the afternoon and evening.

F9.
The clay slab in front of the sleeping tukuls is for sitting in the evening, sleeping at night, prevention of blowing dust and protects the tukul entrance from being flooded in the rainy season. The floor inside is also the same clay, preferably covered with plastic/vinyl. The slabs in front of the tukuls are also a form of decoration. If there is a higher stage, it shows that the woman of the house, or the oldest daughter is capable of doing hard work. Which is a sign of status.

Engaged couples sit on the highest slab that is present. Sometimes they are allowed to spend the night on this clearly visible spot.

F10.
For some Dinka only a physical obstruction like a fence hinders them to take a shortcut, even if it were through someone's living place.

F11.
Dinka often have some cows in their compound for milk and cow dung. A space for 2 to 4 cows is normal. In rural areas this is often some more. Cow dung is burnt at night to keep insects at a distance.

F12.
Next to the cows (the herds remain in cattle camps, outside the village) the Dinka keep goats and chickens. For both of them a covered sleeping place is required. In some situations these animals sleep together with the people. The small cattle need some form of protection because of hyenas which hunt at night.

F13.
A special 'function' of the tukul walls: After giving birth to a child, the umbilical cord of the woman will be buried right next to the wall of the tukul in which she sleeps. If this traditional and very complicated burying process goes well, the next child will come. If not, the belief is that the woman cannot make any more children.

3.2.3 Design
3.2.3.1 Present traditional housing design
The tukuls have different forms and functions, as the tukul is to be interpreted as a room. Some tukuls are rectangular, but most are round, which is the ancient tradition. Rectangular is nowadays considered the best way to build, because of maximum inside space and placing of beds and furniture.
Inside a rectangular sleeping tukul

A round tukul

A tukul with some decorative painting

The standard for modern construction in Rumbek [UNOPS]

Brick housing under construction. Clay is used as mortar...

A modern house under construction by Ugandan men

Trusses and concrete
The two most important types of tukuls: the rectangular - closed ones for sleeping and the round- more transparent ones for cooking and social gathering. This doesn't mean that no one sleeps in the more transparent ones. Other types of tukuls are: toilets, shops, storage, etc. Overall they are alike: approximately 11 square meters, square or round with a conical roof of grass.

An exceptional type of tukul is the one on poles (see page 62). Originally these tukuls are to keep food or sleeping people safe from animals. Underneath these tukuls there is a shaded space for social and household activities. The poles have a big advantage in the rainy season; the floor of the tukul always remains dry. The way to solve the problem for flooding of the tukul on the ground, is the placing of a clay slab as a type of stage for the entrance. Also the walls are being strengthened with an extra broad base of clay blocks, finished with clay plaster. The clay slabs and the massive base of the tukuls are two main ingredients for the typical looks of a Dinka hut.

The climate inside a tukul is very agreeable, considering the heat outside and comparing to a structure designed for AC (Air Conditioner). The thatched roof has an overhang, not very big, but the walls are pretty low (±1.6 m) so there is not too much direct sun heating up the structure. Other reasons for the good climate: rigid walls of mud (±20 cm) and a continuous open space between roof and wall. This open space provides some light (more than available from the regular two small windows) and some air refreshment. The grass roofing provides good insulation because of the airy total package.

For Dinka it is important to show off their social level, their status. The most important ways to do so -considering the built environment- is to decorate a tukul and to foresee it with extra additions. A smooth plastering and a well formed clay slab with some markings signifies that the women are capable of doing hard work. The women are the most important properties of the proud men. The use of colors and patterns for the decoration of walls of tukuls has no specific meaning. It is just about decoration and showing that the women -who maintain and decorate the house- have the time and the means to do so. Another form of decoration is the Christian cross on top of a roof, or a South Sudanese flag on a pole in a compound. Religion has no further influence on the design of tukuls or facilities.

About the design of compounds and tukuls is to say that they are formed by mainly practical reasons. It is mostly not about aesthetics, but about use. For example the beautiful clay slabs and stages have some important functions, like sitting, sleeping, engagement of a young couple and more.

3.2.3.2 Present modern housing design

Today Dinka are starting to build rectangular tukuls with fired bricks and an ironsheet roof, sometimes with extra grass on top of it. Those tukuls are becoming larger; more rooms are being planned inside. The aesthetics of the forms becomes less important, because a durable building material like a brick or ironsheet, has more status than anything else within the tradition of tukuls. These new types of structures are always rectangular, a box construction with window and door openings, and trusses to support the ironsheet saddle type of roofing with a slight overhang. The walls are often quite high, about 3 to 4 meters, to keep the indoor climate acceptable.

The designs of facility buildings, often done by people from an organization like authorities, churches, NGO's, are very much alike. Most of these designs are inspired on the colonial British architecture from the past century. It is the type of design as described above. Sometimes a wall is replaced with a series of columns, creating a gallery or veranda. The walls of these buildings are quite high as well, but the indoor climate is often being conditioned with an AC (Air Conditioner).
Two of the drawings that were made in Rumbek. The small huts with a line coming through the roof are latrines with an air pipe.
3.2.3.3 Wishes for future design

The first wishes about future house design are from a group of 8 to 12 year old children in Rumbek. I organized a workshop with 49 children and asked them to draw what their ideal future house, seen from the outside. All 49 drawings are included in Annex 7. From these drawings a few matching elements are noticeable:

A house consists of several (separate) structures (the preferred toilet is always separated);
- Water should be available within or nearby the house;
- Decoration and colors are very important for the exterior of a house;
- A roof should preferably be traditionally conical or a saddle type (a ramp);
- A fence, ironsheet roofing, masonry walls, plants, flowers, a flag and a latrine are all elements that should be included;
- A house should be durable: permanent (that's why they wish for ironsheet, brick walls and a fence to protect their precious structures)

Until now there are few different designs for new buildings in Rumbek. Because the large humanitarian and governmental organizations and businessmen all build the same type of architecture, the Dinka have very few examples to stimulate their senses. It is hypothetically the main reason why they only want houses with the same design and materials as what is being built all around. The outcome is that the Dinka want to build their tukuls with the modern materials. Because the materials are very expensive, they will not make the tukuls much larger or higher, not caring at all about the bad indoor climate as a result.

Not only do the Dinka forget to think about alternative materials or smart protection of traditional materials, neither are they thinking about any other type of form than the primitive as a plan for a room or a few conglomerated rooms. This is a reason why it is very hard to get good input from the Dinka on what they wish for a house to live in.

The Dinka are of a very firm opinion about the way their future house should be: rectangular concrete or brick walls, trusses and ironsheet shed roofing. Nothing should remind them of their tukuls: no round soft corners, but tight sharp edges. (Theory behind that wish: Showing that a building is not built with clay, which decays quickly after a rainy season. No (soft)wood being eaten by termites and no roof being eaten, so they won't have to replace it every 1-2 years.)

In the case of this research, the opinions of most Dinka should be considered as questionable. As stated before, they have too few references for new possibilities or innovative solutions for current problems with tukuls. The best way to convince the Dinka of an alternative is to build a pilot model on scale 1:1. The Kenyan NGO 'Pamoja Trust' made some real-time models with a wooden construction and (draped) textile, see some images on the next page. The SHF however, intends to carry out a pilot building at location with the real materials and all there is to it.

For this thesis the design work will be developed into a scale model and a few drawings. The scale model should be understandable by the Dinka, keeping in mind their lower level of abstraction. Furthermore the explanation of a design should be revealing the direct advantages compared to their tukuls and the present modern way of building in Rumbek.

Concepts of house models, experiment in Rumbek

When introducing something new in a tradition-based culture, the social and human factors will be harder to conquer than the technological factors. Technologies, forms, all kinds of things which people are not used to, always demand a lot of effort to introduce and implement. In any culture. [R.Dierkx, Annex 8]

To get an image of how Dinka react on new designs for houses, 10 concepts for new forms of housing were presented to a few Dinka. Please find the list of proposed concepts in Annex 9. Their following comments on these concepts are personal answers and therefore not really representing a target group. A critical view is necessary to filter useful conclusions in a
Some real-time models with a wooden construction and (draped) textile of the NGO 'Pamoja Trust'
[Becky Telford]
later stadium. These are the comments:

- Planting bamboo, grass or trees for construction purpose will not easily be accepted.
- Clay roof tiles won't compete with iron sheet.
- Appropriate technologies might all be of great value. For example a solar power from a central compound distributing to surrounding houses.
- Eco toilet, for agricultural use; absolutely impossible
- Wind catcher, may be accepted, but ONLY after the concept is fully understood.
- The technology of filling up two layers of wire mesh in a rib/cage with polystyrene filling has potential. The cement mix needs special treatment in a machine.
- SHF Dome. Positive, because of the concrete solidness of the structure. The dome is best suited in rural areas and most positive for the rainy season.
- More rooms inside one structure would be smarter than what happens now. The idea is accepted, but now mostly being built by entrepreneurs for rental.
- The concept of a patio house is accepted, but people are used to a lot of open space (a large yard) A toilet inside is unacceptable, as is a kitchen for cooking. So limit the inside space of a house with rooms in one structure. A toilet inside is an advantage, especially for night times, is what another Dinka shared with me.
- Sleeping on the roof. The idea is ok and understandable but space is not limited in most areas, which is true for the rural situation. The idea is interpreted as an upgraded tukul on poles which were originally built for protection from lions.
- Row housing. When building row houses, it would be better to make every house visible as one. One straight lined (pitched) roof for a group of houses is not easily accepted.
- System buildings, partially left unfinished, won't work because it's extra work for the beneficiaries and thus it won't happen.
- Appropriate technologies. A wind catching chimney (badgir) would be good, if properly tested. Solar energy is now mostly used for individual machines, like a fan. A community providing solar panel station(on a compound of someone) would be great and would work well.
- Labour intensive model. Extra work if unnecessary (at first sight) is not easily done. The main idea of producing building materials for commerce as well as own building activities is supported.

3.2.4 Materials

Underneath several types of materials will be discussed. First of all the locally available materials are important. Secondly, materials that are most likely to be imported from Uganda or Kenya. Thirdly a list of producible building materials with the present local raw materials. Fourth point is about the acceptation of building materials. Fifth and last part is about future possibilities for local building material production.

3.2.4.1 Locally available materials

This paragraph is about all the useable materials for building discovered in and around Rumbek. Besides materials that are produced locally, or extracted from nature, also some imported materials that are possible to buy locally are considered as locally available. Underneath a list of those materials will be presented. In Annex10 this list is included as a database with pictures and specifications.

a. Water
b. River sand
c. Pit sand
d. Black cotton clay soil
e. Termite mounds
f. Laterite as aggregate
g. Laterite as blocks
h. Murram
i. Hardwood timber
j. Bamboo
k. Wooden poles
Imported steel

Imported sun and rain block netting

Ugandan cement

Concrete blocks made in Rumbek [SSL]

A CSEB

Clay blocks

(Imported) plastic sheets to keep dust outside

Bricks made in Rumbek
I. Palmera timber  
 m. Palmera leafs  
 n. Grass for thatching  
 o. Iron sheet  
 p. Rebar  
 q. Wire mesh  
 r. Cement  
 s. R6  
 t. Oil (for clay treatment): local Lulu oil  
 u. Plywood panels  
 v. Waste  
 w. Muna (Dinka)  
 x. Cow dung  

3.2.4.2 Imported materials  
Materials that are manufactured, like cement, steel, nails, tools, are all imported from Uganda or Kenya. Which is why they are relatively expensive on the local market.  
Some materials for consideration to import:  
a. Screws, tools, equipment  
b. Cement (50 kg bags)  
c. Rebar  
d. Steel netting  
e. Ironsheet  
f. Steel (frames, beams)  
g. Plastic sheets  
h. Sun/rain block netting  
i. Doors  
j. Softwood timber  

3.2.4.3 Building material production in Rumbek  
The translation of raw materials into building materials is the basis of the producible goods in this paragraph. The production processes are treated very minimal. If a building material proves to be useful for the design, it's production process will be examined a bit further to stimulate a quick start of a future pilot project in Rumbek.  

Concrete blocks (CBs)  
Advantages: big size (200*400*200 mm) for less actions of the mason and high quality. Possible production on site. The blocks are for sale in Rumbek: 4.5 USD per block, which is a commercial price.  

Hydraform -a commercial company name- blocks (CSEB)  
A mix of lime sand and cement, compressed with a patented hydraform machine. The blocks need 14 days of curing with water. For 70 stones one 50 kg bag of cement is needed. The hydraform blocks in Rumbek are not considered as load bearing and therefore only used for interior walls.  

Compressed (& Stabilized) Earth Blocks, C(S)EB  
Riversand mixed with cement. On site production is likely, with or without compressor. For blocks with a size of 200*400*200 mm, one 50 kg bag of cement is needed for 20 blocks. Hand mixed, minimum 7 days curing with water, then drying. Some contractors construct modern buildings with cement (1 wheelbarrow), black cotton soil (2 wheelbarrows) and riversand (3 wheelbarrows) to make building blocks. Most builders do a safe bet: only riversand & cement (4 to 1 wheelbarrows for cement), for less load bearing blocks 5:1. The section about future possibilities for local building material production will explain some more about CSEB and its advantages. -See page 73  

Clay blocks (stabilized & compressed)  
Blocks from the most common soil, mixed with water and moulded into form. The blocks are rarely stabilized with cement and/or compressed in a (hand)machine.  

Bricks  
Clay blocks burnt with a temporary kiln construction. The quality is very low. [Rob, NRC]
MCRs

Bamboo along the road to Rumbek

Good soil for CSEB production [Auroville, 2006]
3.2.4.4 Acceptation of building materials

Some inhabitants of Rumbek shared opinions about which materials should be used for house construction:

- Bricks or blocks are preferably blue and they must be 'tight rectangular'. Stucco is preferably grey, as a proof of use of cement. The brick color is also right, but is considered very expensive. The choice for blue may signify the wish for a color that is absolutely not natural, but mechanical and industrial.
- The roof should be made of ironsheet; people are tired of changing the thatched roofing. The Dinka are convinced that the internal heat accumulation will be solved by placing an insulation sheet underneath the ironsheet.

For acceptance of materials goes the same as for wishes for future design. The Dinka have too few references and therefore praise the new imported materials to the skies. In a piloting phase of the SHF it would be interesting to test whether the Dinka are flexible in their current opinion.

3.2.4.5 Future possibilities for local building material production

The following production processes are not treated to the fullest at all. If a building material proves to be useful for the design, it's details will be examined to stimulate a quick start of a future pilot project in Rumbek.

Doors and window frames

Some doors are being made, but the quality is low. Doors are therefore often imported from Kenya. To set up a production of good (hardwood timber) doors would be filling up a gap in the market.

MCR, Micro Concrete Roofing tiles

This is a possible technology for local production. Necessary ingredients are cement, river sand, fine aggregate and water. Although the knowledge and equipment needed are heavy demands, these tiles may possibly become a future competition for iron sheet. [Bhawan, Nirman, 2006]
Press in Rumbek

Press in Uganda, copied from Auroville

Press developed by Auroville Earth Institute, India

Cnvaram - The first press for compressed earth blocks

Aaram press 3000 - Multimould press (16 moulds)
Many stabilizers can be used. Cement and lime are the most common ones. Others, like chemicals, resins or natural products can be used as well. The selection of a stabilizer will depend upon the soil quality and the project requirements. Cement will be preferable for sandy soils and to achieve quickly a higher strength. Lime will be rather used for very clayey soil, but will take a longer time to harden and to give strong blocks. The average stabilizer proportion is rather low, being minimum 3% and average 5% in case of cement stabilization and minimum 2% and average 6% in case of lime stabilization.

The strength of a block is related to the level of compression and to the quantity of stabilizer. The Auroville Earth Institute in India recommends the use of heavy manual presses as equipment. Cheap light manual presses have a low durability, a low output and do not produce very well compressed blocks. A motorized press will present the advantage of a high productivity, with a better and more regular quality. But it will require energy and a more complicated maintenance, and its cost are much higher. Therefore, heavy manual presses are most of the time the best choice in terms of optimization for the investment, output and quality ratio. This does also apply for the situation in Rumbek.

Apart from the fact that CSEBs consume less energy and pollute less than fired bricks, they are most of the time cheaper than fired bricks. This will vary from place to place and specially according to the cement cost. The costs would be within these figures when using the “AURAM press 3000” [Auroville, 2006]:

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor</td>
<td>20 - 25%</td>
</tr>
<tr>
<td>Soil and sand</td>
<td>20 - 25%</td>
</tr>
<tr>
<td>Cement</td>
<td>40 - 60%</td>
</tr>
<tr>
<td>Equipment</td>
<td>3 - 5%</td>
</tr>
</tbody>
</table>

Advantages of CSEB:
- It uses local materials, saving on transport, fuel, time and costs.
- Requiring only little stabilizer the energy consumption is very low.
- A cost effective alternative, through the use of natural resources and semi skilled labor. The final price will in most cases be cheaper than fired bricks.
- It is a simple technology requiring semi skills that are easy to acquire in only a few weeks.
- CSEB allows unskilled and unemployed people to acquire a skill, creating a job opportunity.

Home grown building materials
Dinka are not used to the phenomenon of growing their grass or bamboo for construction, they are used to live near a source. If you live in a town, one should just buy them. You are not allowed to just cut a material somewhere close to a town, because there is business involved. Trees are cut down everywhere for construction. Only Mango, Morgan & Teak trees are planted, for home use. Water is the main problem for cultivating anything. But technical possibilities are positive, when the water issue is solved. Prove is the planting and growing of one or two own trees on several (newly built) compounds.

The long term effect of planting for construction is a reason why acceptance is very hard. If there is no direct visible advantage, then the Dinka find it hard to invest. ‘Carpe Diem’ is their motto when it comes to their choice for economic activities.

An option to solve the main issue for the Dinka, is to provide an irrigation system. Across is experimenting with gardening which goes quite well. They use a pump system from Appro-Tech, from Nairobi, a foot-pump for irrigation, put in a tank of waste water from a hand pump.

Furthermore anything can be planted successfully, especially in the rainy season. In the rainy season the whole of Southern Sudan is very green, anything pops up out of the ground. Bamboo, trees, grass, they all have the potential to grow well in Southern Sudan. Sometimes some shade (of a tree) is a precondition, to prevent a crop from burning.
Adobe blocks + mud & poles, three ways to make a roof

Roof construction with nails

Roof construction with palm leaves

Tukul with wall of poles in rural area

Sometimes a tukul is just a roof
Possible crops to grow for construction:
- Grass for thatching
- Bamboo; many (fast growing) possible types!
- Trees for (hard)wood
- Trees for oil production (Lulu or Oky trees; Dinka names)

3.2.5 Building technologies
Before making a translation of raw materials into a method of building it is important to see what the currently used building technologies are in Rumbek.

In Rumbek there are two main ways of building: Traditional and Modern.

Or: Tukuls and Concrete shacks. Of course there are more types of modern buildings in Rumbek but almost all of them are built with concrete blocks or bricks, roof trusses and iron sheet. The year 2008 will be the first year for a multi level (modern) building to rise.

3.2.5.1 Tukuls
All tukuls are built in a comparable way. There are different types of walls, people use different materials for the roof construction and use slightly different methods to build, but the results are all comparable.

Different types
There are a few different types of tukuls. The differences are based on the different functions a tukul houses or simply because of a (in-)capability to build another type. The next few types are about ways to build the wall of a tukul. The first three wall types are used as load bearing for the roof. The last type normally has a separate construction for the roof.

- Poles (two types):
The tukuls with semi open walls are built by putting wooden poles in the ground (this is the ‘foundation’), covering those with a beam consisting of bamboo or other wood which is then to support the roof. The distance between the typical sticks with a V-formed end varies from 0.5 till 1.5 meters.
More towards the rural areas more poles are used in a way that the distance between them is as minimal as the sticks themselves allow. Not all those poles are carrying the roof, the distance between the carrying ones remains the same. These types are built because better protection is needed for wildlife (that doesn't like to come far into urban areas anymore). The latter type is comparable with the next one.
- Poles and interweaving:
The same as the first one, but then the empty space between the sticks is filled in with an interweavement of sliced bamboo the same way as fences are being made. Three horizontal rows of sliced bamboo are nailed or strapped onto the poles. Then plenty of sliced bamboo is bent vertically in between the bamboo lines.
- Mud and poles: This type is a continuation of the previous type. The interweaved walls are simply filled with mud and finished smoothly, left to dry.
- Adobe blocks: This type is mostly rectangular. Walls are being built with mud and adobe blocks of the same mud and built on the same soil. No strip foundation is being made, the masonry simply starts at about 10-20 centimeters below ground level. Windows are being constructed with a piece of hardwood or smaller windows by using a smart way of stapling the blocks. After the walls are finished, sticks are put around the walls. These are the same poles as in the previous walls. They carry the roof as a separate structure.

Roofing
Unlike the walls, the roofs, whether on top of a square or a round space, have the same structure. The only differences between roofs are the types of wood used, the type of connection used and the method that is used to erect a roof.

The types of wood that are used for roof construction: Bamboo, hardwood, palmera wood and sticks. The connection between the 'beams' and lines is done by ties with palmera leaf fibers or other types of rope or just with nails. See the pictures.
Tukul analogy

Bricks and a concrete beam

New UNICEF school buildings (AC cooled!), built by SSL

Trusses on massive concrete block walls
The roof is rarely connected to the 'ring beam' on top of the poles. Since nails have become available, sometimes a nail is used here and there. Mostly the roof is lifted on top of the structure. Sometimes the roof is thatched already, usually the roof is just the structure ready to be thatched. There are a few ways to construct a roof skeleton but always after the construction of the ground structure. It may be constructed on top of the structure, next to the tukul on the ground or 'moulded' upside down inside the walls.

3.2.5.2 Modern building
When the Dinka speak of modern building, they speak of a permanent building, using materials that are not subject to the fast wear and tear by rain and termites. For modern walls they think of bricks or concrete blocks, because that's all that is available. For the roof only iron sheet is the material interpreted as non-rotting and modern looking. These materials and some hardwood and steel additions are the only ones being implemented in the modern (hardly existing) small scale building industry. In the next paragraph a short description follows about the current most common building method and building form, concluded from the field study in Rumbek, January and February 2008.

Blocks, (columns & beams) trusses and a sheet
For the modern buildings goes that they are larger and higher than the tukuls. Therefore they need a good foundation. The foundation is a strip foundation, about 1,5 meters below ground level. The foundation consists of concrete. Sometimes a cement mix is poured over larger laterite rocks. The building continues with concrete blocks or bricks and -optional- the moulding for concrete pillars. At the top side of the window frames often a concrete ring beam is being moulded. Sometimes a lintel of (hard)wood is sufficient.

On top of the ring beam or on the wooden lintels often a few lines of bricks or blocks follow. After that, the (hard)wooden trusses are being put in place. The connections with the walls differ. Sometimes the roof trusses are simply put on top of the walls. And sometimes the trusses are connected to a base board, which is being wrapped onto the top of the wall with a steel tie which is bricked in. But mostly the trusses are put into a left-open hole in between the blocks.

Large pieces of wood for large trusses are normally not available. To extend the boards, the end-grains are 'moulded into each other' and tied together with a steel tie. Another way is to simply nail a piece of board on two ending pieces to connect them. Then the trusses are directly stabilized with beams on top and the roof construction is ready for the iron sheet.

There are three ways to make these types of buildings' indoor climate comfortable.
• The first and oldest one is to build high enough and make sure there are enough large openings and semi transparent blocks above windows for a good natural ventilation and outlet of hot air. This solution is rare, but was the method used by the British when they colonized the Sudan.
• The second is to install air conditioning machines.
• The third is to thatch the roofs, on top of the iron sheet.

3.2.5.3 Wishes
From the Dinka it is clear that they wish for modern buildings. They consider the tukul as a temporary house. That is because they have to replace their roofs every one or two years and have to keep maintaining their walls when it has rained. The termites and the rain are the reasons why the Dinka have to rebuild their tukuls every few years. Their wish for the latter modern way of building leads to a type of architecture which is totally incoherent to the traditional architecture. Evermore it leads to architecture which is climatically and culturally not always very responsive.
A modern house and an unfinished tukul next to it
To repeat the central objective: A wish for this thesis is to develop a building method which shows an appropriate use of durable/local materials for permanent housing and at the same time providing security for a culturally and environment responsive building form.

3.3 Conclusions
Because half the information in this chapter is ready-to-use but very broad, this paragraph intends to limit the amount of information. It is however still too much to base any concept on, so further narrowing down is a necessary next step before the phase of (sketch) designing in chapter 6.

3.3.1 Summarized urban facts
- The infrastructure in Rumbek is often based on water points. The urban centre in Rumbek however has many water points and therefore its infrastructure has changed to make more different services reachable. New needs are becoming more and more important since modern services have become available after the CPA. Needs like:
  - Electricity;
  - More types of shops;
  - Bars or pubs.
- These needs should be considered for the development of an urban structure on a larger scale as well as a smaller scale.
- Trees originally are important landmarks for the Dinka.
- Living within areas of other clans is no problem.
- The future urban situation of Rumbek is a grid of rectangular plots. There are 3 different plots:
  - Class 1, a plot of 40 by 50 meters, most remote from centre;
  - Class 2, a plot of 30 by 40 meters;
  - Class 3, a plot of 20 by 30 meters, most downtown.
- Plots of 6 by 7 meters or 8 by 7 meters in the commercial area (market) are also for sale. Another type of shop is a private one on the edge of a compound.

- Traditionally, Dinka compounds are not protected with a fence.
- The contrast between the current urban structure in development and the rural structure is remarkable. One way to deal with this, is proposed in §3.1.3.2, pages 58-59.

3.3.2 Summarized architecture facts
Tukuls are not considered as permanent houses. A house should be durable & permanent (that's why Dinka wish for iron sheet, brick walls and a fence to protect their precious structures)

Functionality
- Definition of a Dinka house: a compound filled with several tukuls representing different rooms with different functions.
- Cooking always happens outside or under a roof (a kitchen(luxury) or the semi open hut) when it rains.
- Distances between tukuls: privacy
- Functions from important to least important:
  1 - bedroom for the man (and wife), 2 - for every wife a separate bedroom, 3 - bedroom for children, 4 - bedroom for visitors, 5 - storage, 6 - kitchen.
- A shower or toilet is put at a good distance from the kitchen.
- In the middle of a compound people hardly ever place tukuls.
- A porch mostly is located at the eastside, to have shadow in the afternoon and evening.
- The clay slab in front of the sleeping tukuls is a form of decoration, is for sitting, sleeping at night, prevention of blowing dust and protects the tukul entrance from being flooded in the rainy season.
- For some Dinka only a physical obstruction like a fence hinders them to take a shortcut, even if it were through someone's living place.
- A space for 2 to 4 cows in a house is normal. In rural areas this is often some more. Cow dung is burnt at night to keep insects at a distance.
- For goats and chickens traditionally a covered sleeping place is required because of animals that hunt at night.
Design
- The clay slabs and the wall base of the tukuls are two main ingredients for the typical looks of a Dinka hut.
- The design and the total package of a (closed) sleeping tukul make a very agreeable indoor climate. Only one (hot & dry period) month a year people sleep outside.
- Decoration of a house shows the status of a family.
- Durable building materials like bricks and iron sheet have more status than anything else within the tradition of tukuls. The modern way of building with these materials, a box construction with trusses to support the iron sheets, is a negative reaction towards the tukuls.
- Water should be available within or nearby the house.
- A roof should preferably be traditionally conical or a saddle type (a ramp).
- A fence, iron sheet roofing, masonry walls, plants, flowers, a flag and a latrine are all elements that should be included.
- More rooms inside one structure is an accepted concept.
- The concept of a patio house is accepted, but people are used to a lot of open space (a large yard).
- Sleeping on the roof is an accepted concept but the reason should not be a lack of space.
- One straight lined (pitched) roof for a group of houses is not easily accepted, it would be better to make every house or room visible as one.

Building materials in Rumbek
The use of locally produced building materials is better for the support of a local economy, is cheaper, may be better for the environment and is easily adaptable to local wishes.
- Clay roof tiles won't compete with iron sheet. But the main idea of producing building blocks for commerce as well as own building activities is supported.
- Concrete blocks are produced widely in Rumbek for modern structures. The blocks are massive and need a big amount of cement related to (pit- and river-) sand and the local laterite aggregate. This type of block is used if total water resistance is a demand.
- Hydraform blocks are a type of CSEB but with less cement, have a form connection and are used to build walls without mortar. The sand used has to be imported from far: lime sand.
- CSEBs are producible with local riversand and cement. Sometimes the local clay soil is also added.
- Rammed earth needs the same ingredients as CSEBs, but needs a good formwork, usually made of wood.
- Adobe is the cheapest block to build with. The soil in Rumbek is full with clay but the dried stones need protection from water.
- Bricks in Rumbek are made with the same soil as adobe blocks. The mixture could be much better and the burning process and temperature as well.
- Bamboo is locally harvested, but some kilometers away from Rumbek. It is so far used for roof construction and for interweaving of fences and walls.
- Grass is harvested near Rumbek and is only used for thatching. Use as a fiber in plasters or new building materials is an option.
- Termite mounds may be used to make mortar for adobe block walls.
- Materials are preferably absolutely not natural, but mechanical and industrial looking.
- A pilot real-time model with alternative material use is the only way to test the willingness to a change of mind of the Dinka.
- Rumbek has a lack (of variety) of the following building materials: Doors and window frames, Roofing tiles, CSEB, home grown materials like bamboo, grass, trees for wood or oil (home growing is unacceptable for Dinka for several reasons)

Building technologies
- Most striking about the tukul building technology are the separated structures for roof and the walls, however sometimes integrated. Unlike the walls, the roofs, whether on top of square or round spaces, have the same basic structure.
Modern buildings are larger and higher than the tukuls. They have a strip foundation of concrete, walls of concrete blocks or bricks (sometimes adobe) and optional pillars and (ring)beams of concrete, instead of hardwood lintels. Wooden or sometimes steel trusses on top carry the iron sheet roof.

There are three known ways to make the indoor climate of ‘modern’ buildings comfortable:
- High walls and good natural ventilation through large windows and hollow blocks;
- Air Conditioning machines;
- Thatch roofs with grass on top of the iron sheet.

The technology of filling up two layers of wire mesh in a rib/cage with polystyrene filling has potential. The cement mix needs special treatment in a machine.

Appropriate technologies like a solar power station from a central compound distributing to surrounding houses are very welcome. Also a wind catching chimney (badgir) would be accepted if properly tested and explained. However an eco toilet for agricultural use would absolutely not be accepted.

Adobe clay is used as mortar for burnt brick masonry! Often the clay is dug on the direct spot of the building or even inside the house under construction! When the clay earth is dug, for block production or whatever, it is better to dig at a place where a ditch or a hole may have a certain function.

### 3.4 Literature

Most of the information provided in this chapter is derived from interviews being held in Southern Sudan. Additional sources used for this chapter:

- Google Earth, used with the SHF architects think tank on September the 22nd, 2007. The result, an urban proposal for Rumbek, is shown in §3.1.3.2.


- http://www.earth-auroville.com and http://www.auroville.org were used for information about CSEB’s.

Part C:

APPROPRIATE BUILDING
Chapter 4
Climate responsive design

What can be learned from examples in the field of habitat for developing countries?

CT. How should a building respond to the climate of Rumbek?

Climate responsive design is the first and oldest craft of sedentary civilization. [Hyde, 2000]
Climate is clearly one of the prime factors in culture, and therefore built form. It is the mainspring for all the sensual qualities that add up to a vital tropical architecture. [Tan Hock Beng, 2000]

In Southern Sudan the climate consists of the two general types known in the tropics: 'Hot & dry' as well as 'Hot & humid'. This dual climate is the effect of a six to eight monthly rainy season changing to a six to four monthly dry and hot period. This makes climate responsive designing even harder. In a hot and arid climate the sun is mostly kept out (and the air is humidified). In a hot and humid climate the moist heat is often carried away by airflows, thus building as open as possible. In Rumbek those two solutions are both at hand. Those two known ways to deal with two climates are hard to combine, but a compromise or a smart combination could be a solution. It is important to find out more about how to deal with the climate in Rumbek.

For the development of the design toolbox in this research part, a bio-climatological analysis would be necessary. The 'Mahoney Tables' are a useful tool for the early stages of a design. [R.J.Dierkx, Supporter June 2007]

When speaking of climate and the built environment, the term 'comfort' is inevitable. The definition of comfort may be summarized as the complete physical and mental well-being. Climate responsive designing has the goal to change people from being not comfortable into being comfortable.

Therefore a few factors affecting the physical and mental well-being are of importance for the designer. The main environmental factors affecting comfort are: air temperature, radiation, air movement and humidity. For the case of Rumbek people are not comfortable with the heat of the sun in the hot and dry period, nor with the overload of rain in the rainy season. That is why the people sit under trees, wear hats, sometimes sleep outside and use fans in the hot and dry season. In the rainy season most people stay inside when it rains, hoping their house won't flood and feeling hot because of high humidity. Thus in Rumbek the people are dealing with all main environmental factors affecting comfort.

4.1 Mahoney Tables results
The recommendations and additional comments for the location Rumbek following from the "Sketch design recommendations" table, as a concluding table from the Mahoney tables which are filled in according to climate statistics, are as follows:

- Recommendation nr. 3: "Open spacing for breeze penetration";
- Recommendation nr. 6: "Rooms single banked. Permanent provision for air movement";
- Recommendation nr. 9: "Large openings, 40 - 80% of North and South walls."

Note: The spacing of the openings depend on the positioning of the building, on the direction of the prevailing breeze, trees in the environment, etc. Also the inlet of too much sunlight as well as rainwater, should be considered;
- Recommendation nr. 16: "Space for outdoor sleeping required."

Note: from the local research for this thesis it seems to be normal to sleep outside for 1 month per year. The reason why people sleep outside more than this month (March), is because of a lack of inside space.
- The last recommendation (nr. 17), "Protection from heavy rain needed", shouldn't be considered according to the statistical facts.
However, the total average of rainfall per month doesn't seem to be a good indicator for the situation of Rumbek: The rainfall comes in intervals of one or sometimes two days in the rainy season, but very heavy. This means the roof should be resistant to heavy rainfall. Furthermore the soil in South Sudan contains a lot of clay and has a hard, load bearing surface not too deep. As an effect the rainwater remains on the surface and causes severe problems for, among others, the clay plastered walls. In short the recommendation for rain protection could be:

*Use a “good hat” and some “good shoes”.*

For the complete tables, see Annex 11. The tables are copied from [Egmund, E.L.C; Erkelens, P.A.; Janssen, Jules J.A., 2003, Bouwtechniek voor de Tropen ON365, dictaat(concept) TU/e]

From the results it is clear that (natural) ventilation is an important recommendation. The fact that outdoor sleeping may be required implies that the air temperature is very high. During the day the same problem occurs whereby the sun is the main evil. To keep a structure cool then, is to protect it from the direct radiation of the sun.

Let us find out more about how to create a well ventilated structure and about ways to protect a structure from the sunshine in the next paragraph.

### 4.2 Solutions for Rumbek

**Conclusions for climate responsive design**

#### 4.2.1 Natural ventilation

Natural ventilation is a simple concept by which to cool a house using the following nine techniques and strategies, schemes are from [Watson, D/Labs, K, 1983, Climatic Design, McGraw-Hill book company]
2) Shape and orient the building shell to maximize exposure to summer breezes:

- Windward roof plane experiences suction will not be suitable for ventilation inlets.
- Umbrella roof keeps rain off side walls, allowing fullest use of wall vent in openings.

Building acts as an air flow dam—within residential scale construction, higher facades mean greater pressure and better air movement through dwelling.

"Piano nobile"—the elevated living floor—is a design practice commonly found in the tropics and coastal states where high humidity levels demand the most of ventilation. Air currents are stronger higher above the surface, and elevated design keeps the underside of the house dry.

As a general rule long facade should be centered to face into direction of prevailing breezes. Plan may be rotated off axis up to 20° or 30° without seriously impacting ventilation performance.

3) Use "open plan" interior to promote air flow:

"single pile"—one room deep—houses are common vernacular throughout mid-Atlantic states. Stacking rooms high instead of deep offers best cross ventilation opportunities. The two story, one room deep style is known as an "I" house.

Louvered wall panel affords visual privacy between rooms on the same level and a sensible semi-direct link to outside. This idea is especially appropriate to corridors and across master bath, dressing room, etc.

The open plan can be executed in an overlooking mezzanine arrangement to preserve privacy between quarters.
The best cross ventilation is obtained with single-room-deep house plans. House at right was designed by architect Albert Hill in the 1940's. Large terraces and carpet funnel in wind flow. A second bedroom could be located at the opposite end of the house to preserve the single-loaded corridor scheme.

4) Provide vertical airshafts to promote air flow:

Central stair to vent capped with skylight & monitor makes an excellent "central ventilating" system as well as a potential sales appeal item.

5) Use double roof and wall construction for ventilation within the building shell:

"True" cross ventilation requires both exterior inlets and outlets in same room. A popular way of achieving this in the 1950's and '60's was with split-level roof and louvers or operable clerestory windows.
6) Orient door and window openings to facilitate natural ventilation from prevailing breezes:

Flow path of air thru the interior is determined by location of inlet opening with respect to exterior wall, and location of outlet with respect to direction of incoming air current. Diagrams may represent individual zones on floor plan, provided wall opening relationships are maintained. Compare to relative driving pressure differences for these locations indicated in FIG. 49c.

- Place door in direction of wind to maximize ventilation.
- Use overhangs or awnings to deflect wind flow.
- Use side ventilation outlets to balance wind flow into the interior.

7) Use "wingwalls", overhangs, and louvers to direct summer wind flow into interior:

- Use "wingwalls" to "trap" air pressure under the eaves, increasing pressures which force breezes into the house. Note deeper "pressure pocket".
- Parapets increase air damming action and create greater ventilation-driving pressures. They may also help keep current in the living zone, instead of along the ceiling by balancing opposing exterior pressure.
Window located near a corner will normally direct air flow in against the wall and around the room's perimeter—leaving a still air pool in the center (left).

Hinged shutters or fixed panels outside of window (to air gap here) direct air stream—pull flow where it should go.

Vertial wall panel serves as cufent diuct to
crows.

8) Use louvered wall for maximum ventilation control:

A major benefit of jalousie windows is rain control, and with opeus or heat absorbing glass leaves, even screening is also achieved.
9) Use roof monitors for "stack effect" ventilation:

4.2.2 Sun protection

Cooling buildings can simply be done by protecting them from the direct radiation of the sun, as shown in the following five techniques and tactics, schemes are from [Watson, D/Labs, K, 1983, Climatic Design, McGraw-Hill book company]

1) Use neighbouring land forms, structures, or vegetation for summer shading:
2) Shape and orient the building shell to minimize exposure to summer sun:

![Diagram of building shell orientation](image1)

Roof shape has little effect on mid-day gain when sun is high.

3) Provide shading for walls exposed to summer sun:

![Diagram of shading for walls](image2)

4) Use heat reflective materials on surfaces oriented to summer sun:

![Diagram of heat reflective materials](image3)

Roughly appropriate overhang dimension W can be calculated by selecting the shade line factor (SLF) from the following table and inserting in the formula:

\[ \text{Desirable overhang } W = \frac{H}{\text{SLF}} \]

<table>
<thead>
<tr>
<th>Shade Line Factors</th>
<th>Latitude in degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>South 1</td>
<td>1.9</td>
</tr>
<tr>
<td>South 2</td>
<td>1.9</td>
</tr>
<tr>
<td>South 3</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Above: High summer sun delivers greatest heat load to roof, east and west walls (the latter receive about half of a flat roof). South facade receives relatively little radiation—especially if there are even small overhangs.

and (without visual):

5) Provide shading for glazing exposed to summer sun.
4.2.3 Summarizing

Natural ventilation:
1. Use neighbouring land forms, structures, or vegetation to increase exposure to breezes;
2. Shape and orient the building shell to maximize exposure to summer breezes;
3. Use “open plan” interior to promote air flow;
4. Provide vertical airshafts to promote air flow;
5. Use double roof and wall construction for ventilation within the building shell;
6. Orient door and window openings to facilitate natural ventilation from prevailing breezes;
7. Use “wingwalls”, overhangs, and louvers to direct summer wind flow into interior;
8. Use louvered wall for maximum ventilation control;
9. Use roof monitors for “stack effect” ventilation.

Sun protection:
1. Use neighbouring land forms, structures, or vegetation for summer shading;
2. Shape and orient the building shell to minimize exposure to summer sun;
3. Provide shading for walls exposed to summer sun;
4. Use heat reflective materials on surfaces oriented to summer sun (South wall is relatively unimportant);
5. Provide shading for glazing exposed to summer sun.
Part C: APPROPRIATE BUILDING

The Cal Earth method: superadobe

The moladi method in Zimbabwe

A tukul in Juba, SS

A communal building in Gambia, WFP
Chapter 5
Projects for Developing Countries

What can be learned from examples in the field of habitat for developing countries?

C2. What are the most important aspects to consider for habitat projects according to experts/expats from the field?

C3. What results from other projects might be useful for application within a new habitat?

The selection of examples drawn from literature, history and common-life experiences offers the following advantages:

(1) such examples better serve the purpose of illustration;
(2) they function as projects for moral inquiry;
(3) they better connect both reader and author to the moral issues being discussed; (...) 
[William Vitek, 1992, Converging Theory and Practice]

Introduction
At the beginning of this thesis, a group of 11 bachelor students wrote a report about the SHF and intentionally comparable organizations. The report aimed on other organizations and some of their projects of which SHF could learn and improve. In Annex 12 a summary of the report is included.

On June the 16th in 2007, SHF held a meeting with the architects’ think tank. A presentation of selected organizations and projects, which was based on the summary of the report, was a kick-off for discussion on this master’s thesis.

The final conclusions of the discussion about the presentation. They are similar to the conclusions included in the presentation:

- To use the building process as a learning process, as an education;
- A chain reaction approach: start with small adaptations of traditional ways and when accepted try to move on. When everyone is convinced start applying heavier improvement, which than will be accepted more easily and taken over by the people themselves. This approach needs a suitable context;
- When completing buildings, include a maintenance report;
- Improvement of existing techniques;
- Implementation of local materials, while applicability and acceptation are the main concerns.

An advice from the think tank for this thesis was the deletion of a question which was presented in an early framework. The research question “How is it possible to stimulate a sustainable development by means of habitat?” was deleted and answered in a hypothetical way. (See §1.1.1)

The hypotheses from this paragraph were used for the development and structuring of the assessment instrument to compare examples of projects in developing countries.

The reason why this part is part C, and not part A or B, is because the chapters involve some knowledge about Rumbek as well as SHF. Four of the examples in this chapter were visited during the field research in Rumbek that was presented in Part B.

5.1 Instrument for example assessment
This paragraph contains the sub-questions resulting from the pre-research with the bachelor students group, the conclusions of the discussion with the architects think tank and interviews with experts from the field of building in developing countries. For the full interviews, see Annex 8. The underneath sub-questions are concluded from the interviews and formulated in order to compare several projects. Furthermore the questions have been separated into categories, which are based on the hypotheses towards long run development from §1.1.1.
Practical Action built these five houses in Kenya, to let the beneficiaries make the choice for their best option.
Example Assessment Instrument for habitat projects in developing countries:

**Economic aspects**
- Affordability
  Are the costs the same or less than the costs from conventional building?

**Ecological aspects**
- Ecological responsibility; cradle to cradle
  Are environment friendly materials and non exhausting resources used?
- Environment response
  Does the built work respond sufficiently to the environment, e.g. climatic design and rainwater harvesting?

**Social aspects**
- Demand driven
  To which extent is the target group the basic initiator?
- Participative approach
  Does the involved target group take a clear part in the (building) program?
- Capacity building
  To which extent does the project contribute improvement of organization of the participating group?
- Acceptance for long term
  After cooperation with e.g. a foundation, does the population know how to continue the building, it's maintenance and start new building processes?
  Cultural acceptance is a basic factor for this principle.

**Technical aspects**
- High quality living environment
  Does the building method guarantee a long term quality?
- Cooperation with professional local parties
  Is knowledge from local cooperating parties used for synergetic advantage?
- Acceptance for long term
  Are the techniques understood by and preferably implemented in the future for local people (based on traditional techniques with known materials)?

### 5.2 Examples

The idea of analyzing examples is to be able to choose and maybe use solutions from projects that are most inspirational. A conclusive table will provide an orderly view over all analyzed projects and their values.

Choice of analyzed projects.

The intention is to present a very broad list of different projects, because maybe only one single aspect of a project could be interesting to consider for this thesis. Something one wouldn't think of without seeing an example. That's the main reason why examples of projects, and the assessment of them, are considered valuable.

To prevent from choosing too many projects, the projects should be in line with at least one of the aspects of the idealistic SHF vision:

1. Durable solution
2. Cost effective; affordable for the target group
3. Participative approach
4. Improvement of community spirit (capacity building)
5. High quality living environment
6. Improvement of dependence and responsibility
7. Demand driven projects
8. Cooperation with professional local parties
9. Ecological and social responsible

To include in addition:
- Projects in a similar climate as Rumbek, to obtain concrete examples
The letters in the table show combinations of aspects. A letter with an accent (hypothetically) shows on which aspect the score is lower, because of the choice to score better on the aspect for which the same letter without an accent is noted. This thought is explained with a passage per letter.
next to the climate response guidelines.

- One or more projects with the intention to offer a solution for many locations: (cost effective, durable, high quality, social responsible are mostly the advertisement words, the same aspects used by SHF) to see if this approach is stimulating any development.
- One or more projects which just help poor people in supplying improved constructions as gifts.

For the written analysis of the examples see Annex 6.

5.3 Evaluation of Project Assessments

See the evaluation table, comparing fourteen projects for the aspects as presented on the previous page.

To draw good conclusions only the evaluations above satisfactory are considered as valuable. Thus the green spots are the only spots to properly look at. The satisfactory spots may only become of interest when looking at a combination with a green spot.

Every aspect will be discussed on significant relations with other aspects and matching examples for architecture. For every aspect other examples than the numbers 3, 6 & 10 are treated, because these overall excelling examples will be discussed afterwards.

A. The Red Cross in Vietnam shares an excellent result for affordability with a satisfactory high quality result. The use of a high quality frame for people to fill in, seems to work out well when looking at the costs for building. However the system should be more developed as a community effort. The lack of social implementation makes this project not very successful, but a great example of a good idea which is not carried out very well. (The frames were built by expats and left to be filled in by beneficiaries, the level of cooperation with beneficiaries is minimal) The idea to create a certain core which people may extend, is an idea that can be executed for lower costs than creating more than the core. But the future quality/durability might be at risk.

The SHF however prefers to pay a little more for a higher quality, which is the case with more examples. The strength of appropriate architecture at this point is to create high quality with low cost materials. Which means local materials in the case of Rumbek.

B. The aspect cradle to cradle has the worst overall scores. That is because cradle to cradle is a relative young philosophy, for which the world is not really ready yet. However, the traditional way of building in Rumbek is the best way of building with the lowest ecological impact ever. The adobe school in Rumbek is also doing well at that point. But both examples show that a combination of cradle to cradle and high quality is hard to achieve. The reason for this is the weak environment response. If naturally degrading materials as used in both examples would be better protected for weather influences and other environmental dangers, then the quality level would automatically go up. The adobe school shows that the use of a cement plaster on adobe could be a way to do so, but is not sufficient.

C. But what happens if a good environment response is achieved? Logically a building would be adapted to local influences and therefore acceptable for a long term. This is true for the examples 8 and 9, but not for the examples 1 and 7. In those two cases one building method is considered as ‘the best way’, for many situations. The SHF (1) is aware of the discrepancy in that hypothesis and discusses their buildings with the local people to adapt it to their wishes. Cal Earth (7) is acting quite arrogant and says to have the ultimate design for every situation.

D. The examples 1, 2, 8 and 13 show the coherence between the levels of acting demand driven, being participative in the approach to the beneficiaries and capacity building of an involved community. When a project is requested from the people that need it, it is more likely for an organization to listen well to the request. So working demand driven means
creating more chance for successful improvement of the social life and eventually should result in a better socially accepted building. The SHF (1) seems to score acceptable on this aspect (long term social acceptance), but a note has to made that the beneficiaries are currently very content with their domed houses.

E. About the relation between technical long term acceptance and the high quality of a building, there is one thing to say. When a building is technically understandable and thus easily repeatable in the future, there is a danger of choosing a technology that is not up to quality standards. This may be the case in many developing countries, where the knowledge level often isn't very good. Examples 4 and 8 have in common that a minor adaptation of the traditional way of building is being introduced. If that adaptation is not further developed into a more advanced way of building, then the quality won't improve very much. Most important question here is: how important is a high quality then? The example of PA in Kenya (8) proves that in their case the quality has risen up to a very acceptable standard. Thus high quality is not an absolute demand.

The aspect 'cooperation with local parties' was introduced as a condition for appropriate technical knowledge in the field. But cooperation with a local organization may also be of great value for good contact with the target group. Conclusions about evaluations of examples on the field of professional cooperation are not being discussed, because relations with other aspects are not very strong (for these examples).

5.3.1 NRC school in Rumbek (3), School in Burkina Faso (6) & PA in Northern Sudan (10)

What makes the best examples score so well? Let us start with what these organizations did: find a suitable target group. The community that was involved, takes a clear part in decision making. But the most striking similarity between these three projects is the use of appropriate (low-) technology. In these cases there is a maximization of the use of local sources, but with a strict preservation of quality. The quality demand often results in the use of steel and cement, which is why these examples score only satisfactory on the ecological field, cradle to cradle.

The NRC school is constructed with much necessary cement and steel, but aims at using as much locally produced earth and concrete blocks as possible. The water they need is stored in water tanks on site, women get it from the local pumps for a small payment. A few young men are chosen from (& by) the community to be trained as construction workers. These ways NRC supports growth of the local economy.

The school in Burkina Faso is constructed for a very large part of CSEB. The stones are protected with a large lightweight steel roof which functions as a second skin. The only difficulty for the construction was to learn the local people how to weld steel trusses made of rebar.

The project of Practical Action in Northern Sudan is all about small improvements of traditional technology. That is the most appropriate way to act as an intervening organization. In order to do so, PA motivated the people to start their own cooperation and trained some people in the field of entrepreneurship. In this case they found a rest product of local agriculture which seemed to be a perfect substitute for wood to burn clay bricks. Also ways to mould bricks, the proportions of clay and sand and more efficient ways to build ovens were introduced step by step.

The last three projects make clear that using appropriate technologies is a very effective way to contribute to change and improvement of lives in underdeveloped areas. Therefore it would be a recommendation to use or develop appropriate technologies for the situation of Rumbek. Ways to construct, like with CSEB, rammed earth, concrete (hollow) block systems are examples that are surely worth to consider.
5.3.2 Review of SHF vision

The vision of the SHF in short again:

1. Durable solution
2. Cost effective; affordable for the target group
3. Participative approach
4. Improvement of community spirit (capacity building)
5. High quality living environment
6. Improvement of dependence and responsibility
7. Demand driven projects
8. Cooperation with professional local parties
9. Ecological and social responsible

Looking back at the developed list of aspects for the assessment of the examples, there is a remarkable match with the vision of SHF! SHF emphasizes a bit more the importance of the social embedding of their projects and also stresses the importance of a long term development. The only aspect missing from the assessment sheet, is the long term technical acceptance. It is not the core business of SHF, but more attention to this aspect may lead to better projects and more positive long term effects. Especially when it comes to productive durable building without anymore intervention.

5.3.3 Design development

For architectural design of a house only half of the treated aspects are directly relevant: Environment response, High quality, Long term acceptance (social and technical). The projects that score best on these combined aspects are the examples 3, 6 & 10.

5.4 Literature

* Cal Earth: http://www.calearth.org
  http://www.calearthpakistan.org
  http://www.fondationpourlarchitecture.be

* Practical Action: http://www.practicalaction.org

* The example of the school in Burkina Faso was first spotted in the museum of the tropics in Amsterdam. The Aga Khan website link: http://www.akdn.org/agency/akaa/ninthcycle/page_04text.htm

* http://www.veerhuis.biz (Veerhuis shelter solution)

* Leersum, A van, 2007, Red Cross Housing Programme; A socio economic impact study, Technische Universiteit Eindhoven. This report is, together with a presentation of the author at 21 November 2007, the source for the assessment of the example of RC in Vietnam.

* Helm, Heleen van der, 2004, Vrijwilligersopdracht Gambia, A Programme of TPG and WFP, MS PowerPoint presentatie.


There are many more interesting examples which are worth looking at and to learn from. Because material use is considered as very important in this thesis, the example of Shigeru Ban who uses cardboard for shelters is very interesting (but more in the direction of so called transitional shelter).

Part D:
DESIGN DEVELOPMENT
Chapter 6
Design Suggestions

This chapter contains the vision of the author, concerning the design of housing according to the main research question. The vision is based on the research results and on experiences in the field of Rumbek. The formulation of a design question is necessary in order to meet the wishes within the vision. The design question will be the general basis for the design of a Dinka house.

6.1 WHAT to build

When executing the research in Rumbek one of the most difficult questions were: for which target group and at which location? Because finding answers was practically impossible, the target group will be a common group and there will be many possible locations. A house design will therefore have to be repeatable and not adapted to a certain direct environment. This way the SHF is able to implement the design in any future situation in the area of Rumbek.

6.1.1 Why design a House for the Dinka in Rumbek

- Rumbek is expected to grow and become a relatively large city (what it was before the war). If people continue to build ('modern' permanent houses) with the low quality materials at hand in the village, then Rumbek will become a city of slums.
- Currently there is a housing shortage: building is an increasingly expensive activity. People can often simply not afford a (new) hut. The quality of living is decreasing due to weakening structures, leaking roofs and not enough inside sleeping space.
- Tukuls are no permanent structures, they don't last in the climate of Rumbek and are originally huts of semi nomads. People now long for a lasting home.

6.1.2 Demands

The demands are based on observations in Rumbek.

Urban situation

A house for the Dinka people should be a repeatable model, for possible large scale implementation (SHF). Furthermore, a -hypothetical- choice of a location in Rumbek was not possible, so the model should be applicable for different urban situations. To realize that in a realistic way, a house will be situated on a compound within a plot-system as is now being implemented by local authorities.

There are three different sizes of compounds [MoPI Lakes State]:
- Class 1, a plot of 40 by 50 meters, most remote from the centre;
- Class 2, a plot of 30 by 40 meters;
- Class 3, a plot of 20 by 30 meters, most central.

Functional demands

- Living space minimum 16 m² (semi open);
- 3 bedrooms of minimum 10 m²;
- A covered cooking place; [Joseph Ssemanzi, Bros]
- On the compound a toilet (or at the neighbours), a shower place and possibly an animal home.

For this thesis only the house itself will be designed.

6.2 VISION

The next targets for the design of a Dinka house are a result from the previous chapter. See page 103, §5.3.3.

6.2.1 Objectives

1. A low cost but durable solution (Affordable & Durable Quality)
2. The design of a house should contribute to the protection of the low cost materials it is built with and should be guaranteeing comfort for the dual climate of Rumbek (Environment Response, or: Inclusive
Design)
3. The forms and functions of the house should respect the Dinka cul­
cure (Long Term Social Acceptance)
4. Use of easily understandable techniques with local sources, making
a low threshold for future continuation without intervention of a
humanitarian organization like SHF (Long Term Technical Acceptance)
5. In addition, the design should be smart and provide direct -short
term- advantages from the climate, the surroundings and whatever
more. If a solution provides a long term advantage, a short term
advantage opposite it is often necessary to make the solution accept­
able. [Tomas Viguurs, SHF]

6.2.2 Design question
Above objectives should be the basis for any building design in Rumbek.
In this case the focus is on housing. The design question, in order to
answer the principal research question will be:

What could be an appropriate design for a self help house in Rumbek, if it should
be affordable, durable, environment responsive and both social and technical
acceptable for a long term?

The next paragraph is dedicated to fill in the best answers to this ques­
tion in the form of a strategy and a detailed list of optional factors which
influence the design of a Dinka house.

6.3 HOW to build

6.3.1 Main strategy
1. Low cost, high quality & technical acceptance
   • Use earth and make Compressed Stabilized Earth Blocks (see §3.2.4,
   page 73)
     1. CSEB may become a source of income and can be a durable
        building material if treated well.
   2. Protection from heavy rain is necessary.
   3. A CSEB is much stronger than a locally produced brick. Further­
      more, the size makes the masonry less difficult.
   4. Self-help building is likely, because of the embedded way of
      producing and building with clay blocks.

CSEB is the most important material because
the walls take most of the volume of a
building. But it would be smart and cheaper
to use adobe for internal walls.

2. Weather proofing (environment response)
   • Apply a roof to protect the walls from sunshine and rain. Use a water
      proof plinth to protect the walls from the occasional flooding. In
      short: Use a "good hat" and some "good shoes";
   • And/or: Protect the walls with a plaster or a panel. This however will
     make costs rise. The "hat and shoes" are a design solution, while this
     option is an additional solution.
3. Response to climate (environment response)
   - Ventilate, see §4.2.1;
   - Create shade, see §4.2.2;
   - Water management: harvest rainwater and use ditches to prevent the house from being flooded.

4. Insect proofing (environment response)
   - Choose steel or cement for the roof surface. Those two materials are most common to import into Rumbek and make rainwater harvesting possible. If iron sheet is applied in a smart way, then it may also be climate responsive.
   - Make anti termite detailing. This appropriate technology is additional, because the preferred wood will be hardwood—which is not subject to complete decay because of termites—which is locally available. If softwood or bamboo is used, it can also be impregnated.

5. Social cultural response
   To support a social embedded design, the list of aspects in the next paragraph is important. But the best support would the feedback on sketch designs of the Dinka themselves. It would thus be recommended to contact the Dinka and ask their opinions about different options for house models.

6.3.2 Exhaustive solutions and aspects to choose from
   This paragraph presents many possible factors indirectly or directly related to the four stated objectives from §6.2.1. Most of them are extracted from the conclusions of the chapters in 'Part B: Rumbek'. (See §2.3 & §3.3) Some aspects are supplemental and some are alternatives for what is chosen in the main strategy of §6.3.1.

Social cultural response
   The forms and functions of the house should respect the Dinka culture (long term social acceptance), so consider:

Location and situation
   - Tukuls are normally built in corners of the compound or along the borderline, not in the middle.
   - Distances between the tukuls and the very small windows offer a lot of privacy.
   - A Dinka preferably marries more than one woman for his social level. Newlyweds always build their own house and each wife gets her own tukul/room.
   - A porch mostly is located at the eastside, to have shadow in the afternoon and evening.
   - Water should be available nearby the house.

Functionality
   - Cooking always happens outside or under a roof (a kitchen—a luxury—
or the semi open hut) when it rains.

- Functions from important to least important.
  1. bedroom for the man (and wife), 2. for every wife a separate bedroom, 3. bedroom for children, 4. bedroom for visitors, 5. storage, 6. kitchen.
- A shower or toilet is put at a good distance from the kitchen.
- The clay slab in front of the sleeping tukuls is a form of decoration, it is for sitting in the evening, sleeping at night, prevention of blowing dust and protects the tukul entrance from being flooded in the rainy season.
- The design and the total package of a (closed) sleeping tukul make a very agreeable indoor climate. Only one (hot & dry period) month a year people sleep outside. Sleeping on the roof is an accepted concept but the reason should not be a lack of space.
- 2 to 4 cows occasionally stay in a compound, but goats and chickens need a covered place for the night.
- More rooms inside one structure is an accepted concept.
- The concept of a patio house is accepted, but people are used to a lot of open space (a large yard).
- Fences are used for privacy and prevention of people taking short-cuts through a compound.

**Form**

- The clay slabs and the wall base of the tukuls are two main ingredients for the typical looks of a Dinka hut.

- Decoration equals status.
- Durable building materials like bricks and iron sheet have more status than anything else within the tradition of tukuls.
- A roof should preferably be traditionally conical or a saddle type (a ramp).
- Iron sheet roofing, masonry walls, plants, flowers, a flag and a latrine are all elements that should be included.
- One straight lined (pitched) roof for a group of houses is not easily accepted, it would be better to make every house or room visible as one.

**Appropriate Technologies**

- Technical solutions for the situation of Rumbek like solar energy panels, rainwater or waste water harvesting systems or water purification systems can easily be implemented and will surely have a positive effect on the standard of living.
- Solar water disinfection: plastic bottles on an inflammable roof for water purification. A corrugated metal sheet is necessary to practice this simple technology.

![Solar Disinfection](image)

- In countries where there is a lot of sun-shine, the heat and light of the sun can be used to kill disease-causing organisms. This method is becoming very popular because it is cheap, simple, and requires little work. Research has shown that if used correctly, the treated water is as clean as boiled water. The process is called solar disinfection (SODIS).

- Rainwater harvesting with e.g. a (ferro)cement tank, because of the long rainy season and the dry season afterwards. A steel roof or a smooth (ferro)cement surface are the easiest ways to obtain plenty of (clean) water.
Ecology

- The first level of ground water in Rumbek is becoming more and more polluted due to dumping of (industrial) garbage and pit latrines.
- Biological dangers for the Dinka and their tukuls are termites, mosquitoes and hyenas among others. In rural areas a solution for larger wild animals like hyenas was building a tukul on poles. For storage of food this was also done to protect from animals like rats.

Climate response

See §4.1, Page 87.

Urban issues

- Traditionally, Dinka compounds are not protected with a fence.
- Rental or selling of (pieces of) compounds happens for an income.
- The contrast between the current urban structure in development and the rural structure is remarkable.

Building materials in Rumbek

- The main idea of producing building blocks for commerce and self-help building activities is supported.
- Concrete blocks are produced in Rumbek for modern structures. This type of block is useful if high quality and total water resistance is a demand.
- CSEB's are producible with local riversand and cement. Sometimes the local clay soil is also added.
- Rammed earth needs the same ingredients as CSEB's, but needs a good formwork, usually made of wood.
- Adobe is the cheapest block to build with. The soil in Rumbek is full with clay but the dried stones need protection from water.
- Bricks in Rumbek are made with the same soil as adobe blocks. The mixture could be much better and the burning process and temperature as well. Deforestation is at hand if burnt bricks are going to become a standard for modern housing.
- Bamboo is locally harvested, but some kilometers away from Rumbek. It is so far used for roof construction and for interweaving of fences and walls.
- Grass is harvested near Rumbek and is only used for thatching. Use as a fiber in plasters or new building materials is an option.
- Termite mounds could be used to make mortar for adobe block walls.
- Materials are preferably absolutely not natural, but mechanical and industrial looking.
- Rumbek has a lack of variety of the following building materials: Doors and window frames, Roofing tiles, CSEB, home grown materials like bamboo, grass, trees for wood.
- To protect materials from termites: burnt motor oil is used to impregnate wood. For clay sometimes a rest product of a local alcoholic drink is used (the Dinka name is 'muna'). An alternative is an extraction from leaves of a local tree.

Building technologies

- Most striking about the tukul building technology are the separated structures for roof and the walls, however sometimes integrated.
- The technology of filling up two layers of wire mesh in a rib/cage with polystyrene filling has potential. The cement mix however needs special treatment in a machine.
- When the clay earth is dug, for block production or whatever, it is better to dig at a place where a ditch or a hole will have a certain function (water management).
Part E:
FINAL RESULTS
<table>
<thead>
<tr>
<th>What</th>
<th>Price/unit (see Annex 10)</th>
<th>9m Dome type L</th>
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</thead>
<tbody>
<tr>
<td>Cement</td>
<td>27 USD/50kg</td>
<td>4.725 USD</td>
</tr>
<tr>
<td>Rebar</td>
<td>27 USD/10mm*12m</td>
<td>8.235 USD</td>
</tr>
<tr>
<td>Bricks</td>
<td>?</td>
<td>-</td>
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<tr>
<td>Hardwood</td>
<td>20 USD/4m<em>2</em>4 inch</td>
<td>PM</td>
</tr>
<tr>
<td>Iron Sheets</td>
<td>27 USD/0.82m*3m</td>
<td>-</td>
</tr>
<tr>
<td>Thatch</td>
<td>10 USD/bundle</td>
<td>-</td>
</tr>
<tr>
<td>Bamboo</td>
<td>3 USD/bundle</td>
<td>-</td>
</tr>
<tr>
<td>Clay soil</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>River sand</td>
<td>235 USD/3m3</td>
<td>PM</td>
</tr>
<tr>
<td>Pit sand</td>
<td>200 USD/3m3</td>
<td>PM</td>
</tr>
<tr>
<td>Water</td>
<td>?</td>
<td>PM</td>
</tr>
<tr>
<td>Labour</td>
<td>?</td>
<td>PM</td>
</tr>
<tr>
<td>Electricity</td>
<td>?</td>
<td>PM</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>12.960</strong> USD</td>
</tr>
</tbody>
</table>

Table: Cost estimation of a dome in Rumbek
Chapter 7
Domes in Rumbek

This report is aiming at an alternative way of building for SHF. However the Solid House Foundation has always had a few good reasons to build their domes. That is why it would be of interest for SHF to know how to implement a SolidHouse concept in Rumbek. This chapter aims at recommending SHF how to build a concrete dome in Southern Sudan, while the next step is to develop a new method. This chapter is a continuation of chapter 6, as it is written with the therein-mentioned vision as a basis.

Introduction
The local research mission was based on an open-minded view towards any type of building for housing. The results are therefore also suitable for further development or adaptation of the dome concept for this new situation. The next sections are divided according to the four objectives from the previously presented vision (§6.2) and will argue which properties of a SolidHouse are suitable for Rumbek and how to adapt a dome to the situation of Rumbek.

7.1 Affordable durability
The dome is a solid house, literally. It needs a vast amount of cement to become as solid as it should be, because it is the main ingredient to the shell. A dome will therefore be more expensive than a building with a minimized amount of cement. But the dome may still be competitive with the new upcoming way of building with lots of heavy concrete blocks in Rumbek, because the surface of the walls of a dome is much smaller than the surface of the walls and roof of a 'rectangular' building.

However, the quality of concrete in Rumbek is questionable. The aggregate that is used there - it is far too costly to import aggregate from Kenya or Uganda- is of poor quality. Furthermore, not always the right proportions are used for the mix. For a dome this is bad news, because concrete cracks. If the concrete is of low quality, the cracks may become worse. On top of that, another inevitable material for the dome is also of low quality: reinforcement bar/rebar. They are basically twisted 10mm iron bars. The grip for hardening concrete is therefore lower than for the rebar we know in Europe. See the picture on the left.

Furthermore, the costs of cement and rebar are very high in Rumbek. According to the latest calculations of material use in Sri Lanka, a 9m diameter dome (type L) uses about 175 bags of cement, not including the floor rendering. Together with 305 pieces of rebar, the material costs for cement and -just the 10mm type- rebar are approximately 13.000 USD. For the calculation, see the table (left) and Annex 15.

Because concrete domes develop cracks -which may be even worse in Rumbek- water proofing for rain resistance will be a mayor issue. In order to prevent the use of a special paint or plastic sheeting, which may dramatically increase the price, it is very important to consider the right way of applying the finishing outside layer for the dome. First, the concrete shell should be cured for at least 5 days with moist gunny bags. After that, pure cement and a little water should be applied to smoothen the concrete, which is then prepared for receiving the outside plaster layer. This layer contains cement and a white powder called “Padloy” (2 kg for 50 kg cement) and should be cured also for 5 days. Important is that the final plastering happens from the base to the top(!), where special attention is needed for the joints between old and new parts of the plaster. The Padloy powder, the curing with gunny bags and the strict way of making the shell waterproof make expenses rise for the proper construction of a dome in Rumbek. [Waterproofing the shell: Eelke van der Werf, mei 2008]

Now let us try to make the dome less expensive. An obvious possibility is the main conclusion from Carli Hammer’s thesis: Construct the dome of ferrocement. Ferrocement is a word which defines the combination of
Catenary dome (funicular curved) [C. Hammer]

Possible alternative openings for domes [pirs]

Ferrocement structure sketch

Climatic performance of an SHF dome

- Thin roof/shell
- Walls are subject to sun
- Sun comes inside
- Rainwater harvesting
- No cross ventilation
- Hot air outlet; stack effect ventilation (depending on temperature differences)
chicken wire and cement (with water). The total amount of needed cement is lower than the amount of cement for the concrete shell. Furthermore, the rebar quality will no longer be a problem.

Another option would be the use of stabilized riversand mixed with a bit of clay. The only way to apply those (steel reinforcement is not possible) is when using a balloon that follows the downward pressures: a funicular curved formwork. Because of the rainy season, this structure won't hold for more than one or two years. It could however be a type of emergency shelter. But the tukul may still be a better way of building temporary homes, because it is how the people are used to build.

To continue with the same form, construction of a funicular curved dome with ferrocement could be an interesting development for permanent housing. It needs not too much cement and chicken wire is the only steel needed to keep the dome erect. Caution should be taken when making openings for doors and windows, they should preferably follow the downward pressure lines as well as the catenary dome itself does.

The interior walls of a dome could be made with adobe blocks, because the dome is fully protecting the interior from rain and water coming in, if realized properly. If adobe is not accepted, CSEB would be a wise alternative. It creates jobs and its quality is very high compared to adobe or burnt bricks.

7.2 Environment response
As referred to in the previous paragraph, the wall thickness - if reinforced concrete is the applied material - will have a positive effect on the interior climate of the dome. Only some months in the year a warm construction will not be appreciated, because the night temperatures are then very high. But despite this wall thickness a dome can still get hot if not ventilated well. The tukuls are similar in this way: the walls are very thick, and are ventilated quite well. The advantage of the tukuls is that they are much lower and have a protective roof.

It would be risky to simply apply a dome design as used in Sri Lanka, because ventilation may be more important in Rumbek than in Inspector Eatham. A hole in the roof for temperature driven ventilation may not be sufficient since the temperature differences between inside and outside are not very big. A wind driven ventilation - cross ventilation - will be the most effective one for a more comfortable interior climate experience. A good reason to take a closer look at ways to create openings in a dome - other than the conventional ones - for stimulus of cross ventilation. The examples on the image respect the forces inside the construction. These are some possible alternative openings for domes.

A disadvantage of a dome in Rumbek would be the lack of outside shading. The Dinka are used to spend most of their time outside, where they need shade and rain protection. The dome initially doesn't offer a space like that. But for every problem is a solution. As the image with possible openings shows, it could be considered to create large openings or a colonnade and a separate interior structure of cheaper materials inside. These large openings result in less use of cement. Instead of creating openings, creating a porch connected to the dome, or other constructions that provide shade, is another challenge for the designer. When using ferrocement it may even be possible to make a 'fluid' extension of the dome skin. An important note for ferrocement structures is that the thin - max. 5cm - layer insulates less than the thicker - approx. 10 cm - concrete layer.

For a short overview of the climatic characteristics of a standard dome, see the left page.
Some concepts for domes in Rumbek
7.3 Social acceptance
Because a SHF dome is very solid the Dinka may like it, as they are wishing for permanent structures. But fact with a dome is that it is initially a strict and closed structure. That may be solved with openings in the shell, but the different functions inside are often connected through each other. This is a design challenge, because the Dinka are used to have rooms - tukuls - totally separated from each other. How to realize that, if also cross ventilation and a shaded semi-open space are a demand?

It is hard to compare the rounded domes with the (round) tukuls in Rumbek. In fact, there is no comparison at all. A dome consists of one shell and rooms within that shell. A tukul is one room, constructed of clay and a totally separate roof structure. They are the opposites of each other.

7.4 Technical acceptance
For building a SolidHouse electricity is inevitable. This is very expensive in Rumbek. The only way to get electricity is to rent or buy a generator and fuel it. The fuel comes from Kenya. Solar power is an alternative, but also expensive and less reliable which is a demand for the balloon.

The concept of a balloon is totally new for the Dinka. The Dinka are good learners in practical work. Despite that fact, they are also known to work best under constant supervision. The experience of NRC (Norwegian Refugee Council) in Rumbek is a good illustration: They trained a few young Dinka of whom one became a small contractor, working for NRC. The new way of building this contractor adapted from his training, was not of the same quality as he had learned to build together with skilled workers from Kenya. Therefore his work needed to be checked. This example is about a building method with more precision work than with the conventional way of building. For SolidHouses construction - where even more precision work is necessary - the training and supervision will thus be of high importance. That could be a reason why expenses may rise compared to a more conventional way of building.

7.5 Conclusions & Recommendations
Based on the previous argumentations two conceptual sets of sketches suggest ways to adjust the dome to the circumstances of Rumbek.

For three suggestions see the concepts on the left.

As stated within this chapter, the costs of a dome may be higher than a conventional construction, but the use of ferrocement could be a solution. However, when thinking forward about alternative ways of building, cheaper construction is possible when minimizing the use of imported materials like cement and steel. This makes the dome less interesting as a housing unit, also considering social and technical acceptance and quick self-help building as important factors.

So maybe no large scale production, but how about a few domes?

Domes could perfectly be any important facility building. The high quality of a dome may invite local people to appreciate and maintain it. The most desired type of facility in Rumbek is sanitation. SHF intends to initiate her appearance in Rumbek with the building of sanitation domes. It would be a good start. If these sanitation facilities turn out to be successful, then some domes may be built for other common services. Like a community building, a school (class) or a hospital unit. But even more helpful to the people of Southern Sudan would be the continuation of building sanitation buildings and expansion to other places. It will provide more possibilities to get involved in habitat projects in the future.

Advice about how to technically achieve the construction of a (sanitation) dome is not an objective of this report. Neither would it be appropriate for an inexperienced dome builder as myself to do so. But some important aspects to consider are the following:

- The quality of the concrete mix. Search for the right types of sand and aggregate: Riversand (local), Lime (import), Pit sand (local), crushed Laterite rock (local), cement from Kenya or Uganda;
Some concepts for ferrocement domes in Rumbek.
• The quality of rebar in combination with the type of cement mix is not good. Try and find an alternative, like chicken wire with ferrocement or fiber reinforced cement;

• The formwork for door and window openings should not be made of wood. There is very little softwood available and the quality of local formwork (partly because of the wood quality) is low. Ferrocement or masonry would be good alternatives;

• Think about building domes in the rainy season. Perhaps make a cover with palm leaves and bamboo (in combination with scaffolding) Just a little bit of moist is welcome for the curing time of the concrete, but protection from the short but very heavy rainfall is necessary;

• Solar power, especially in the dry season;

• In the opening in the top of the dome a wind turbine can be added to stimulate a chimney effect. The wind turbine can be made of flattened tin cans or other low cost materials.

• Find trainers and supervisors from Kenya or Uganda to lead and train the Dinka, but shift the leading tasks whenever possible towards the - ever proud- Dinka men.

The use of ferrocement deserves special attention:

• Think about using ferrocement for a funicular curved/catenary formwork. If rebar is not necessary anymore, the costs and the way of building will become much more comfortable. On top of that, there is a great possibility that chicken wire excludes the use of a balloon! Or at least the balloon won't be as important as it is with the round SolidHouses. For example: Build one catenary dome and use it as a formwork for many next ones; fold the chicken wire, take it off and place it on a new floor. (Another possibility: Dig a catenaric hole for the formwork) See the sketches on the left.

The exclusion of a balloon will make costs drop. Furthermore the foundation doesn't need to be as heavy as needed for the concrete domes.

• The eventual costs of a catenaric dome completely constructed of ferrocement will make a big difference for dome building in Rumbek, since not only cement but moreover rebar are very costly in Southern Sudan. A pilot building may lead to an economic optimization of the dome concept for Rumbek.

• For further development of ferrocement domes in Rumbek, two characteristics should be considered: acceptance because of 1) functional demands and 2) climate response:

1) The functional demands could e.g. signify that a dome as a just a single or a double room would be most accepted. Then more material is needed and the affordability would drop. Furthermore the difference between a catenary dome and a round dome has consequences for the costs.

2) The climatic comfort of a ferrocement dome is totally dependent on extra insulation and/or ventilation, because the shell thickness is heavily reduced. An extensive calculation of the climatic performance of a ferrocement dome would therefore be very valuable.
Chapter 8
Final Design

This chapter presents the final proposal - as an alternative for the SHF dome - for a Dinka house in Rumbek. It is based on the design objectives as presented in chapter 6. The development of the model was supported by a few Dinka from Rumbek. The result is an interpretation of their comments as well as an advice to them, based on literature and research in the field of Rumbek.

8.1 Design
This introducing part of the chapter shows what the final proposal looks like. Why this design should be the most appropriate one for the Dinka of Rumbek, will be explained in paragraphs §8.2 till §8.6.

8.1.1 Compound lay-out
In Rumbek the compounds are relatively large compared to the buildings. The composition of buildings on a compound depends on taste of the family living on it. Mostly the houses are built near trees, for the shade. The final model already has a shaded place and a roof overhang to cover the walls with shade, so the location depends only on its orientation to the sun. The placement within the compound differs according to the orientation of the plot and the taste of the owner. This way the model is autonomous and repeatable in any situation.

8.1.2 Design
The building consists of three bedrooms (each 11m²), two covered outside living spaces for men and women (approximately 22m² & 11m²), and possibly three attics as semi-open sleeping or storage spaces. A stabilizing cross splits the space in half, which prevents the use of the attic as a permanent room. This is to maintain the function of the roof plane as a second skin. The second skin is to keep the sleeping rooms as cool as possible. In addition, the large roof plane is useful for rainwater harvesting. Section BB' shows just two attics, because it would be recommended to find out on site whether the second floor has a positive effect on the interior climate. The walls consist of CSEBs, CEBs and CBs. The roof is made of ironsheet and the supporting construction of hardwood. The floors inside and outside are made of the traditional clay soil which is all around. The second floor has hard wooden beams to support a -traditional- floor of interwoven bamboo (and clay soil).
8.1.3 Building Method

A visualisation of the building method in several steps:

01 - Excavation of the foundation
02 - Fill with (laterite) rocks
03 - Pour the rocks over with a sand cement mix and level it
04 - Start the masonry (under ground level) with the concrete blocks (200*400*200mm)
05 - Use Concrete Blocks (CBs) until approximately 30cm above ground level. Use stones of 200*300*200 to make a strong bond at the place where an inner wall is situated
06 - Start with CSEB masonry, beware of the door aperture
07 - Continue building
08 - Continue
09 - Continue until approximately shoulder height
10 - Start with measuring the place of the windows, using the right sizes of blocks. Three length sizes for C(S)EB production are recommended: 400, 300 & 200
11 - Continue building
12 - Continue
13 - Continue

14 - Level the last row of blocks for the windows and place iron ties for the trusses

15 - Place a continuous ring of hard wooden boards

16 - Continue the CSEB bricklaying

17 - After two rows, place beams - which are not more than 200mm in height - for a second floor and continue bricklaying

18 - Lay one more row on top of the beams
19 - At this level, fill the pillars with concrete. Don't forget some rebar and most important a wire to connect the trusses.

20 - Place the trusses and immediately fix with the beams for the iron sheets to keep the trusses up right.

21 - Use the iron ties from step 14 to fix the trusses.

22 - Continue bricklaying with two or three more layers, to fix the trusses in the walls.

23 - Start applying iron sheets.

24 - Now it is time to finish!
Rebar used as anti-theft elements in window openings

The scale model in its context
After the last step, it is time to finish the floors, to fill in the second floors, fill in windows -with netting, chicken wire or anti theft bars- and door gaps, and maybe protect the attics with wire gauze or netting. An option to ensure the stability of the trusses is to make a cross from one truss to another, lengthwise.

8.2 Affordable Durability
As clarified in §6.3.1, the use of CSEB as the main material would lead to a few advantages. A protective roof and the combination with a minimum amount of Concrete Blocks (CBs) for the plinth are required for a durable quality. If protected and executed well, the CSEB building will exist for a few generations.

Instead of CSEBs, CEBs for some walls would reduce costs considerably. The calculation in Annex 15.1 shows that for the presented model still 120 bags of cement are necessary. However, that is without the use of CEBs and a full coverage of CBs for the walls below ground level and the plinth. The social and technical acceptance of this idea is not known. The CB's in the calculation are massive blocks. Hollow blocks will dramatically decrease the need for cement.

The roof is the most expensive part of the design. It is not easy nor recommended to reduce costs on the roof construction, because it is an essential part of the house.

The maximum costs of the most expensive and essential materials of the final model are 7.500 USD. See Annex 15 and the table on the right.

A comparison with other models based on affordability is difficult, because of different durability/quality levels. The quality, aesthetics and functions of a model should be decisive for the Dinka, because those provide some direct advantages. These advantages -among others- for the proposed design will be discussed in the next paragraphs.

8.3 Environment Response
The CSEB walls need protection for rain. The rain in Rumbek creates floodings. That is why the plinth of the walls is made with CB's. The extended clay slab also protects the interior from being flooded. This is the traditional way to protect huts from the rainwater. A maximum roof overhang prevents the sunrays and the rain to hit the walls until a certain degree. The maximized roof combined with a gutter and a tank make the harvest of rainwater possible.

A gutter as a border line of the compound should protect the building(s) from being flooded. The earth that is dug from the compound border can perfectly be used for the production of CEBs, CSEBs, floors and the

<table>
<thead>
<tr>
<th>What</th>
<th>Price/unit (see Annex 10)</th>
<th>Final model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>27 USD/50kg</td>
<td>3.240 USD</td>
</tr>
<tr>
<td>Rebar</td>
<td>27 USD/10mm*12m</td>
<td>216 USD</td>
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<td>Bricks</td>
<td>?</td>
<td>-</td>
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<tr>
<td>Hardwood</td>
<td>20 USD/4m<em>2</em>4 inch</td>
<td>1.800 USD</td>
</tr>
<tr>
<td>Iron Sheets</td>
<td>27 USD/0.82m*3m</td>
<td>2.214 USD</td>
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<td>Thatch</td>
<td>10 USD/bundle</td>
<td>-</td>
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<tr>
<td>Bamboo</td>
<td>3 USD/bundle</td>
<td>PM</td>
</tr>
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<td>Clay soil</td>
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<tr>
<td>River sand</td>
<td>235 USD/3m3</td>
<td>PM</td>
</tr>
<tr>
<td>Pit sand</td>
<td>200 USD/3m3</td>
<td>PM</td>
</tr>
<tr>
<td>Water</td>
<td>?</td>
<td>PM</td>
</tr>
<tr>
<td>Labour</td>
<td>?</td>
<td>PM</td>
</tr>
<tr>
<td>Electricity</td>
<td>?</td>
<td>-</td>
</tr>
</tbody>
</table>

| Total      | 7.470                     | ≈ 7.500 USD |

Table: Cost estimation of the proposal in Rumbek
Part E: FINAL RESULTS

Different blocks in the final model: CBs, CEBs & CSEBs

Bricks and plastered CSEBs as decorative elements, Uganda

A protective ditch as compound boundary

Climatic performance of the proposed design

+ DOUBLE (SKIN) ROOF
+ LITTLE SUN ON THE WALLS
+ NO SUN THROUGH OPENINGS
+ RAINWATER HARVESTING
+ CROSS VENTILATION
+ HOT AIR OUTLET FOR THE ROOF (OPPON FOK STACK EFFECT THROUGH SECOND FLOOR)
traditional clay slab. Apart from flooding protection and being used as a source, the boundary gutter is a free way to mark a private plot.

To prevent termites from eating parts of the construction, the materials hardwood, metal and cement are inevitable. The natural materials used for the second floor need an anti-termite treatment. One way is to include a downward pitched strip of metal in the plinth of the walls. A cheaper way is to use a repellant. A repellant can be made of locally available natural sources and should be sprayed over a material. If the spraying should be repeated needs some further research, see §9.3.

Protection form bats and other vermin. Southern Sudan is teeming with (smaller) animal life. Every tukul, school building or church houses some small animals. Especially bats and insects are able to house themselves underneath the roof. To prevent that, netting or chicken wire may be used to fill the gap between the roof and the walls. However if the attic is used for storage, the goods will be covered with sheets if it were only for the dust. For sleeping always goes that mosquito nets are used. Despite the many precautions that are being taken, animals like rats, scorpions, bats and insects always find their way inside.

The climatic comfort depends on a few matters. The most important ones were all considered while carrying out the creation of the proposal. See the picture on the left.

According to the formula concerning the desirable roof overhang at page 94 (§4.2.2), the overhang should be approximately 0,29 meters for the South wall and 1,25 meters for the West wall. Because with this formula just the windows are not subject anymore to direct sun radiation, a larger overhang is desired to cover an entire wall with shade from the roof. For the South a maximum height of 5 meters leads to an overhang of 0,50 meters. The proposed overhang in the drawings is 0,75 meters, a full coverage. For the West façade a height of 2,2 meters leads to an overhang of 2,75 meters. Here an overhang of 1,50 meters is chosen which covers the windows, but not the whole wall. Concluding that the South, North and East walls are fully protected and the West wall is sufficiently protected. [SLF for South wall = 10,1 and windowsill at H = 3m. SLF for West wall = 0,8 and windowsill at H = 1m]

8.4 Social Acceptance
As stated in §6.3.1, the social acceptance should be supported by using feedback from the Dinka. Next to the useful input of the Dinka, the designing process is influenced by some characteristic elements from the local building culture. A complete list of the useful characteristics is given in §6.3.2.

8.4.1 Some characteristics
The clay slab in front of the tukuls is implemented in the design. The floors inside and the slab outside can be made traditionally and cost nothing but labour.

Decoration is a personal thing in the land of the Dinka. The support to their culture of decoration as a status symbol, is the idea to use different blocks. Masonry with CB, CSEB and CEB is decorative in a modern way. Painting of the stones may happen with a colored lime or cement plaster. Maybe a mud plaster is even possible, because the walls should be sufficiently protected for rain according to the roof design.

On the left page a reference of how to use different blocks in a decorative way, from an economical point of view.

A saddle type roof made of iron sheets was one of the most definite wishes of the children in Rumbek. Their wish for decorative and edible plants within the compound may become true if harvested rainwater will be used for e.g. agriculture.
<table>
<thead>
<tr>
<th>First suggestions</th>
<th>Dinka comments</th>
<th>Proposals</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Rainwater harvesting from the roof</td>
<td>No understanding, use of rainwater is a taboo</td>
<td>Still place a tank underneath the gutter of the roof, because it will be used as storage of water fetched from the pump.</td>
</tr>
<tr>
<td>2. Dig ditches around the compound to prevent water from flooding towards the house</td>
<td>Fences are preferred, but are also a product of the civil war. The water protection is interesting.</td>
<td>Dig the ditches; use the (clay) earth for creation of plateaus, floors and walls. The ditches also mark a compound and no costs will be made to construct a fence (every 3 years!)</td>
</tr>
<tr>
<td>3. Use of CSEB and only CB where necessary</td>
<td>Ok.</td>
<td>First suggestion agreed!</td>
</tr>
<tr>
<td>4. Use as little material as possible: joined rooms</td>
<td>Costs are not important. It has to be/look spacious.</td>
<td>Make a house VISUALLY more spacious.</td>
</tr>
<tr>
<td>5. Cross Ventilation stimulation</td>
<td>Ok.</td>
<td>First suggestion agreed!</td>
</tr>
<tr>
<td>6. Shaded outside space, for possible expansion</td>
<td>Shaded outside space, as large as possible! To be able to sit together with as many people as possible. Expansion will happen on another spot.</td>
<td>For this aspect it is better to agree with the Dinka, it makes a new design less complicated.</td>
</tr>
<tr>
<td>7. Slim but high windows (for pressure forces and maximized ventilation)</td>
<td>Preferably small -square-windows, because of privacy and what is 'normal'(because of clay strength).</td>
<td>Slim but relatively high windows are still possible, because the walls will be much higher than the walls of the huts. Privacy will be preserved.</td>
</tr>
<tr>
<td>8. Position of doors just near the corner, to make the interior space more flexible</td>
<td>Doors need to be situated in the middle, to maximize the view inside if the door is open, to control children.</td>
<td>The argument of the Dinka is disputable, an experiment is recommended. The advantage of a maximized interior space is very clear.</td>
</tr>
<tr>
<td>9. Roof esthetics with practical value: V-form or one (oblique) sheet. (to catch</td>
<td>A roof should be a saddle type, which means a more complicated roof than a plain plane of iron sheet</td>
<td>A saddle type combined with a V-type...</td>
</tr>
</tbody>
</table>

Table with Dinka opinions versus advice towards them
8.4.2 Feedback from Dinka

Because it is hard to reach Dinka from a distance -considering their situation- only four Dinka were used as a panel to check the appropriateness of the sketch designs. [Karak Mayik, Mathiang Angok, Jacky Adol & Andrea Mayak]

Some different options -based on the proposed method of building- were defined and tested. The questionnaire that was used to find out how the Dinka think about 10 comparable designs is included in Annex 14. Of all the preferences that were signaled, an interpretation is necessary in order to fulfill the objective and the design question. The following table shows the differences between what is thought to serve the Dinka well and what the Dinka think about that. In the third column a solution is suggested.

What is important, is that the final proposal should provide direct advantages. Long term advantages are often not accepted nor understood. Which means that a solution for a long term problem at best should be compensated with a short term advantage. The contents of the table are based on the questionnaire (Annex 14) and a conversation flowing from it.

<See the table on the left>

Because the Dinka paid great attention to visual performance and little attention to plan views, the functionally best options needed to become visually more interesting. The best option is already presented. The other options and the final choice are discussed in §8.6.

8.5 Technical Acceptance

The proposed building method is an interpretation of the local way of building. Copying and slightly adapting some local building technologies maximize the technical acceptance for the long term. Examples from the field -which are used for the proposal- are the best illustration to support this idea.

Ironsheet is chosen instead of cement tiles or boards, because of the demands for the supporting construction. The construction to support self-made (sand) cement tiles or (fiber) boards will have to be more precise and bear more load.

An example from Rumbek and an example from Burkina Faso show the use of bricks and respectively CSEBs to construct a pillar with a reinforced concrete core. In both cases the rebar is applied to connect with a ring beam. For the final proposal the use of large blocks (CSEBs & CBs) make a single stable pillar possible.

[Images of bricks and pillars]
Five final proposals:

I) Characteristics
- 2 internal walls
- Possibly 6 adobe walls
- 4 trusses * 10 meters
- Separate floor construction from trusses (higher walls and more wood)
- Optimal cross ventilation
- Visually attractive
- Simple gutter construction.

II) Characteristics
- 0 internal walls.
- Possibly 7 adobe walls
- 5 trusses * 8 meters.
- Integrated floor construction with trusses
- Good cross ventilation
- Modern gutter construction (see detail above)
- Outside spaces very separate
- No option for a third attic
The connection between the trusses and the wall construction is important, because occasional storms may possibly tear the roof off. There are two common ways to connect a modern (hard) wooden roof construction with a wall: "brick it in", and "tie it up". See the pictures. The strength of both ways of attaching a truss depends on the execution. To guarantee a strong joint, an extra provision is proposed. Four pillars - on each outer corner- are connected with the two outer trusses by a metal wire, which is embedded in the concrete core of the CSEB pillars.

The continuation of a lintel, forming a type of ring beam, strengthens the walls and makes leveling of the masonry less complicated. It also contributes to the aesthetics of the facades. See the reference picture.

8.6 Final pilot proposal(s)
Based on the discussed options and the conclusions flowing from the comments of the Dinka, five options were developed. These five options are the final proposals for an SHF pilot project in Rumbek.

The five presented options all preferably have one (or two) maximized ironsheet roof plane -to catch plenty of rainwater- in common. To make this plane visually more interesting, a steep plane is put half underneath it, suggesting the desired saddle type roof. This roof adjustment has two more advantages. First, there is an outlet for the heated air. Second, the wall is well protected for sun and rain. An additional advantage is that it provides a linear shaded sitting space, which animals can use as well.

One option is yet recommended to become a pilot model. For that choice, all the differences will be considered. To recognize the differences, first let us look at what they have in common:
3 bedrooms, 3 shaded outside spaces, 2 elevated floors, rainwater harvesting tank, a gutter that is situated above open space, a ventilated roof (which functions as a second skin), large overhanging trusses for wall protection and space enlargement.

Starting on the left page, for every option a list of variable characteristics clarifies the differences:
Detail of the gutter construction for the final design

The gutter could be a piece of cut out iron sheet.
The first option is the most interesting one, because it is most economical, combined with a visually attractive roof, optimal cross ventilation and the technique to place the gutter is kept simple. The choice to work out this option doesn't mean that the other options are not interesting anymore. They will be valuable if SHF returns to Rumbek and needs to provide the people with more than one option (after having built a test model with the proposed method). The five options will also be valuable for the development of housing in other areas of the world. [architects think tank SHF, 24-05-08]

8.7 Recommendations for further development

- Develop an execution plan (long term). Thinking about setting up a production facility, the rainy season that splits every year in half and tasks for men and women. To follow the same strategy as is done for the design, the design of the execution plan should be appropriate for the traditions of working and building in Rumbek.

- Find out if the combined use of CSEBs and CEBs is acceptable for the Dinka. Or are they able/willing to invest more in CESBs?

- The final proposal should be built to show the Dinka the true intentions of the model. It is the best way to explain, because the level of abstraction is limited. To show the Dinka the importance of the proper protection of CSEB's, an additional wall should be built without any protection. This wall could e.g. be a wing wall of the pilot building, increasing pressure for cross ventilation. Furthermore the difference between a covered sleeping space with a second floor and a sleeping place without a second floor on top, should prove the difference between on one hand the climatic function of the roof as a second skin and on the other hand the climate of a room with just a lifted roof. Other valuable tests in the field could be the positioning of doors and windows, different colored stones and other material finishes.

- An extensive physical calculation of the proposal would be very valuable. Because the wind -cross ventilation- and other air movements are very important for the climatic performance, a dynamic model should be developed to finally calculate the thermal comfort inside the house. For this recommendation goes that actual construction would be the most effective way to test the performance.

- The guide as presented in §8.1.3 should be further developed when a pilot building will be constructed. Think about the presentation of the guide. Is a paper guide/booklet sufficient? Furthermore a maintenance guide -for a finished home- should be added.

- Development of the gutter construction. This should happen on site. For this thesis calculations of the sagging of the gutter could be questionable, because all dimensions and qualities of available construction materials are not known. In other words; the rainwater harvesting system should be further detailed and worked out on site. A more standard/modern construction of a gutter could be considered, but only when future import possibilities and affordability grow to be better.
## Table with costs for three types of houses in Rumbek

<table>
<thead>
<tr>
<th>What</th>
<th>Price/unit (see Annex 10)</th>
<th>9m Dome type L</th>
<th>Final model</th>
<th>Modern Tukul</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>27 USD/50kg</td>
<td>4.725 USD</td>
<td>3.240 USD</td>
<td></td>
</tr>
<tr>
<td>Rebar</td>
<td>27 USD/10mm*12m</td>
<td>8.235 USD</td>
<td>216 USD</td>
<td></td>
</tr>
<tr>
<td>Bricks</td>
<td>?</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Hardwood</td>
<td>20 USD/4m<em>2</em>4 inch</td>
<td>PM</td>
<td>1.800 USD</td>
<td></td>
</tr>
<tr>
<td>Iron Sheets</td>
<td>27 USD/0.82m*3m</td>
<td>-</td>
<td>2.214 USD</td>
<td></td>
</tr>
<tr>
<td>Thatch</td>
<td>10 USD/bundle</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Bamboo</td>
<td>3 USD/bundle</td>
<td>-</td>
<td>PM</td>
<td></td>
</tr>
<tr>
<td>Clay soil</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>River sand</td>
<td>235 USD/3m3</td>
<td>PM</td>
<td>PM</td>
<td></td>
</tr>
<tr>
<td>Pit sand</td>
<td>200 USD/3m3</td>
<td>PM</td>
<td>PM</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>?</td>
<td>PM</td>
<td>PM</td>
<td></td>
</tr>
<tr>
<td>Labour</td>
<td>?</td>
<td>PM</td>
<td>PM</td>
<td></td>
</tr>
<tr>
<td>Electricity</td>
<td>?</td>
<td>PM</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

Total 12,960 = 13,000 USD 7.470 = 7,500 USD (all inclusive) = 8,000 USD

Private house of a German aid worker, at first not appreciated at all, but when it was almost finished the Dinka started liking it.
Chapter 9
Final Conclusions

The conclusions flow from looking back at the research, the design development and the final results. Recommendations for further development are written for the pilot project that SHF intends to carry out in Rumbek.

9.1 Conclusions
The main conclusions are aiming at a comparison between the proposed model, the SHF dome and the modern-traditional tukul.

A general conclusion about the development of housing in any situation: To create a house according to the rules of thumb of climate response is a good way to prevent the designer from having too much freedom. But to fill in some of the treated aspects as presented for the assessment of examples in the field of habitat for humanity, is the best design aid of all. The chosen four most valuable aspects for the designer are used to structure every chapter in Part E.

9.1.1 Afford a ble durability
See Annex 15 for the calculation of the estimated cost difference between the final proposed model and the SHF dome. A semi-modern tukul with comparable square meters is used in the comparison as well. The dome model that was used for the estimation was the 9 meter diameter dome with a height of 4,5 meters, as built in Sri Lanka. The used data were obtained from the latest and technically optimized domes. [E. vd Werf, 2008]

The concluding table from Annex 15 is presented on the left.

The rebar for the dome makes a huge difference in costs. If ferrocement would be considered, the dome will become much cheaper. This depends on the costs and availability of chicken wire, but also on the chosen form. It is recommended to find out the cost reduction if using ferrocement in Rumbek. (see §7.5, page 119)

The alternative model still uses a big amount of cement. This amount will be much less if the fully protected walls (at least the interior walls) will be built with adobe blocks, maybe reinforced with CSEBs at the corners. Underneath these walls it is not necessary to use CBs for the plinth and the below level wall; CSEBs are sufficient. Instead of the standard massive CB's, hollow blocks will lead to a dramatic decrease of the need for cement. Furthermore, some pieces of hardwood can be replaced with local wood, but to protect the softwood from termites, an anti-termite detailing is required.

In other words: both types of buildings can be optimized, economically. Therefore the difference of 5,500 USD (42% of the costs of a dome in Rumbek) per home concludes that the alternative model will be less expensive than the dome in the situation of Rumbek. The durability level of both methods will be considered equal. The dome can develop cracks and the steel roof can corrode, both might need some small reparations in the future.

But the modern version of the tukul is cheaper than the proposed model, because it is an all inclusive price. However, the Dinka don't seem to care much about (small) price differences. They care much more about direct advantages, especially when they affect their status. Aesthetics and usefulness of a house are direct advantages compared to the characteristics of a modern version of the tukul. The only long term advantage the Dinka care about, is the durability.Durability should be visible in the form of materials like concrete or steel, which means it is also a status symbol. A proof of the fact that status sensitivity leads to spending a little bit more money -which the Dinka have in the form of cows- is that the Dinka neighbours of a German architect were persuading him to build his -somewhat more expensive- house for them like he did for himself. [Martin Grütters, gruetters.com]
Climatic performance comparison of the SHF dome, the tukul and the final design of this thesis:

- **Thin roof/shell**
- Walls are subject to sun
- Sun comes inside
- Rainwater harvesting
- No cross ventilation
- Hot air outlet; stack effect ventilation (depending on temperature differences)

- **Tukul**
- Thick insulating roof
- Little sun on the low walls
- No sun through openings (except door)
- No rainwater harvesting
- ± Cross ventilation, but minimal
- ± No hot air outlet, however thatch allows air to escape

- **Double (skin) roof**
- More sun on the walls
- No sun through openings
- Rainwater harvesting
- Cross ventilation
- ± Hot air outlet for the roof (option for stack effect through second floor)
9.1.2 Environment Response
Let us compare the climate response of the dome and the traditional tukul with the climate response of the final proposal. The main conclusion from literature research is that the interior comfort in Rumbek is best when there are plenty of facilities for shading and cross ventilation.

See the sketches (left) for an overview of the three types of houses for the climate of Rumbek.

The final proposal offers a roof as a second skin, thick walls and a large roof overhang, which is needed because the walls are much higher than the tukuls' walls. For every orientation the proposal offers a sufficient overhang to almost fully cover the walls in shadow for the largest part of the day. Furthermore there are as many small windows in the single banked sleeping rooms as possible to make cross ventilation possible.

9.1.3 Social acceptance
Because the dome is not comparable with the tukul or any type of building known to the Dinka, there is just a small chance that the concept will be easily accepted. To make the dome more comfortable for the Dinka, it will have to be adjusted -functionally re-designed- and adapted to the dual climate.

The alternative design was based on Dinka opinions. Therefore the social acceptance is higher than in the first case and theoretically the alternative proposal would be preferred.

9.1.4 Technical acceptance
The main conclusion of Part A of this study is that the development of a new/alternative building method is the most innovative way to find a solution that is best fitted to the situation of Rumbek. One of the motives is written in the objective, which aims at arriving at a self-help building method. The meaning of self-help in this case is to build with the least training possible. For an SHF dome it is sure that extensive training and supervision are essential for sufficient results.

Furthermore, the construction of a dome is a way of building that is unknown to all Dinka in Rumbek. The use of CSEBs, CEBs and CBs is -partially- known and applied in the area of Rumbek. Building with self-made blocks is an annual routine to all Dinka men and even women. The use of trusses with iron sheet roofing is also known and being applied increasingly.

The modern type of tukuls are being built with bricks and reinforced concrete. Most Dinka do not know how to build with those materials. Using simpler techniques, like the exclusion of difficult moulds for concrete and the use of larger blocks instead of small and irregular bricks, promotes the self-help construction of the proposed design.

9.2 Conclusions & recommendations for further development
- For a pilot project it is recommended to test more than one design. To properly compare an adjusted dome with a ferrocement dome and the alternative concept, the best way is to build them all...
- Testing of any model scale 1:1 is the best way to present the thoughts for improvement of habitat. A scale model and pictures may work for a selection of the Dinka, but a real house -preferably owned by a known man in the village- will do the trick.
- Build several small walls with or without several types of plaster. The people are then able to see (over time) which type of block, mortar, plaster and finally which combination is the best choice for a sustainable home. In addition, test the anti-termite detail the same way. Build one piece of wall with the detail, one without and cover them both with something edible for termites. See the picture for an example of this idea, carried out in Uganda.
• Development of a habitat-building-concept by doing evaluations of projects according to the assessment list as presented in §5.1, page 99.

• Development of an urban plan with a long term view concerning economics and a lay-out with a maximum facility provision. Because there are no maps available of Rumbek, an expat should make a map on site like SHF [R. Fukken] did for the project in Sri Lanka. Cooperation of the local government is an important factor for a successful plan.

• When using iron sheets, start the promotion of Solar Disinfection (SODIS) with plastic water bottles. (See §6.3.2, page 110)

Recommendations for further design development:
See §8.7, page 137.

Recommendations for dome development:

9.3 Recommendations for further research
Part B handles the field research results. The presented information is not only valuable for the objective of this report, but also for continuing research or activities for Rumbek or other places in Southern Sudan.

• Chapter 5 of this report describes a few examples of projects for developing countries (the full descriptions are put in Annex 6). The developed assessment which was used in the chapter, is useful to examine some more examples. The assessment list could be further developed with more attention to details and lead to the (re)development of more and/or better concepts for habitat projects in developing areas.

• Search for possible ways to realize a ferrocement roof structure. A ferrocement roof gets interesting when there is hardly any extra supportive roof construction needed, like trusses. A ferrocement roof can be moulded and lifted onto a structure. To search for possible ways to produce cheaper ferrocement roofs is recommended because the roof is one of the most expensive parts of a building. It is also an essential part for the climate response. However, a ferrocement structure won't be as easily accepted for self-help building in the future as a more traditional type of structure. Or would it?

• Develop a list with valuable translations of raw materials -in the area of Rumbek- into building (related) materials and which means are needed to realize this translation.

• Find out whether Lulu oil -a locally produced oil- is useable for floor rendering. Linseed oil is known as a good floor renderer. Since Lulu oil is also a vegetal oil, it may have the same effect as a floor finishing material, combined with clay earth.

• Find out the exact mix of ‘Nim’ tree leaves, cow dung and boiling water, which is used to make an extract for termite repelling. The extraction is sprayed on natural materials to prevent termites from eating it. It would be recommended to find out how frequent a treatment should be repeated, why people are not using it in Rumbek and how effective it really is.

• Find out if the application of anti-termite detailing is functional in Rumbek.

• Find out the truth about types of trees that the Dinka claim to be resistant to termites. Is it possible to plant those trees for local building? Or plant bamboo? The trees are only known by Dinka names. The following trees are most desired in order of durability:
  1. Jier tree. Termites won't eat it. This wood is very long lasting, the poles will be passed on from generation to generation, for many tukuls;
  2. Pok tree;
  3. Rak tree;
4. Mahogany tree/hardwood

Palm tree wood is also not eaten by termites, but decays quickly because of rotting.

- Study for the effect of an adapted building technological design on the startup and the process of a habitat project in a developing country. Compare the effect with other models, designs and plans.
- Try and search for ways how to make the diplomatic world better understand the aims and results flowing from the phenomenon 'habitat development'. Make sure that good examples deserve the media-attention they need.
## Abbreviations & Acronyms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CB</td>
<td>Concrete Block</td>
</tr>
<tr>
<td>CBO</td>
<td>Community Based Organization</td>
</tr>
<tr>
<td>CEB</td>
<td>Compressed Earth Block</td>
</tr>
<tr>
<td>CHF</td>
<td>Common Humanitarian Fund (in Sudan)</td>
</tr>
<tr>
<td>CSEB</td>
<td>Compressed Stabilized Earth Block</td>
</tr>
<tr>
<td>CPA</td>
<td>Comprehensive Peace Agreement (signed in Addis Ababa, 2005)</td>
</tr>
<tr>
<td>DC</td>
<td>Developing Country</td>
</tr>
<tr>
<td>DG</td>
<td>Director General (The right hand of a minister)</td>
</tr>
<tr>
<td>DVD</td>
<td>Digital Video Disc</td>
</tr>
<tr>
<td>EPS</td>
<td>Expanded Polystyrene</td>
</tr>
<tr>
<td>GoSS</td>
<td>Government of South Sudan</td>
</tr>
<tr>
<td>IDP</td>
<td>Internally Displaced Person</td>
</tr>
<tr>
<td>MCR</td>
<td>Micro Concrete Roofing (Tile)</td>
</tr>
<tr>
<td>MDG</td>
<td>Millennium Development Goal</td>
</tr>
<tr>
<td>MDI</td>
<td>Monolithic Dome Institute</td>
</tr>
<tr>
<td>MHLPU</td>
<td>Ministry of Housing, Lands and Public Utilities (GoSS organ)</td>
</tr>
<tr>
<td>MoPI</td>
<td>Ministry of Physical Infrastructure (GoSS organ)</td>
</tr>
<tr>
<td>NGO</td>
<td>Non-Governmental Organization</td>
</tr>
<tr>
<td>NRC</td>
<td>Norwegian Refugee Council</td>
</tr>
<tr>
<td>PA</td>
<td>Practical Action</td>
</tr>
<tr>
<td>RC</td>
<td>Red Cross</td>
</tr>
<tr>
<td>SHF</td>
<td>Solid House Foundation</td>
</tr>
<tr>
<td>SPLA</td>
<td>Sudan People Liberation Army</td>
</tr>
<tr>
<td>SPLM</td>
<td>Sudan People Liberation Movement</td>
</tr>
<tr>
<td>SS</td>
<td>South Sudan</td>
</tr>
<tr>
<td>SSL</td>
<td>South Sudan Logistics (a large company)</td>
</tr>
<tr>
<td>UN</td>
<td>United Nations</td>
</tr>
<tr>
<td>UNICEF</td>
<td>United Nations International Children and Education Fund</td>
</tr>
<tr>
<td>USD</td>
<td>United States Dollar</td>
</tr>
<tr>
<td>WFP</td>
<td>World Food Programme (UN)</td>
</tr>
<tr>
<td>WWI</td>
<td>Women for Women International</td>
</tr>
</tbody>
</table>
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For more information about used sources, or a request, please contact the author at willemd@gmail.com

Read & Recommendation:

• IS, Internationale Samenwerking, een gratis magazine over internationale hulpverlening en al wat daarmee verbonden is.

Websites

http://www.un.org/millenniumgoals/
Consulted: 12 - 2006

http://www.habitat.org/eca/
Consulted: 12 - 2006

http://www.een.nl/index.php?pageID=7&n=4
Consulted: 01 - 2007

Websites of habitat organizations:

Cal Earth
• http://www.calearth.org
• www.calearthpakistan.org
• http://www.fondationpourarchitecture.be

Intervolve
• www.inter-volve.org

Stichting Bouwen
• www.stichtingbouwen.nl
• www.kinderhulpgambia.nl

INBAR
• http://www.inbar.int
• http://www.wikipedia.org

Practical Action
• http://www.practicalaction.org
• http://www.maasai-association.org/maasai.html
• http://www.bestpractices.org

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