Research Informing Design: A Zero-Energy Health Center in Rural Tanzania

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When designing a project in western industrialized society, one can seek effective passive design solutions to reduce energy or achieve high marks in a building rating system such as LEED. Energy modeling and other assessments often occur, but according to recent press in the New York Times (08/31/09), "The [USGBC]'s own research suggests that a quarter of the new buildings that have been certified do not save as much energy as their designs predicted and that most do not track energy consumption once in use."[1]

Over the last 18 months I have been managing the design of a health center for 25,000 African villagers who have no other access to healthcare on a site with no power, no clean water and no infrastructure for waste or sanitation with an extremely limited budget. Every design decision will impact the quality and duration of the lives of thousands of individuals in this region. In this context, the role of qualitative and quantitative assessment becomes absolutely essential throughout every step of the design process. Any consideration of a design decision that doesn't come from an understanding of its constructability, transferability, energy performance, structural performance, programmatic flexibility and cultural appropriateness are irresponsible decisions by any measure.

From its inception, this has been a collaborative project in which University of Cincinnati students, faculty and practitioners from the disciplines of architecture and design, engineering (civil, environmental, hydrological, structural, materials, acoustic, and thermal), medicine and nursing, geography, history and sociology have worked collectively with members of this Tanzanian village to respond to the complex, rigorous, ever-changing criteria for this project.

INTRODUCTION

> *"Village leaders identify their own needs," the doctor explains. "Then we strategize with them on how to solve those problems together. This buy-in solidifies the idea that they are going to do their part. It's a 'hand up rather than a hand out' mentality.*[2]

Village Life Outreach Project (VLOP) is a non-profit organization whose focus involves providing health and educational improvement measures to the people of the Rorya District of Tanzania, East Africa - a region in which there is one doctor for every 50,000 people[3]. In these efforts, VLOP aims to not simply provide handouts, but rather to provide "hand-ups" – that is to empower local villagers to address the issues that affect their communities – through community-run committees. The issues that VLOP addresses are in the realms of Health, Education and Life. By illuminating and joining the struggle against poverty in Africa, VLOP hopes to also strengthen the local community by promoting ideas of humanitarianism, service, and social responsibility[4].

In spring 2008, VLOP received funding to support the development of a health center in this region of northern Tanzania at a location that would benefit all the villages with whom VLOP interacts and would serve approximately 25,000 villagers. The Roche community provided a 21-acre building site; though there was no existing power generation, clean water sources or infrastructure for sanitation or waste – all of which would be critical for the health center. Thus began a collaboration with the faculty and students from the University of Cincinnati Colleges of Architecture and Engineering, with assistance from Arup Engineers in Chicago, Los Angeles and San Francisco and engineers from the Environmental Protection Agency in Cincinnati, researching and designing for the short-term and long-term needs of this community in regards to health, education and life.

Dr. Lewis and Professor Dan Oerther, an engineer who was leading the VLOP Life Committee, contacted me in spring 2008. They asked if I would be a LEED consultant for a health center design that had been proposed by a Tanzanian architecture firm based out of Dar Es Salaam (over 500 miles from Roche). This firm provided a set of rough construction documents for a health center without actually visiting the site or meeting the villagers. Their proposal showed no consideration of the site topography, the local climate and environmental conditions, the lack of infrastructure and minimal choices of materials available in the region. The design proposal was influenced by American suburban layout with extensive parking (though there are basically no vehicles in the region at this time). There were materials proposed that were completely foreign to the region and the aesthetic was expressively colonial.

I assessed the proposal and informed the leaders of VLOP that the design that they had been given was not going to provide the local community what they needed. The goals of sustainability that VLOP proposed were not being addressed by this proposal. At that point, I didn't know what the community wanted or needed, but I knew it was not an American suburb in rural Tanzania.

Following extensive research spanning culture, climate and construction, the initial goal of designing a health center expanded into the development of a community center, educational center for health, sanitation and construction and housing for medical personnel. And, given the goals of sustainability shared by VLOP and my own research and practice, every aspect of the proposed design of this zero-energy health center had to be fully transferrable to the village community.

THE SITE

When we were in Roche, Tanzania meeting with the Roche Village Council in October 2008, we asked

Fig 1: Roche Council at health center site

them if there were any stories or myths that we should be aware of as we design the health center. The Village Leader, Alfred, told us that re-telling the full story would take five hours, so he told us the short version. According to the translation, Alfred is the great grandson of the original King of the Kamegata people (a sub-tribe of the Luo), who are now the predominant group in present-day Roche. The Kamegata people had been located in Sudan until about four generations ago when the King decided that they needed to settle in a more fertile land. They sent out a committee in search of their new home and discovered their ideal site in northern Tanzania. They initially settled on the specific piece of land that they have provided for the Health Center. Soon after, a group of foreigners attempted to take the land from the community, but the community was able to fend off the foreigners and protect the land.

Before the King died, he told the people that the community should welcome the next group of foreigners who came to this site. He told them that this group of foreigners would be critical for the development of the people of Roche. Alfred informed us that to the Kamegata people the members of Village Life Outreach represent that group. As a result, they have donated their most precious piece of land for the health center. This story only reinforces the responsibility that everyone working on this project feels to the Roche community.

DEVELOPING A DESIGN METHODOLOGY FOR RURAL TANZANIA

Though, as a practicing Architect, I had worked on projects of varying program types and scales in Europe and the U.S., I was clearly unprepared to lead a design project in rural Tanzania, on the African continent, with a tribal community that spoke no English and had a fundamentally different relationship to design and healthcare.

I have relied on a series of theories and approaches to design that have grounded all our work on this project. The qualitative research has been critical in the assessment of the culture, social and political relations and programmatic needs. The quantitative research has revolved around assessment of every aspect of infrastructural design for power, water and sanitation, for materials and construction and every aspect of the climatic conditions.

The design methodologies that I have pursued throughout this project have included:

1. Engaging the VLOP principles of sustainability and collaboration
2. Contemporary post-colonial theory
3. Theories of appropriate technology
4. Climatically-responsive design
5. Design for transfer of knowledge

This paper addresses some of these design methodologies as the roles of research have intertwined through all of these methodologies.

DESIGN RESEARCH

The budget and schedule limitations of architecture practice would not permit 18 months of research on a project whose total budget is estimated at $350,000. Not one person working on this project has received financial compensation. Education has been the predominant form of compensation for everyone involved. The focus is purely on the successful development of this project for all constituents in Tanzania as well as for all students involved. We have the luxury of time without the benefit of financial resources.

Within the design discipline "research" takes many forms. In this project we have had to continuously differentiate what we particularly like or resonate with from what will actually benefit this community long term. The research has spanned qualitative and quantitative assessment through various modes of research.

The integration of this research into a comprehensive, elegant, appropriate design expression is our architectural imperative, though also not addressed in this paper.

Qualitative Research Types:

Modes: scholarly research**,** data collection**,** data analysis and synthesis**,** critiques**,** on-site interviews, local interviews, committee meetings**,** theoretical models

Content: precedent analysis**,** socio-cultural context**,** political and historical context**,** design context**,** program needs**,** growth and flexibility**,** environment**,** construction skills

Quantitative Research Types:

Modes: scholarly research, data collection, data analysis and synthesis**,** energy modeling**,** models and drawings**,** mock-up

Content: context**,** environment**,** climate**,** energy**,** water**,** soils**,** materials, construction skills, and resource availability

RESEARCH MODES, DISCOVERIES AND RESULTS

Fig 2: Meeting with Roche Village Council

We began extensive research into every conceivable body of knowledge that could impact the success of this project. In each case, data significantly altered our assumptions and impacted the design.

As the complexity of the project has unfolded, a series of specialized committees were organized to distinguish between the core building design issues being addressed in studio and the infrastructural issues being addressed by students, faculty and practitioners of engineering. There is a Roche Health Center Infrastructure Committee, a water sub-committee, a power sub-committee and a ventilation committee that is undertaking a computational fluid dynamics analysis of the project.

What follows is not a comprehensive list of every aspect of research but instead a few examples with descriptions of the modes of research, the discoveries and the results of the research.

1. Cultural Research: Understand the existing and historic culture, politics, social structure, issues of power between gender and class, demographics, customs and traditions of the region.

Qualitative Research:

Modes: Scholarly research, relevant theories of post-colonialism, critiques of African Aid, on-site interviews with villagers and committees, comparative design assessments, interviews with African academics in U.S., and precedent studies.

Discovery: Recognizing that the local culture is descendant from the Luo tribe and that the tribal system of governance, at times, superseded the national Tanzanian governance was a critical factor.[5]

Result: We have worked closely with the local village governance as well as with the District Managers for Tanzania.

Discovery: We discovered that our demographic would be split between the medical personnel coming from the major cities in East Africa and the local villagers and staff who would be villagers from this region.

Result: This has huge impacts on the design, from the expression of the buildings to the types of social spaces to the type of toilets that would be expected by each group.

2. Programmatic Research: Analyze the architectural program as defined by the Tanzanian Guideline Standards for medical facilities and assess how this impacts the design in each phase of development.

Modes: Site visits to clinics and hospitals in Kenya and northern Tanzania, precedent research into African clinics, critiques and meetings with medical personnel working in Africa as well as medical personnel who have worked in global health.

Discovery: There is a detailed document that defines criteria for medical facilities at four scales in Tanzania – dispensary, clinic, health center and hospital.[6] However, after visiting several medical facilities, there was none that actually met these standards. According to these standards, there are two distinct programs required for a rural health center in Tanzania – the medical facility as well as housing for the doctors and nurses.

Result: The housing must be appealing to medical personnel coming from cities with medical schools – Dar es Salaam and Mwanza. The character of these houses must appeal to these medical personnel, but must also be contextually appropriate in rural Tanzania.

Discovery: The goals of VLOP include on-going education and development in the areas of Life, Health and Education.

Result: The initial health center program expanded to include community and educational buildings, areas for training villagers on health and sanitation and advanced training for medical personnel.

Discovery: There is no "center" for Roche Village. Villagers often meet at one intersection in the village though there are no resources or commerce at this location.

Result: The overall design program expanded to include a market edge for local commerce along the street.

Discovery: At the existing hospital in Shirati, there is no canteen and the families of patients (typically 5-8 people) join the patient so that they can do the cooking and laundry for the patient. They often rent a house nearby and spend the days near the patient. We had assumed that this was the villagers' choice for care, but when they were asked about this process, they all agreed that this should be available for those who can't afford to purchase food from the clinic, but their preference would be to purchase the food from the clinic, which they assumed would be safer and cleaner, thereby leading to a quicker recovery for the patient.

Result: We are including dorm housing for patients' families with areas for safe cooking as well as a canteen where food can be purchased for the patients.

3. Sanitation: Evaluate appropriate technologies for grey-water and black-water waste as well as physical waste disposal and medical waste at the site.

Modes: Collection of examples from the region as well as low-income projects around the world, interviews with the local villagers and medical personnel, exploration of similar sanitation projects in low-income areas, cost-benefit analysis of water-use, permanence, cleanliness, cost, and cultural acceptance.

Discovery: Presently the only toilets in the region are pit latrines. Given the negative impact on the soils in a region where most people's water comes from surface water, we are hoping to introduce composting or solar toilets that will create a resource instead of negatively impacting the soils. However, the question remains as to whether this technology will be accepted culturally. There are similar projects in low-income areas that have failed because of the cultural stigma attached to cleaning out toilets (even if it is actually compost).

Quantitative Research:

1. Climatic Data: Analyze the climate and local weather conditions with available weather data, energy-modeling software and through interviews with villagers.

Modes: This region is not actually on any map that we know of. Given that there is no specific weather data for this specific location we utilized data from regions of similar altitude, adjacency to mountains and water and within a few hundred miles within Tanzania and Kenya. For temperature and humidity, we have taken interior, exterior and surface measurements on our recent trips in October 2008 and 2009. However, we are hoping to install data loggers soon to get more accurate annual data.

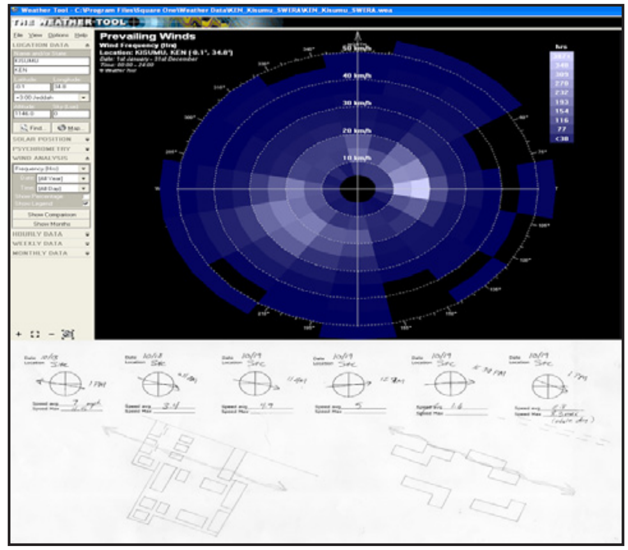

Fig 3: Ecotect Wind Analysis

Discovery: Because of the elevation of Roche (3753' above sea level), the heat and humidity is much less severe than on the plains of East Africa.

Result: With effective shading and ventilation, people are comfortable in this region. Therefore, all interior and exterior spaces will be designed for effective shading and ventilation.

2. Precipitation: It was critical to assess the times and quantities of precipitation throughout the year for thermal comfort as well as potential rainwater harvesting.

Modes: There is no published data that we were able to find that outlines the precipitation in this location. However, one of the local doctors had been tracking rainfall since 1997. This data was extremely helpful and was consistent with the generic data for the region.

Discovery: There are two rainy periods in the region: March – May and November – December (averaging 18cm and 11cm monthly). However, June – September are quite dry (averaging less than 3cm of rainfall monthly). When we discussed water collection with the villagers, they claimed that there was no reason to invest in storage because of how little it rained.

Result: With assistance from engineering students, we have discovered that we can average

22,000 gallons collected from each 1,000sf roof. As a result, a 4,000-gallon water tank could provide half the annual water for a 5-person family using 20 gallons/day/person. Every roof will be designed to incorporate water storage for the housing and clinic design.

3. Passive Design Strategies: Achieve thermal comfort and effective daylight in all spaces within the health center without any active mechanical system. Develop an approach for passive heating and cooling that would require no equipment, no maintenance and low cost.

Modes: Extensive building documentation including orientation and layout, materials, potential strategies for passive heating or cooling and interviews with the community about their comfort levels in different buildings. Then, extensive energy modeling as well as physical mock-ups were built to test strategies.

Discovery: Most typical brick buildings in the region are not designed to effectively shade or admit ventilation, though when they are used, they are extremely effective.

Result: Thermal mass, natural ventilation and shading strategies effectively employed should provide all necessary passive cooling. Passive heating for cool nights can be achieved with operable vents that can be shut at night to retain internal daily heat gains.

4. Materials and Construction: Evaluate availability, durability, quality consistency, maintainability, costs, emissions, and thermal and acoustic properties of local materials and construction techniques.

Modes: This assessment included extensive cataloguing following on-site visits with photographic documentation, visits to immediately local and regionally local hardware and construction supply stores. There have been critiques with structural and materials engineers, builders and designers with experience in low-income design.

Discovery: There are numerous discoveries that were made regarding materials and construction based on quantitative criteria. Additionally, discoveries about cultural stigma associated with certain construction types limited our palette.

4a. Walls

Fig 4: traditional fired brick ISSB brick

Discoveries: The typical construction for the post-1961 "permanent" construction has significant problems as a result of the wall material and construction as well as the roof construction and connections. The bricks that are used are typically made using local soils with spent-termite mound, organic soils as the binder. These bricks are hand-formed and fired in a kiln for 3-days. This kiln is built of the same bricks (leading to extremely inefficient firing) and the firing requires the use of a tremendous amount of timber that is quite sparse in these villages, due to their elevation (approximately 4000' above sea level). Once fired, approximately half of the fired bricks are useable. With those that are used, construction requires an extensive amount of mortar due to the inconsistencies of the bricks. The results are extremely unsound walls. There are several examples of buildings where the walls have failed and portions of buildings have been destroyed.

Results: We have proposed replacing the traditional fired brick with an interlocking stabilized soil block that uses local soil with a minimal ratio of cement to soil (typically 1:16) that is pressed in a manual brick press and then cured outside for 14 days (with no need for firing). These are much more durable, stronger and longer lasting than traditional bricks, they require a minimum of mortar every 4 courses and the walls are straighter and more plumb than with traditional brick. Two presses have been purchased as of November, 2009 and the community is building mock-ups for testing.

Qualitative and Quantitative Overlaps:

1. Thermal Comfort Zone: We tend to take the thermal comfort zone for granted (approximately 68F – 78F). We can refer to the bio-climatic chart to see how passive and active systems can stretch the comfort zone and there are other variants that show how physical activities can also impact the thermal comfort zone.

Discovery: In speaking about the experience of temperature in these villages, Dr. Lewis said, "I've never seen anyone uncomfortably warm inside, even when we are sweating." Additional interviews and research suggested we needed to shift the comfort zone and that underheating at night was a much greater concern than initially anticipated.

Result: We have shifted our thermal comfort zone to 73F-83F.

2. Roof: There are three basic roof materials options available within this region:

1. thatch, which is found in the traditional houses
2. corrugated metal roof, which is the most common element on institutional buildings
3. cement or clay tiles, which are found on higher income buildings

The thatch is incredibly appealing because of its natural waterproofing and ventilation properties. It is also all local, inexpensive, thermally and acoustically effective and easily replaceable. There are issues with insects, but we were considering this material as an outer layer, with metal roofing beneath.

Results: There is a cultural stigma associated with thatch. It was not seen as contemporary and we had clearly negative reactions when this was discussed for the health center.

3. Electric Lighting: though there is no permanent electric lighting in the region presently, this will be critical for the clinic and housing components of this project.

We are considering four types of electric light:

type of light	wattage	lifespan (hours)	replaceability	cost	waste
Incandescent:	100	700-1000	easy	$1.00	
Fluorescent tubes:	20-40	10,000-20,000	easy	$3.00	Hg
Compact fluorescent:	20-40	10000	difficult	$6.00	Hg
Light emitting diodes:	10-20	30,000-80,000	very difficult	$50.00	

Results: Based on quantitative criteria, even including the very high upfront cost, LED lighting is definitely the best choice for critical electric lighting. However, there are serious concerns with LED – what happens when it burns out or is broken? Does this become a liability when others find out how much they cost? Fluorescents seem to be a good compromise except for the fact that there is mercury in these tubes. There is no infrastructure for waste in the region and most garbage is burned with open flames. As a result, this could be a significant toxic hazard.

CONCLUSION

Research has and continues to play a pivotal rule in every aspect of this design project. There have been many **discoveries**:

Fig 5: Image of proposed Health Center entry

1. For every question, there are multiple opinions and perspectives.

2. All forms of research can lead to contradictory results.

3. Even with research we will make mistakes

The **result** has been the recognition that, in addition to the role of all of this research, to make progress in a project, we need to:

1. Clearly define goals and intention for project including prioritization.

2. Prioritize and organize research as related to goals and intentions.

3. Recognize disparities in research.

4. Make (and track) assumptions to enable progress.

5. Design for flexibility as research unfolds.

6. Continuously re-assess impacts of research.

Design research is not a linear process. At every step, new information can alter the course of a design process. My students have been frustrated many times when new information comes to light. It has been critical to develop a flexible design process that incorporates iteration.

One major goal for the project is "only design what can be replicated by those building within the community." Because of its local availability, the roof structure had been considered in wood, steel and masonry. Masonry was ruled out because of our location in a seismic zone and steel was ruled out because of its lack of availability locally. We were nearing completion of schematic design with a wood truss design when an Engineer from Arup LA asked, "How long do you want this building to last?" We hadn't set a number of years, but clearly the clinic was intended to be a durable, safe, long-lasting building. He pointed out that the wood truss would likely need to be replaced in 5-8 years as a result of termites. When we clarified that we only intended to use local materials and construction techniques, he asked us to reflect on what the villagers response would be if we asked them, "Would you rather have a roof that you could build, but that has to be replaced every 5 years or a roof that you couldn't build, but that will last 50 years?"

With more information come more questions. However, the first priority is to provide this community a building for their health care facility. Construction will begin on phase one in January 2010 and we will monitor the results closely so that we can make adjustments as construction continues.

BIBLIOGRAPHY

Hazeltine, Barrett and Christopher Bull editors, *Field Guide to Appropriate Technology*, Academic Press. Elsevier Science, USA 2003

Navarro, Mireya, "Some Building Not Living Up To Green Label", New York Times, August 31, 2009

Rapoport, Amos, Development, "Culture Change and Supportive Design", Habitat International, Vol. 7, No. 5/6, pp.249-268, 1981, Great Britian

Rieselman, Deborah, University of Cincinnati (UC) Magazine, "Doctor to Africa's desperate poor", http://www.magazine.uc.edu/0509/doctor.htm (accessed nov 11, 2009)

Said, Edward, "Culture and Imperialism", York University, Toronto, February 10, 1993, http://www.zmag.org/zmag/articles/barsaid.htm (accessed Nov 4, 2008)

The United Republic of Tanzania Ministry of Health, Overview of Dispensary and Health Center Requirements: *Guideline Standards for Health Facilities*

All photos by author unless otherwise noted

ENDNOTES

1. Navarro, Mireya
2. Rieselman
3. World Health Report, 2006
4. www.villagelifeoutreach.org
5. Julius Kambarage Nyerere (April 13, 1922 - October 14, 1999) served as the first President of Tanzania and previously Tanganyika, from the country's founding in 1961 until his retirement in 1985. Nyerere had tremendous faith in rural African people and their traditional values and ways of life.
6. *Tanzanian Guideline Standards for Health Facilities*