African Technology Development Forum

ATDF JOURNAL Volume 7, Issue 1/2 2010

SCIENCE; INNOVATION; TECHNOLOGY; TRADE; DEVELOPMENT

Design-Revolution in Architecture and its Impact on Development

‘Less is More’
Mies van der Rohe

HIGHLIGHTS:

Tile Vaulted Systems for Low-cost Construction in Africa

Design and Construction of the Mapungubwe National Park Interpretive Centre, South Africa

The Problem and Potential of Sustainable Design in Resource Poor Settings: Cases from Rwanda

NESTown: New Ethiopian Sustainable Town A Real Life Experiment

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ISSN: 1817-2008
Abbreviation: Afr. Technol. Dev. Forum j

http://www.atdforum.org/

September 2010

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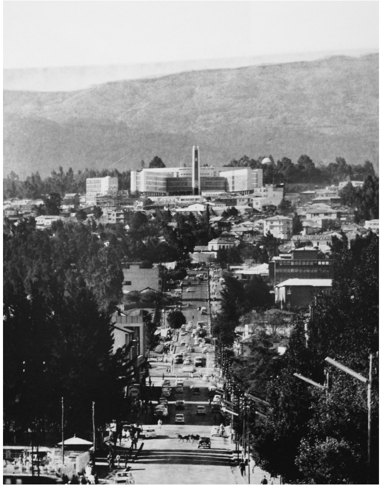

Editorial

Architects and development specialists often live in different worlds and it is difficult to create a public awareness for the development dimension of innovative architecture. This special issue of the ATDF Journal aims to change this by bringing the two worlds closer together showing a variety of innovative projects and discussing their impact on African development in general and sustainable urbanization and local entrepreneurship in particular.

The papers in this issue cover a wide range of topics and activities dedicated to the improvement of the overall quality and sustainability of the built environment for people with lesser means. As architecture is concerned with the translation of theory into practice and therefore dependent on the continuous interaction with practitioners and scholars form other disciplines, this issue pursues an integrative approach. It addresses aspects on the a macro level (urbanistic concepts, global sustainability, new construction economies, capacity building strategies), the medium level (housing requirements, structural systems, in-door climate control) and the micro level (material research) and links them in efforts to find comprehensive solutions to sustainable architecture and urban design.

This important field of applied research, discussed and illustrated in many different facets in this issue, has the potential to become an important model for implementing new building technologies in the developing world. The beauty of the portrayed projects is that they may allow a country like Ethiopia to turn scarcity, one of its perceived weaknesses, into an asset, generating sustainable growth through innovation. Ethiopians have already great expertise in finding more efficient ways to use scarce resources and make better use of manpower; but they could further enhance the value of their expertise by combining it with innovative new techniques to improve the quality and affordability of their products and services. Its very constraints, therefore, could become its saving graces, as Africa could become a leader in dealing with innovative low-cost solutions to climate change adaptation. The methods and techniques shown in this issue could serve as a benchmark of sustainable building practices and help initiate research and projects that pursue a sustainable approach on all levels, from the choice of materials to the construction design and its implementation and finally to challenges related to operation and maintenance.

I take this opportunity to thank the editors of the ATDF Journal for inviting me to edit this issue. It is a great opportunity to bring our field of research and practice to the attention of a new and wider audience. Changes need to happen to address the acute challenges of Africa, and I am hopeful that this publication can spread the awareness of this urgency. Last, I would like to thank all contributors for being part of this special issue and writing their insightful papers despite their many other commitments.

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Tile vaulted systems for low-cost construction in Africa

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Abstract:

This paper discusses the potential of tile-vaulted structural systems to provide sustainable and low-cost construction for Africa, based on experiences both in academia and practice.

The proposed tile vaulting building technique adopts an unreinforced masonry construction method with a 600 year tradition in the Mediterranean, where the bricks have traditionally been made from fired clay. [1] The technique is now combined with the local tradition in Africa of cement-stabilized, soil-pressed bricks, which use locally available soil. In this context, Social and economic concerns were jointly addressed with local leaders and inhabitants to ensure that the structure is relevant to the local culture and successfully implemented. The proposed vaulting technique has the potential to meet three primary objectives: to provide an environmentally-sound building solution using mainly local materials, to engender social cohesion and pride within the local communities by drawing upon traditional methods, and to stimulate economic growth by providing local jobs, while reducing dependence upon imported materials.

Keywords: tile vaulting, soil-pressed bricks, low-cost construction, capacity building

1. Introduction

With an annual growth rate of almost 7%, Ethiopia is one of the fastest growing countries worldwide, yet it also remains among the poorest ones. In 2008, Ethiopia was home to approximately 81 million people and by 2025 this number could reach more than 125 million. There is an immediate need to enhance indigenous construction capabilities and create more awareness of the economic value of local materials to meet the urgent need for housing. This is of particular concern to poorer areas, where dwellings are often constructed from corrugated metal. These dwelling units cannot be expanded upon for multi-story construction, yet sprawl outward, consuming limited resources including wood, expensive imported materials, and land (Figure 1). Innovative solutions are necessary to address these pressing issues in a sustainable manner, considering the shortage of building materials, economic resources, and skilled labour. While the urgency for action might be extreme in Ethiopia, its socio-economic conditions are nevertheless comparable to other parts of Africa and throughout the developing world.

Historical methods of vaulting have remained economically viable in the contemporary construction markets of Spain and Mexico, mainly because tile-vaulting is also being reinvented as a contemporary construction technology [2]. One such example, the Mapungubwe National Park Interpretive Centre in South Africa, which was built using tiles pressed from local soil, was named the World Building of the Year at the 2009 Architecture Festival [3, 4]. The impressive forms of the Mapungubwe vaults demonstrate the elegance of the design possibilities using structural tile (Figure 2.a), and even more extravagant forms are possible. More recently, a similar methodology was used to build a prototype vault for a more modest (and more repeatable) tile floor system in Ethiopia (Figure 2.b). [5, 6] These two buildings signify the re-emergence of a technology, which could provide a solution to sustainable low-cost housing.

Fig. 1. b-c a) Traditional dwellings/huts as they can be found in rural Ethiopia (Amhara region); and two versions of newly built houses: b) built with found corrugated metal, and c) with Eucalyptus wood and plastered mud with a corrugated metal roof.

Fig. 2. a) First completed vault of the Mapungubwe project in South Africa (Image credit: James Bellamy); b) Unreinforced thin-tiled floor system of housing prototype for Ethiopia: simple barrel vault with stiffening diaphragms (Image credit: Lara Davis).

This paper discusses the potential of tile-vaulted systems which make use of local material, and follow the tradition of compressed earth block (CEB) construction in Africa to meet the need for more sustainable construction technology in the field of low-cost housing.

An introduction to the structural and construction principles of tile vaults will be presented, followed by a discussion of the engineering advantages and challenges of tile vault construction. Ethiopia will serve as a case study to exhibit the challenges of implementing this historic construction technology in a rapidly urbanizing society.

2. Tile vaulting: Origins, methods and structure

2.1. Origins and method

To construct a brick vault between parallel walls, one of several different vaulting methods may be considered (Figure 3). European-style vaults (Figure 3.a) would provide a durable solution from local materials, though excessive formwork (centering) should be avoided to protect scarce timber resources in many African locations. Mediterranean tile vaulting (Figure 3.c) makes use of thin ceramic tiles for structural vaults in which minimal centering is required during construction. This type of construction flourished in medieval Spain, and was successfully imported to the United States by the Spanish immigrant, architect and engineer, Rafael Guastavino (1842-1908). [1] The R. Guastavino Company built thousands of thin-shelled masonry vaults in the late 19th and early 20th century, including such prominent buildings as the Terminal of Grand Central Station and the Cathedral of St. John the Divine in New York City and the Boston Public Library. With high load capacity, fire resistance, and long spans, these structures were a cost-effective solution to spanning space.

Tile vaulting is a construction technology requiring little to no formwork as well as minimal material for the shell. The technology was developed during a period in which building with local material was a necessity, and not

Fig. 3. Three methods of brick vault construction [7]: a) Northern European vaults require extensive wooden centering; b) pitched brick vaults, built in North Africa and Mexico, eliminate the need for centering; and c) Mediterranean tile vaults may be constructed without centering.

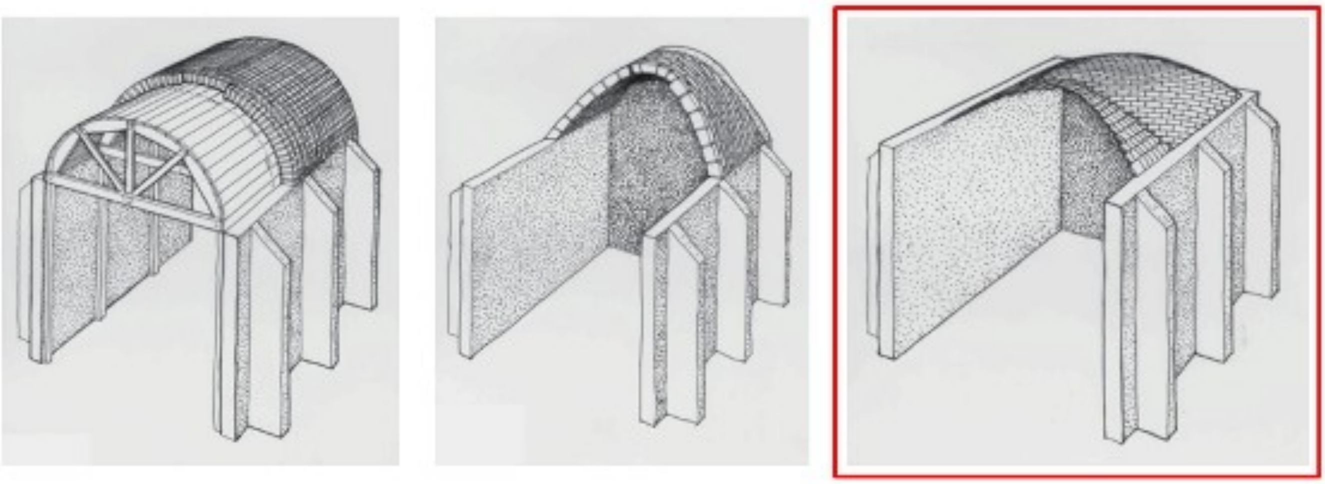
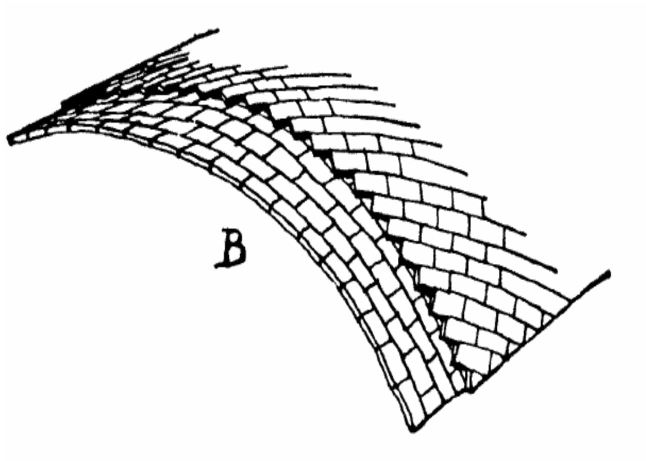


Fig. 4. a) Layered tile construction at Mapungubwe (Credit James Bellamy) b) Tile vaulting, built from multiple layers of thin bricks laid flat [9]



merely fashionable. Such frugal practice is rapidly becoming a necessity again. This system employs typically three layers of thin brick, the first of which is set with a fast-setting Plaster-of-Paris mortar, with subsequent layers built with a typical cementitious mortar. The tiling pattern is altered in each layer to prevent tile joints from being continuous between layers and to establish a strong structural bond (Figure 4). The flat bricks are typically 3cm thick.

2.2. Structural capacity

The layered tile vault can be remarkably thin when it has a suitable structural form. A funicular shape is the most efficient geometry to resist loads as it acts in pure axial tension or compression. One example of funicular geometry is the hanging chain, which acts in pure tension (with no bending moments) and takes the shape of a catenary under self-weight only. Bending moments require a great deal of material to carry loads, so structures without bending moments can be very thin. Another funicular geometry is created when the hanging chain is inverted. However, the inverted structure acts in pure compression rather than pure tension. Thus, the same catenary geometry may be used to form a funicular arch, which carries loads in pure axial compression for the specific loading condition, i.e. self-weight only [7, 8]. In order to develop arch action in this compression structure, the arch needs to be properly supported at its ends, able to resist the outwards “thrust”.

The proposed vaulting system takes advantage of funicular geometry to limit the amount of material required, and to avoid tensile reinforcements. Stresses are low within the structure, so soil tiles with relatively little material strength can be utilized. However, the geometry is only funicular for one specific loading condition, so the vaults must have additional support to account for other possible loading conditions. This is achieved for example by adding thin stiffening walls on top of the thin vault to give the vault additional structural depth (Figure 3.b).

Such a floor vaulting system is not entirely new. Indeed, the Guastavino Company was particularly successful with their very efficient floor system (Figure 5). Its reinvention in the African context is quite appropriate as it requires minimal steel reinforcement and formwork and makes use of readily available, low strength, soil materials. Most critically, it allows for a structurally sound, multi-story construction to address urban density.

2.3. An African floor system

For the vaulted floor prototype in Addis Ababa, the two different systems for stabilizing thin, funicular vaults used by the Guastavino Company (Figure 6.b), has been implemented. The left approach adds structural depth to the vaults by adding lightweight stiffening walls, and the right approach adds a stabilized fill. The latter does two things: it adds structural depth, but also adds extra weight to the floor system, causing asymmetric live loads to have less effect in comparison to the more dominant self-weight of the floor system. By combining the two systems, the stiffening walls can be made very thin, as they are stabilized by the compacted fill. The continuous fill furthermore prevents that the vault can is point-loaded locally, which is not recommended for single curvature vaults. Instead, these point loads are nicely distributed over an area of the vault and the stiffeners.

The material of the first thin layer of tiles is Trachyte stone, the same type of stone used for the interior of Cologne Cathedral in Germany, which has a high compressive strength (≈150MPa) and is locally available in Ethiopian quarries. This stone tile layer was laid with locally produced gypsum mortar, which was custom-produced by a manufacturer and burned at higher temperatures to meet our optimal requirements for the speed of setting. The vault was designed with the subsequent layers of soil masonry units, produced with a press and stabilized with an 8% inclusion of cement. Because the masonry vault is designed to have an efficient, funicular geometry (a catenary curve derived from a hanging chain, see Figure 7.a), the compressive strength required for these tiles is only 4

MPa. All masonry on the upper layers was laid with a cementitious mortar, a mixture of sand, cement, lime and water. The spacing between the tiles set with plaster was on average 4mm (varying between 1-7mm), and that between the tiles set with cementitious mortar was on average 8 mm.

The span of the structure is approximately 5.8 meters, with a vault thickness of less than 10 centimeters. This does not include the fill for the floor system, which is a lightweight, semi-hard composition of pumice and lime. The theoretical line of thrust, which represents the path of compressive forces through the masonry vault, must travel through the cross section of the masonry for the vault to be stable without tensile reinforcements. The vertical diaphragm walls of masonry, built at intervals of 0.9 meters, provide reliable, alternative load paths for the masonry vault, effectively resulting in a structural depth at the supports of the full rise of the vault (50cm). This becomes important when the vault is heavily asymmetrically loaded (e.g. a group of people standing on one side of the vault), resulting in asymmetric thrust lines which no longer fit in the thin section of the vault. It is very important to note that such diaphragms are critical structural components for a barrel vault, which has only a single degree of curvature. Single-curved vaults are very vulnerable for asymmetrical loads, particularly applied at the quarter point of the arch. A vault with double-curvature is more stable.

For this prototype housing unit, the vault was nonetheless designed as single-curved barrel so that no thrust would be directed into the terminal edges of the vault, in order to reduce the reinforced concrete edge supports and to allow stop the vault at any point to allow for a stair well to the second floor. A simple barrel vaulted shape also has as important advantage that the guidework for building the vault can be minimized to two stiff arch profiles on each side with strings tied between

Fig. 3. a) Rafael Guastavino standing on a newly built arch during construction of the Boston Public Library, Boston, Massachusetts, 1889. [10] b) Guastavino Rib and Dome System, New York, 1902. [11]

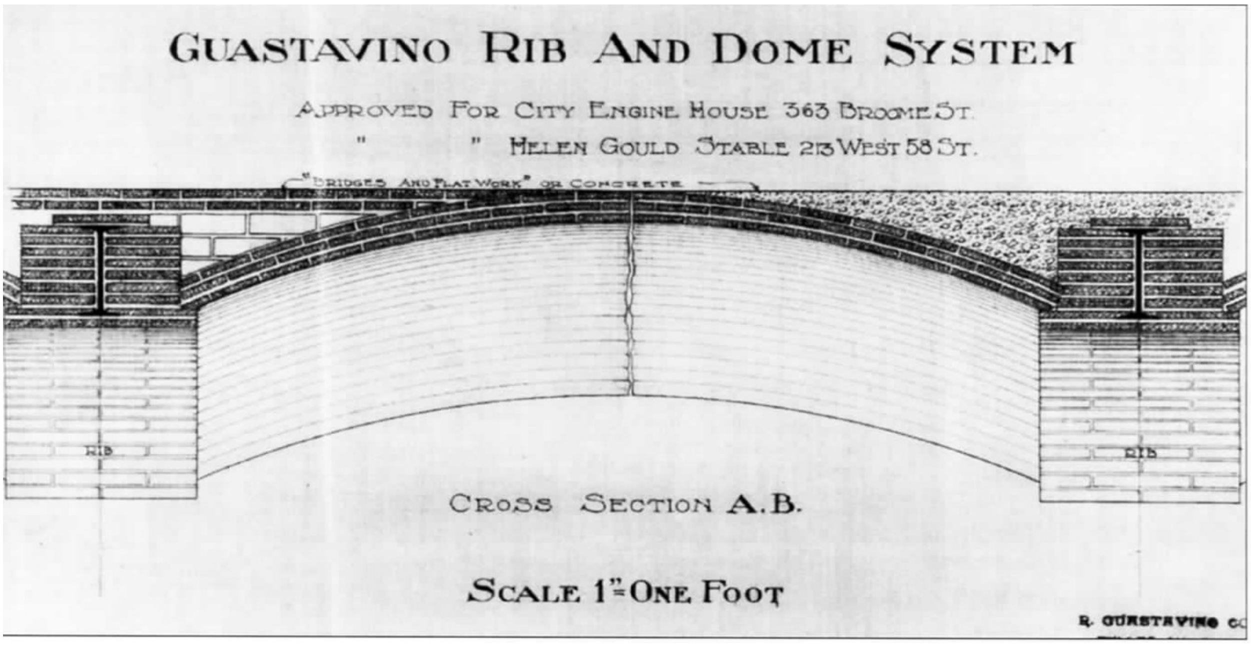


Fig. 6. Unreinforced thin-tiled floor system of housing prototype for Ethiopia: simple, single-curved barrel vault with stiffeners (Image credits: Lara Davis).

them (Figure 7.b-c).

A barrel vault needs linear edge supports to receive the horizontal thrust exerted by the vault. To avoid the transmission of these horizontal forces in the walls, the two reinforced concrete edge "beams" are tied back with four steel tension ties, spaced at intervals of approximately two bays.

For estimated sizing of the required tension ties and thickness of the vault at the crown, the following calculation can be used to calculate the horizontal thrust (H) in the vault,:

$$H = wL^2/8f,$$

where *w* is a linear, average line load representing the self-weight of the vault (including fill) for a 1 meter strip, *L* the vault span, and *f* the rise of the vault at midspan.

3. Implementation: Ethiopia as a case study for social context

3.1. Challenges of low-cost housing in Africa

In rural areas of Ethiopia, there is no sufficient building practice which would allow for the construction of towns to proceed with minimum standard, multi-floor living units. Many of these present dwellings – essentially vernacular huts – are still built incorporating traditional techniques such as mud plastering, known as "Chikapet" in Amharic (Figure 1.a). These vernacular construction techniques contribute to a fairly well-developed common knowledge base of the diverse local soils.

Current demand for new housing, however, is answered with the construction of poorly made shacks, assemblages of (eucalyptus) wood, straw and mud, utilizing sheet metal for roofs, doors, openings, and occasionally for walls (Figure 1.b-c). Inhabitants of rural areas resort to these fast, low-quality solutions, because of a lack of available building materials, constructional know-how, and financial resources. It is not unlikely that the local construction market is ignoring the needs of the inhabitants as many of them cannot afford to pay for the services they could. These constructions typically result in very low standard living conditions. The use of thin sheet metal with poor acoustic and thermal qualities for example cause extreme temperatures during day and night. These constructions furthermore do not utilize Ethiopian resources in a sustainable manner (e.g. the abundant use of wood contributes to deforestation and resulting erosion, a perennial environmental concern in Ethiopia with important, corresponding economic implications) [12]. An interesting phenomena is that the dependency on imported sheet metal has not only economic reasons. This inappropriate building component bestows upon the rural people a sense of 'quality' and assurance associated with modernity and development [13]. This building practice though precludes the possibility for safe, multi-story construction.

Fig. 7. a) Inverted hanging chain to find the shape of the compression-only vault, b) simple guidework and mason's line, and c) building the vault into space without the need for formwork (Image credits: Lara Davis).

Fig. 8. A selection of imported – hence expensive – building materials in current "low-cost" projects: a) Precision timber for formwork; b) precision formwork for columns and edge beams; c) interior panels (Made in China); and d) reinforcement steel and Portland cement for concrete.

3.2 Effective Low-Cost Housing

To make housing truly low-cost – with specific consideration to the Ethiopian condition – we must identify what makes traditional "low-cost housing" prohibitive by Ethiopian means. To this effect, elements of a low-cost construction need to be reduced even further in order to make low-cost housing accessible for low-income inhabitants.

Imported building materials commonly used in low-cost projects, such as steel, cement, and construction timber, are scarce in Ethiopia, both as natural resources and in terms of industrial manufacturing prevalence (Figure 8). Scaffolding and formwork for concrete construction are expensive, produce excessive building waste, and put strain upon the scarce natural resource of trees.

'Low-cost' for Ethiopia is classified as less than 1000 ETB/m² (≈ 75 USD/m²). Currently, large construction companies who are heavily subsidized by the government to build western concrete frame/slab construction dominate low-cost government housing. Low-cost housing is expensive because of the cost of imported materials. Compared to the Western paradigms they copy, the only improvement has been the use of precast ribbed beams and prefabricated concrete floor elements – again, both produced by heavily government subsidized programs – resulting in less concrete and simplified formwork. At the end, the cost of the housing provided by the government as 'low-cost' still costs the buyer 2500-3500 ETB/m² (≈ 185-260 USD/m²), and this after heavy subsidies on different levels.

In addition to the need for being more independent from imported materials and minimizing building waste, a 'low-cost' strategy also implies that the construction process should employ local labour. In Ethiopia, the workforce is large, unskilled, and mainly agricultural. Therefore, a structured training program (e.g. in form of formal apprenticeship) to impart the knowledge and practice of new building technique would allow for an upgrade in skills of the local workforce in constructing low-cost housing.

4. Appropriateness of tile vaulting in context

Soil and stone are the primary materials, which can be considered as sustainable in the Saharan/African context, where precision construction wood is often scarce. As stone or soil have limited tensile capacity, building with these materials demands compression-only structural solutions. For walls carrying dominantly vertical loads, this criteria is easily satisfied; however, once a space must to be spanned, beam elements, which work in bending, are typically required and can thus not be built using stone or soil, but in timber, steel or reinforced concrete – all materials that are not readily available in most parts of Ethiopia. A beam, as a structural system, demands that its section can accommodate tension and compression forces, which is not possible when building in stone or soil only.

As outlined previously, structural vaulting provides a solution to this constraint by allowing for compression-only solutions to span space. There are different techniques to build compression-only vaults, but tile vaulting allows for the construction of compact floor systems with a depth of less than a tenth of the span, without the need for any formwork or internal tension reinforcements. Other techniques result in much deeper structures which are inefficient and economically unfeasible for multiple story buildings.

It is important to point out though that soil-pressed tile vaulting is not necessarily an appropriate building technology anywhere in the world. In places where wood or bamboo are not scarce, these materials may be much more sensible construction materials than earth-based architecture, particularly in seismic areas. Fired clay tiles may be preferred where clay is abundant because they are more durable. In Pakistan, for example, there is a tradition of baking bricks using small kilns, and custom bricks are produced in local kilns directly adjacent to the building site.

The proposed technology has the potential to generate successful local entrepreneurship that generates income and employment for the local economy. The structural elements can be produced by people from local commu-

Fig. 8. The floor system in the Mapungubwe project uses a) structural vaults as permanent formwork for b) a mass concrete floor. c) This floor can be built without formwork and significantly reduces the amount of reinforcement steel necessary. In the Mapungubwe project, the edge beams are made in reinforced concrete. (Image credits: James Bellamy.)

nities, and local labourers can easily be trained to master the constructional practices required. The main challenge is to set up the necessary institutions that support training programs and entrepreneurial activities and improve access to credit and investment. Furthermore, political and cultural aspects must be taken into account to enable such a building technology to take root on a regional scale, including the social, political and religious structure of local leadership.

Most importantly perhaps, the discussed vaulting method is not far off from achieving the very tough 'low-cost' limit set at ETB 1000/m². Taking data from previous projects and translating the costs to the Ethiopian context, the method is still 30-40% too high, but this is largely due to the dependency of the technique on the fast-setting mortar. This mortar is not available yet on the Ethiopian market and is thus costly. If such a vaulting method were to become standard practice in Ethiopia, the cost of this product would obviously be reduced.

5. Challenges of tile vaulting in context

5.1 Supervision and Training:

Abundant local labour is clearly a tremendous advantage in the implementation of a technology such as thin-shell vaulting. However, the lack of a reliable skill-base must be comprehensively addressed. Technology-related capacity building and training must be implemented at universities as well as in vocational training centres to guarantee a safe and durable transfer of technology and skills. It needs to be integrated into the curriculum of architects and engineers to design for these new technologies. Moreover, universities should collaborate closely with construction managers in the private sector to manage safe construction of such buildings and ensure quality standards.

This vaulting technique, which allows one to build out into space without any support, may give the false impression that there is no risk. The first basic level of tile vaulting is very easy to learn, yet this tremendous advantage may be deceptive or even dangerous. A brick laid does not necessarily mean that the bond is sufficiently strong to ensure that the position of the brick does not compromise the structural form, or that it does not propagate errors in tiling geometry, which require skill and time to correct.

The learning curve is quite steep when one considers all of the critical aspects of construction. It is extremely important, for example, to understand the sequence of construction. One must always build in stable sections, carefully following geometrical guides throughout the construction. A partial or full collapse may occur (and have occurred) when these important aspects are forgotten. A fully constructed masonry vault is structurally robust if designed properly, but certain states in the construction sequence are less secure than others. Thus, critical supervision, quality control, and a robust training program are necessary.

The authors recommend and have had good experiences with mockups to educate and train for further construction, and to provide the possibility for structural load testing. However, it is important to control those very carefully. An uncontrolled structural failure is unacceptable. On the other hand, it is important to be able to do full-scale load testing to give everyone involved the necessary confidence of this new construction and material combination. Therefore, the authors typically demand two full-scale prototypes to be built on site, the first one to be load tested to failure and the second to remain as a demonstration.

It is critical to address the repeatability and the tolerance of this system to unintended appropriation for the purpose of structural safety. Without the means to hire experienced professional supervisors, it is often unavoidable that others merely appropriate the technique and shapes of tile vaulting. To this end, the vaults at Mapungubwe were a daring precedent, as they are complex shapes obtained and verified with the latest 3D structural form-finding techniques [14]. Such forms cannot simply be repeated without some risk.

Nevertheless, by simplifying the form-generation method, the prototype may serve as a robust and repeatable model. The design of thin-tile vaults may be reduced to ultimately simple structural concepts and constructional methods. In the case of a single-curved vault, a hanging chain may be used to derive the geometry of the vault. This catenary geometry may then be used at the full scale to fabricate a simple, inexpensive, non-structural guide, which serves to describe the geometry of the vault for the masons. Construction may be repeated as a controlled sequence in 1m strips – including an additional diaphragm wall as stiffener for asymmetric loads – to construct a very simple, single-curved barrel vault. On account of this simplified vault form and constructional process, robust constructional systems could be more reliably copied and repeated.

5.2 Technical Challenges of thin-tiled vaulting in developing context

Because the tiles are made from local soils, locally available soils have to be assessed, as soil can differ significantly from location to location. Finding the correct soil and mix proportions is a fairly delicate matter, which depends largely on experience acquired through working with soils. There is a lot of knowledge of soils in Africa, but it is imperative that the "engineering" of the tiles can be controlled and verified. [15] and [16] give a comprehensive manual on how to select good soils for the specific purpose of making soil-pressed tiles, nevertheless, one cannot learn about handling a natural material merely from a book.

This addresses a critical concern regarding material testing. Simple procedures, standards and building codes need to be developed to test tiles, which should not be dependent on expensive laboratory equipment, which is often not readily available. The thin-tiled vaulting technique depends entirely on the use of fast setting mortar, or plaster of Paris, which is a special type of gypsum mortar. This material is typically not readily available and its specific properties are critical for the application of thin-tiled vaulting. Gypsum mortar is also in comparison quite expensive, as it is not a typical material for the construction process. In Addis Ababa, we worked with the plaster manufacturer to custom-produce in a separate batch for our unique material requirements. Of course, this cost could be reduced if demand rises due to a new market based on this technology.

If it is not necessary to have shallow vaults, other vaulting techniques which do not rely upon the fast-setting mortar should be considered. For a roof, deeper structural systems with greater double-curvature are in any case preferred to the asymmetric loads. The Mexican style vaulting technique (Figure 3.b), built with regular mortar, may be more appropriate for these cases. Waterproofing is a very delicate point which still requires a great deal of attention and further research. As the building materials are basically stabilized soil, special care needs to be taken to protect these materials from the natural elements. In the Mapungubwe project this was achieved by continuous layers of cement and tar. Obviously, local materials would be preferred if possible. Special care or even best standard detailing needs to be developed for key details such as gutters or overhangs.

Ethiopia is situated near a fault line in the Rift Valley, causing some parts of the country to be susceptible to moderate seismic action. However, throughout most of the country there are no building codes or requirements to account for seismic loading. In this context, building with 'advanced' materials such as reinforced concrete allows for the construction of taller structures and gives an impression of safety and technological progress. In reality, these buildings require advanced reinforcement design as well as quality construction and detailing. The results can be devastating. For example, the 1999 Kocaeli earthquake in Turkey caused the collapse of thousands of steel-reinforced concrete buildings, and the recent earthquake in Haiti underlines the importance of proper construction techniques to prevent fatal collapses. Thus, concrete frame buildings, although they are becoming popular in big developments in Ethiopian and African cities, must be built properly or they will not perform well should an earthquake occur.

Unreinforced masonry buildings also have a reputation for being susceptible to earthquakes, particularly if constructed poorly. Earthquakes may induce bending loads in vaulted structures which cause tensile stresses within the structure. Thin-tile vaults with single curvature have very little geometric resistance to bending and therefore very little material strength to resist lateral loading if their tensile strength is ignored. Thus, they have a relatively low seismic capacity, and construction of unreinforced tile vaults in high seismic areas should be avoided. However, in moderate seismic areas they remain a viable option if they are designed properly and reinforced as necessary.

To increase seismic capacity, the first option is to build vaults with double curvature. While these vaults may be more difficult to design and construct in some respects, and therefore require more skilled labour, the double curvature provides a cross-section with greater effective structural depth, which thus increases bending capacity and resistance to lateral loading.

For further seismic resistance, reinforcement may be necessary. Steel reinforcement is one obvious option, however, it is not optimal because it must be imported. Furthermore, it is particularly susceptible to corrosion in soil-pressed vaults which are more permeable than concrete. Alternative reinforcement methods are the subject of current research. One possible option is to place a geogrid mesh between the tile layers. Although geogrid also must be imported, it is lightweight, easy to transport, and provides the necessary ductility to allow tile vaults to withstand significant bending action without collapse. [17] Ideally in this context, techniques of natural reinforcement, which use locally available materials (e.g. hemp fibers, rice fibers, bamboo), could be used and are also being explored.

6. Conclusions

This paper has discussed tile vaulting as a viable, alternative construction system for low-cost construction for an African context, while offering the advantage of work for local labour, transmission of skill and material scarcity. As vernacular methods in earth construction are prevalent, this method would not merely suggest the use of local materials, but confer also the advantage of local material expertise. To this end, local labor and entrepreneurship may be mobilized, while enhancing the value of local knowledge and thus pride associated with vernacular construction.

The material economy and structural efficiency of thin-tile vaulting enables the construction of vaulted floor systems without the excessive use of formwork material. These structures, which may be rapidly built, have a capacity to answer the housing demand by being produced at the community level.

Realistic implementation of such methods may occur in various degrees to immediately impact local construction towards economically and environmentally sustainable means. Already, having a tile floor in a reinforced concrete frame structure is a significant improvement to the full reinforced concrete alternative, as it would remove the expense of formwork, reinforcement steel and the cement for the concrete. It might even be preferable in certain contexts to keep a reinforced concrete frame for seismic safety reasons.

We demonstrated the potential of tile vaulting as an appropriate building technology for Africa by designing and implementing a first prototype in Addis Ababa. This experience also confronted us with the multiple challenges related to such an approach. If tile vaulting is to be successfully implemented in building practice in a country like Ethiopia, a lot of further careful research and (controlled) experimentation is required.

Acknowledgements:

The Mapungubwe National Park Interpretation Centre, South Africa was designed by architect Peter Rich of Peter Rich Architects, in collaboration with Michael Ramage, James Bellamy, Henry Fagan, Anne Fitchett, Matthew Hodge and Franz Prinsloo, as well as two of the present authors (Ochsendorf and Block). The project has garnered numerous international awards, including the World Building of the Year at the 2009 World Architecture Festival.

The construction of the Sustainable Urban Dwelling Unit for the ETHiopia Urban Laboratory summer school, held at the Ethiopian Institute of Architecture, Building Construction and City Development (EiABC) in Addis Ababa, Ethiopia, could not have been accomplished without the support of the following individuals: From the EiABC: Scientific Director Dirk Hebel, Herbert Schmitz, Dr. Elias Yitbarek, Tibebu Daniel, Melak Moges, Zegeye Cherenet, Fasil Giorghis; From the Department of Architecture ETH Zürich: Dr. Philippe Block, Dr. Marc Angélil, Lara Davis, Astrid Smitham; From ETH Sustainability: Dr. Christine Bratrich, Catherine Lippuner; From the North-South Centre ETH Zürich: Dr. Barbara Becker, Emma Lindberg; participating students from ETH and EiABC, and local Ethiopian laborers.

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Design and Construction of the Mapungubwe National Park Interpretive Centre, South Africa

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Abstract:

The Mapungubwe Interpretive Centre in South Africa uses novel design and construction techniques to allow local materials and labour to be used in production. The project is developed for labour-intensive construction to enable poverty relief and skills transfer into the surrounding area. Form-finding based on equilibrium thrust line analysis allows the design of thin unreinforced masonry shells that act in pure compression. Digital models let us translate advanced geometry into simple guides for construction. Traditional tile vaulting, using locally-made, pressed soil-cement tiles, allows the complex shapes to be built by newly trained workers without extensive formwork. A hands-on programme of design and construction suggests a new way to jointly manage architecture and development programs. This merging of novel structural geometry with traditional materials and craft has resulted in a new interpretation centre for a trans-frontier national park in South Africa.

Keywords: form-finding, thrust line, masonry vaulting, local production, earth architecture, development

1. Introduction

Mapungubwe National Park, on South Africa's northern border with Botswana and Zimbabwe, celebrates the Mapungubwe Kingdom, an ancient civilisation and trading culture linked to the Great Zimbabwe. It is a UNESCO World Heritage cultural landscape and a game reserve of stunning natural resources. South African National Parks assembled the park from private land in the last decade, and held a competition in 2005 to design the Interpretive Centre. The design by Peter Rich Architects, with structural vaults designed by J. Ochsendorf and M. Ramage, has recently been completed. The design and construction of the Mapungubwe Interpretive Centre is collaboration of architecture and development, and of architecture, engineering and construction. Architecture and development meet in a labour-intensive programme to employ local workers with minimal skill to make both the materials for the building and the building itself. The building is constructed of locally-made pressed soil-cement tiles which are then used to form the thin shell structural tile-vaults of the roof. [Figure 1 - Overall Panorama] Architecture, structural engineering and construction meet in the design of the thin shell vaults, using a 700-year old Mediterranean tradition adapted for the southern African context. Each of the disciplines relies on the other, so that the construction methods inform the engineering that in turn allows reciprocity between the structural forces in the vaults and their architectural form.

2. Mapungubwe Interpretive Centre

Mapungubwe National Park

Sited at the confluence of the Limpopo and Shashe Rivers in far northern South Africa, the Mapungubwe National Park celebrates the UNESCO World Heritage site in the context of a natural setting that re-establishes the indigenous fauna and flora of this region. [Figure 2 Park View] The park has been assembled from private land in the past few decades, and there are long-term plans to create an international peace park joining wild-lands

Figure 1 - Overall Panorama

Figure 2 Park View

across the border in Botswana to the northwest and Zimbabwe to the northeast.

The dramatic rocky landscape of the park is a result of violent geological events that resulted in the Limpopo River changing its course from flowing into the Atlantic Ocean to discharging into the Indian Ocean. Sandstone formations, mopane woodlands and unique riverine forest and baobab trees form a scenic backdrop for a rich variety of animal life. The complex landscape was both the inspiration for the design and the source of most of the materials for its construction, resulting in a composition of structures that are authentically rooted to their location.

3. Design Requirements

The Mapungubwe Interpretive Centre is the result of an invited design competition held by South African National Parks (SANParks) in 2005. The proposals needed to provide about 3000 m^2 of exhibition space for the artefacts of the Mapungubwe Kingdom, interpretive areas for the cultural and natural significance of the park, and headquarters for the park staff, and amenities for visiting tourists. Coupled with these architectural requirements were development aspirations to improve the conditions of communities surrounding the parkland. In merging architecture and development SANParks sought to use poverty relief funding to inject money and skills into the local community. The winning proposal by Peter Rich Architects, Michael Ramage and John Ochsendorf responded to these requirements with a labour-intensive design that employed local people for a year making tiles on site from the surrounding earth.

The project's agenda extends beyond the presentation of ancient and more recent history of the area to awaken an understanding of the local ecology. The problem of a remote site, coupled with a high local unemployment rate also had to be taken into account. These are manifested in the choice of technology, the language of the building, the materials and construction process in which unemployed local people were trained in the manufacture of stabilised earth tiles and in building the tile vaults. The resulting knowledge transfer has been adopted in the local culture of the region, with the masons privately continuing the skills they have learned by using the remaining tiles for their houses in nearby villages. Thus, the centre is not only emblematic of the site, Africa and its unique place in the origin of the world, but has also become part of a story that is still unfolding, of culture developing in symbiosis with its natural legacy.

4. Constraints

In designing the building we were faced with typical constraints of budget and construction time, but also unusual constraints of minimising steel, making use of local materials and putting people to work under the poverty relief program. These limits led to a design incorporating tile vaults made with no reinforcing steel and needing minimal formwork for construction. Making 200,000 pressed soil-cement tiles locally put a dozen people to work for a year. Mapungubwe National Park is ten hours' drive from Johannesburg, so all material that is brought to site has an added financial and environmental cost. This suggested a solution of local material, which fit naturally with the programme requirements. South Africa at the time was undergoing a construction boom associated with the

Figure 3 - side view up stream

run-up to the 2010 World Cup, so both materials and skilled labour were in short supply. Our choice of unreinforced tile-vaults minimised the use of steel in the construction, and being able to train the workers ourselves meant that we would not have to rely on a depleted labour pool. In fact, during construction the price of steel rose over 200%, so the fact that we were using very little of it sheltered the overall project budget from what could have been a large external financial impact.

5. Design Architecture

The vaults delicately rest in the undulating landscape and billow upward, exposing the arched edges of their thin shells. Three vaults are explored – a rectangular large span vault (15m x 8m) resting on four corner supports, a domed vault (topping the round cairns), and a shallow barrel vault (built as permanent formwork for floor slabs above). [Figure 3 - side view up stream] These are choreographed to create a series of sacred, cave-like interior spaces and well-defined external spaces containing exhibition and learning areas. [Figure 4 - interior] Africans believe in the veldt being a place of danger and fertility. Here, the buildings envelop external spaces– creating shelter and safety.

The domical language of vaults is contrasted by the delicate walkways that create a zigzagging ramped route through the complex. The visitor's first view, across a seasonal stream, is of the chameleon-like vaulted forms springing directly from the land on robust buttresses.

Figure 4 - interior

The surfacing of all of the masonry in local rubble stone creates a timeless quality, as if they had erupted from the earth in a geological event

Volumes are linked by terraced seating, contrasting the structured horizontality of the contours with the diaphanous domes and arches. The surfacing of all of the masonry in local rubble stone creates a timeless quality, as if they had erupted from the earth in a geological event similar to that which created the mesas of the site and Mapungubwe Hill.

The use of vaulting and other forms inspired by the dramatic landscape, avoids any overt references to any potentially controversial tribal vernacular (the area has many contesting land claims between different tribal groups).

6. Material

At Mapungubwe, we replaced the traditional use of fired-clay bricks with less energy-intensive stabilised earth tiles. The tiles are made of local earth and sand mixed with 5% cement and pressed using a modified Hydraform block press. The modification allows thin tile production from a standard press on reusable plywood blanks. The tiles are weak, but strong enough for the structural application. They must be handled carefully, and are susceptible to damage from transport and water. Although the tiles have some disadvantages, for this project they are the most appropriate solution to building in the local context. The structural forms of the shells were designed to have low stresses of about 1.5 MPa acting in compression only, because the soil-cement tiles can only withstand about 5 MPa. While stabilised earth has a well-established tradition with close links to sustainable practice, at Mapungubwe it

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is used to create sophisticated engineered forms through the adaptation of a hand-press, typically used for the very common compressed earth blocks (CEB), to manufacture tiles of sufficient strength for vaulting. [Figure 5 - Hand Press] In this way, an established structural system and a well known material is brought together for a novel solution.

7. Structural Design

Our structural form-finding [1] relies on techniques of graphic statics [2]. To define the geometry of the vaults, the envelope of all possible lines of thrust under dead load and asymmetrical loads is found. A line of thrust is a theoretical line that represents the path of the resultants of the compressive forces through the structure. That envelope of generated geometry is translated into architecture using guides to define the shape in space, by taking section cuts through the digital model. We mainly use a mix of commercially available CAD software (Rhinoceros), the application of graphic statics in coordinate geometry programs (Cabri or Geogebra). Tile vaults rely on fast-setting gypsum mortar and thin tiles laid on edge. This type of vaulting, sometimes called Catalan or Guastavino vaulting, is not in common use today, but is a traditional Mediterranean technique which, between 1880 and 1960, was used to build over 1000 buildings in North America by the Guastavino Company [3,4]. The tiles are stuck together using limited structural formwork and geometrical guides help to define the shape during construction [5]. The rapid set of the mortar and the structural shape allow the mason to span between

Figure 5 - Hand Press

guides, relying on structural action to develop while the building is under construction. Recent research at the Massachusetts Institute of Technology and the University of the Witwatersrand has shown that this system could have an important future in Southern Africa and other areas of the world where labour costs are relatively low in relation to material costs. [6] [Figure 6 - HQ under construction] More typical forms of masonry vaults, such as domes, rely on standard masons' tools of taut string (although when thoughtfully applied, the range of forms possible with these is large and exquisite). In particular, the load-bearing masonry is used to construct roof vaults achieving high structural strength with minimal material. We use lower-bound equilibrium analysis based on interactive graphic statics [7] to find the form of the vaults. This is a design method, rather than a design tool, in which the gravitational loads dictate the structure. The role of the architect and engineer is to evaluate and manipulate the forms within the natural constraints of the material, a skill that can be learned. The resulting form is neither geometrically nor mathematically defined, but is instead a direct structural response to the loading. This is crucial to being able to build without steel reinforcing, as the structurally efficient shape leads to a compression-only solution (with no bending), and therefore requires no tensile reinforcing. Using the dead and live loads to develop the initial structural geometry, we then apply reasonable asymmetric loads to determine the thickness and degree of curvature for the vaults such that we can always find a line of thrust that fits within the masonry [8]. The static equilibrium of these surfaces is then checked with recently developed thrust network analysis [9]. The project incorporates ten masonry vaults, ranging in span from 5 meters to 20 meters, and a similar number of regular barrel vaults and domes.

8. Building Programme

Three primary tasks comprise the vault building: tile making, guide work construction, and tile laying. The tile-making proceeded for a year before other work on site began. The construction work on site began with laying foundations to support the vaults. The vaults spring from walls and raised buttresses structurally tied to resist the (horizontal) thrust of the vaults. Once those foundations were complete the guide-work construction and tile-laying could commence. Learning the technique is straightforward; good results come quickly. Local communities supplied the construction workforce. The site is an area of high unemployment with depleted skills, a legacy of the apartheid government. The introduction of stabilised earth manufacture using a manual press is suitable for establishing entrepreneurs with start-up costs in the micro-credit bracket, although for this project SANParks managed the tile making. Moreover, constructing the vaults aided in entrenching good building practice. The tile vaults are 30% less expensive than an alternative in reinforced concrete shells. If we include their socio-economic benefits (standard practice in employment creation), the economic performance is even better. [6] A high ratio of project cost is retained locally, an important factor in a country with a dual economy. The reliance on local labour improves liveli-

Figure 6 - Headquarters under construction

hoods and provides a skill base for future projects. We are actively pursuing projects in the region to make use of the skill base.

9. Construction

Building up tacit knowledge among local workers Building the vaults required training the workers in the construction technique. We organised a workshop where we taught the tile-laying in a series of small vaults, so that the workers would gain skills and confidence in the unfamiliar materials and method. Two or three builders working together built a vault of small tiles against an existing wall, and then stood on the result after only a few days of practice. [Figure 7 - workers test vaults] Teaching new skills to unskilled workers turned out to be easier than relying on existing skills in other trades, such as carpentry, where a severe shortage of expertise delayed the project at significant junctures, especially for the substructures and guide-work for the vaults. Skilled carpenters apparently did not want to come and work at the remote Mapungubwe building site. Vault-building skills were most important on the inside layer, where the form and appearance of the vault are fixed. There was a high turn over of staff which did not pose a huge problem for the labour on the outside tile layers of the vault construction, but it did for the inside tile layers. Of the 24 initial labourers trained on the inside technique, only 13 remained on site at the end of construction. Training new people on the vaults meant more breaking down and repairing of low quality work, more building waste, more loss of time and less aesthetic appeal. Over the eight-month course of building the vaults, there were nearly a hundred people trained in the tile-vaulting technique. Constructing the vaults took significant project management where close coordination between the contractor and the design team was required to avoid idle workers and unnecessary delays.

One challenge for the Western construction supervision team was working in a different culture with a different work ethic and ways of looking at the world. From early on, it was clear that creating relationships based on mutual trust and understanding fostered an effective method of operating onsite. Up to six languages were spoken onsite, each used interchangeably. Sign language, demonstrations and interpreters were the most effective methods to communicate an entirely new skill.

The people onsite had a mix of skills in construction, but the most skilled were accustomed to working with cement mortar and fired bricks. The knowledge and experience of using a trowel was the basic skill required, but the range of new materials, especially gypsum (the fast-setting mortar) with a setting time of less than a minute

Figure 7 - workers test vaults

in the temperatures at Mapungubwe, really tested even basic trowel skills.

Construction in a curve or arch, with minimal forms and guidance, means that the worker has to have an eye for the shape, which is entirely different from most of their previous experience of constructing straight walls and square corners. If the workers are unable to see and feel the shape, prior to laying the tiles, the structure will take the wrong shape, and consequently could crack or even collapse. One way we dealt with this was to print a scale model of the structure on a 3D printer, so that the builders could see and feel a physical version of the final form. This let them visualise the structure which they were building at full scale, otherwise quite a difficult task.

The biggest challenge in constructing tile vaults is the attention to detail. Taking time to lay the tiles to ensure they are placed in exactly the correct angle, pitch and direction takes a lot of concentration. Vault construction requires close attention, so idle conversations were distracting. When song broke out among workers, the attention to detail and work output increased.

The endless ingenuity onsite created great surprise. When a problem faced the workers, it would be discussed and different ideas bantered about, often for some time. As a result, a collective resolution formed and often creative and functional solutions were developed given the minimal resources in the remote location. Some of these included ladders made using fellow workers to access difficult parts of the vault [Figure 8 - Human Ladder] and passing tiles around site like a rugby ball. This turned out to be the most efficient and produced the least amount of breakages while moving tiles around the high scaffolding.

From a structural view point, it is not difficult to see when the shape is incorrect, as when the vault loses its curvature and departs from a compression-only form. It is as simple as a right and a wrong shape, which everyone can see and feel, but often this needed pointing out. It means standing back looking at the work, from different angles and deciding if it is acceptable. If it is not right one learns soon enough, as the tile structure will begin to crack, requiring the work to be redone. Initially, this inaccuracy would need pointing out to the builders, but once they could see where the vault was not flowing right, they knew exactly where they went wrong and would easily correct it with a trained eye.

Table 1 - Vault Costs

Mapungubwe Visitor Interpretation Centre Material Qauntities and Costs

vault type	vault area (m^2)		material cost per m^2 vault	labor cost per m^2 vault	Rand cost per m^2 vault	$ cost per m^2 vault	Hours per m^2 vault	$ cost per ft^2 vault	Hours per ft^2 vault
All	617	Total figures for all Vaults	R 518	R 311	R 829	$111	31	$10	3.6
		Summary by vault type							
BV	218	Barrel Vaults	R 381	R 228	R 609	$81	24	$8	2.3
D	93	Domes	R 622	R 264	R 886	$118	28	$11	3.7
PV	297	Parabolic Vaults	R 582	R 385	R 966	$129	38	$12	4.8

10. Costs

The vaults cost about $110/m² of vault, at a construction rate of 31 hours/ m². By comparison, the Pines Calyx, a vaulted building in England designed by some of the same team members, took 20 hours/ m² and cost about $450/ m² [10]. A more detailed quantification of the construction rates of each type of vault is included in Table 1. [TABLE 1 - Vault Costs] On an individual basis, however, the construction in South Africa used about 3 times as much labour per m² as at the Pines Calyx, but overall was a quarter of the cost. The handmade tiles of the Pines Calyx were expensive at about £2.50 (30 Rand) each, while the tiles in South Africa cost about 2 Rand each. Compared to conventional tiles in the UK, the South African construction is about 1/3 the cost of the UK construction.

Figure 8 - Human Ladder

11. Architecture and Development

11.1 Professional Arrangements

The design and construction at Mapungubwe suggest a new model for the interaction of architecture and development. SANParks specifically requested a labour-intensive building process, which led to a project driven by simple materials made on site and the possibilities for using them. This decision required foresight and courage on the part of the client, as more than a year of work went into making the materials themselves. The adaptation of material, structure and form required close collaboration between architect, engineer, and construction supervision, which in general requires a team founded on mutual respect for all players. This is particularly necessary as material and construction constraints often drove design decisions. An engaged client and a highly collaborative design and construction team are part of what is needed for successful completion of novel development projects. These close relationships suggest a new way of working, which could lead to new contractual procedures. While this project was completed using standard South African contracts, there is an opportunity to innovate in the professional arrangements. Building procurement, design fees and contractual values are generally based on a percentage of a buildings' total cost. Throughout the world this is a perverse incentive for architects and engineers to increase costs, since that would result in higher fees. In developing economies where labour is inexpensive and many materials are imported, a lot of a building's value is embedded in the material it is made of, so when a building is made from the earth it sits on, the value of the construction drops. This is beneficial overall, but lowers the professional fees. Moreover, simplifying buildings and building processes requires more thoughtful design, because they are not part of conventional practice. Fee structures based on value percentages are not the correct way to encourage more professionals to take on projects that are intentionally inexpensive and often time-consuming. An alternative approach could be to base professional fees on savings from typical costs, value delivered to communities, or simply time expended. A solution using conventionally manufactured materials, standard construction and typical architectural forms would have been faster to build, but would have had significantly less impact on the park, the region, and the possibilities for architecture and development.

11.2 Sustainability

Sustainable practice is essential for development, and especially an approach that recognises social sustainability alongside environmental sustainability. Money expended on a project should first and foremost go towards people rather than products, and time should go towards reducing energy in materials and performance. Reducing costs is an equally important aspect of construction, but must be considered over the whole life of a building, rather than just the short period of design and construction, which can often justify higher up-front costs that are offset over time. At Mapungubwe, the labour intensive construction reduced polluting machinery (sourced from far) and replaced it with small format construction methods that have minimal impact on the surrounding environment. This intensive construction involved skills training which has had a positive impact on the socio- economics of the local area, consistent with government strategies for targeting development to local communities. The government-funded poverty reduction programme employed a 60 people to make tiles for a year. Constructing the vaults trained over 100 people and employed 10-40 people at any one time over the course of 8 months. By using thin tile vaults instead of reinforced concrete at Mapungubwe, we saved an estimated 9 m^3 of steel, resulting in an embodied energy savings of almost 120,000 kg CO_2 emissions for manufacture alone, and using local earth bricks instead of fired clay obviously saved the energy that would have been used to fire over 200,000 tiles. A further significant amount of CO_2 was saved by radically limiting transportation of materials. While conventional reinforced concrete construction is responsible for embodied carbon emissions of approximately 150kg/m2, thin earthen vaults are responsible for only 40kg/m2 of carbon emissions, a reduction of nearly 75%. The design proposal uses high thermal mass and exposed construction which has passive environmental benefits leading to lower operating energy as well. Here the exposed, thick construction absorbs thermal shock and acts as a radiant surface, transmitting the 'coolth' from the night time ambient temperatures over the day. A displacement ventilation system, introducing tempered air (cooled from the ground), allows air to rise naturally as it heats to be expelled at the apex of the vaults. The vaulted forms allow natural light to penetrate deeply into the building, further reducing energy expenditure.

12. Conclusions

The chosen technologies for the remote site of the Mapungubwe National Park Interpretive Centre avoid the potential large embodied energy and high costs of conventional solutions by using predominantly local materials. Except for the cement added to the earth to give the tiles strength, and used in the mortar beds between the layers of tiles, all materials (earth, sand, gravel and stones) came from within a few kilometres of the building site. By reducing or eliminating steel in the vault construction, we aim for a longer life span without concern for deterioration due to corrosion. The heavyweight construction has passive environmental benefits over a more conventional solution. The building costs at least 30% less than a conventional solution, and benefits the local population through using predominantly local labour with the added benefit of a tangible skills transfer. The project has provided insight into ways to improve the process for next time, both from mechanical aspects such as the efficiency of tile making (we can now make them 3 times as fast) and from architectural and engineering aspects (we have a better understanding of which forms are better for training and skill-building). We hope to be able to replicate the model with institutional projects in other parts of Africa and East Asia. The building has been recognised with numerous international awards, including the David Alsop Sustainability Award from the Institution of Structural Engineers in 2009, a Holcim Award for Sustainable Construction in the region of Africa/Middle East in 2008, and the World Building of the Year in 2009 at the World Architecture Festival.

Acknowledgements to Anne Fitchett, Matthew Hodge and Hydraform for the engineering of the tiles, Henry Fagan for serving as overall structural engineer for the project, Usna Bouer for contracting the project, and the workers who built the vaults.

Biodata

Michael Ramage has a degree in architecture from The Massachusetts Institute of Technology and currently teaches structural engineering in the Architecture Department at Cambridge University in England. Prior to studying architecture, he had a Fulbright Fellowship to Turkey to study geology and archaeology. He is one of the designers of the masonry vaulting for the Mapungubwe Interpretive Centre in South Africa

which won the World Building of the Year award in 2009. He also designed the domes for the Pines Calyx, the first Guastavino-style vault to rise in the United Kingdom, and the 20-meter span vault for Crossway, one of Europe's lowest-energy houses. His most recent work is The Bowls Project, a contemporary architecture and music installation at the Yerba Buena Centre for the Arts in San Francisco.

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Peter Rich: For thirty five years, Peter Rich has been rigorously engaged in four key areas of architectural practice. As researcher, Peter Rich pioneered the documentation of African settlements so others can learn from them. As an activist, he brought what he has learned to a wider audience. As a teacher, he developed an architectural vocabulary that builds on tradition and has empowered successive generations of young architects. As a practicing architect in his wide variety of work, he has given structure to his discoveries, creating architecture that is deeply embedded in its time and place.

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The Problem and Potential of Sustainable Design in Resource Poor Settings: Cases from Rwanda

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Abstract

The concept of sustainable architecture in the developing world needs to be holistically rethought. In the context of constraint based design, a sustainable movement should adhere to contextual and adaptive systems that are characterized by appropriate, available, and climactic specificity. However, these conditions often evade international development projects in the tourism industry, in which there are examples of "greenwashing" and failure to have a sustainable local impact. Such problems require us to rethink the meaning of "sustainability," expose an inherent ambiguity in the overuse of the term, and suggest the need for better metrics. Architectural projects have the potential to address sustainability in the context of development by employing innovative low-tech solutions that can have reverberant and systemic change on economic, social, and environmental levels. As an example, a naturally ventilated hospital in Rwanda shows how an architectural project can impact public health by mitigating the transmission of airborne disease, reduce energy consumption, energize a local economy, and build a local skilled labor force. In order for this design revolution to truly impact development, it needs to embrace an expanded definition of sustainable design practices that includes a more multifaceted approach to the built environment.

Key words: sustainability, public health, natural ventilation, ecotourism, design metrics, Rwanda

1. Introduction

1.1 Rethinking sustainability

Discussion of the sustainability of buildings has traditionally considered how maintenance systems directly impact the natural environment. This discussion is particularly relevant in resource rich countries, where going "off-grid" has become as much a financial goal as it has become an environmental one. In resource poor settings, however, where the majority of people begin "off-grid," the goals for a sustainable building are more fraught. In this context, sustainable architecture forces its practitioners to rethink the responsibility of architecture to address the links between infrastructure, the environment, and the social conditions that effect poverty. Sustainable design often begins with locally sourced materials because they are low cost, but case studies show that such strategies can have a broader impact by advancing local building practice to be more sustainable in social ways. This is one of several strategies that is central to sustainability in resource limited settings and reveals both the current limitations and potential for expanded impact of the sustainability movement in resource rich settings.

The aim of this paper is to discuss the problems of sustainability when it is deployed in resource limited settings, which in and of themselves often embody the tenets of what the green movement aims to simulate, such as lack of dependency on electrical grids, use of locally sourced materials, recycling of industrial land detritus for construction, and access to communal and public transportation systems. In this context, this paper highlights a naturally ventilated hospital and an eco-lodge in Rwanda that address sustainability by striving to use architecture as a means to reduce poverty and build social value through design. This paper then discusses the problem of "green" design – better known as "greenwashing" – that undermines such goals. "Greenwashing" has come to define the problem of sustainable design and the opportunity to disguise it behind the facade of green innovation. When deployed in poor settings, the result is especially nefarious and reveals what is a cultural tension between an idealized image of energy independence and the realities of resource poverty.

Taken together, these projects demonstrate the need for new metrics to evaluate sustainable design; one that would apply to both resource poor and resource rich settings. The two most applicable metric systems relative to this discussion are the Social Economic Environmental Design (SEED) Certification developed by Bryan Bell, as well as the rating system for ecotourism developed by Martha Honey to reframe the larger social impact that sustainable design has the potential to engender. Such recent metrics were developed response to the United States Green Building Council's rating system for green architecture, Leadership in Energy and Environmental Design (LEED), which has been criticized as failing to take into account the social impacts of a sustainable project [1]. These newer criteria are the first steps towards an effective design revolution in which architects embrace a holistic approach of empowerment, economic potential, and environmental change in order to address global inequities of poverty and health.

2. Butaro district hospital Case study

2.1 Need for an effective medical facility in Butaro, Rwanda

Located on the eastern and northern edges of Lake Burera and home to more than 400,000 people, the Burera District is one of two large Rwandan regions without a central medical facility. Those in need of care are forced to seek services in other parts of the country, often traveling for days on foot before reaching help. The Government of Rwanda, along with Partners In Health (PIH) and the Clinton Foundation, proposed a strengthening of the district health services including retrofits to the current health center infrastructure and a new district hospital in the town of Butaro at the northern edge of Lake Burera.

PIH, a leading NGO in public health, contacted MASS Design Group to assist on the design and construction of the Butaro District Hospital in November of 2007. Collaborating with PIH, the Clinton Foundation, and the Rwandan Government, the MASS design team endeavored to develop a hospital that would have a high impact and be committed to sustainable design strategies revolving around local materials, passive systems of ventilation for increased airflow, and the reduction of cost through the commitment to these strategies.

2.2 Benefits of using local materials and local labor

Locally farmed and manufactured materials were an essential strategy for generating local economies through the use of design. Pumice stone is abundant in this volcanic region and is used as foundations for structures, stone walls for security, and outcroppings in fields. This pumice, which is dark grey when mined and cobalt blue when sliced, was chosen as a cheaper and more sustainable alternative to the red cobblestones typically used for construction in the region. Beginning with the deep excavation of the site itself, the design process began by rethinking not only how to use this stone as one of the main construction materials of the project, but also how to showcase its natural texture and beauty through atypical wall constructions. Local materials and labor were intended as a means to create an environmental advantage to be complemented by the financial benefits of cutting costs and energizing local economies. However, the substantial, positive, and multifaceted influence of this decision was unexpected.

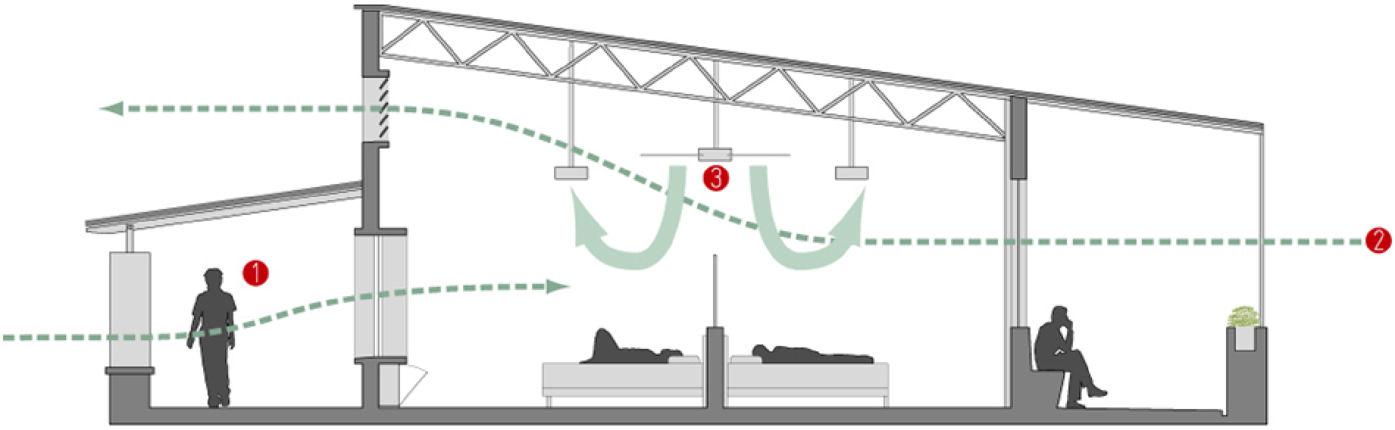
Drawings of the rock walls boasted tight jig-saw puzzle connections with intricate intersections and hidden mortar bonds. When the local masons made a mockup of the wall, the first attempt was dominated by thick mortar joints and imprecise connections. It was not until the fourth mockup that the masons achieved stunningly tight joints and efficient use of mortar that they could then begin work on the hospital walls. When the masons completed the first building, wrapping from the first corner all the way back around to the same spot, they had achieved such a high level of precision that they asked if they could knock down the original five meter wall and rebuild with this refined technique. To the architects and the foremen, this represented a solid example of design's ability to affect change. Skill, pride, craft, and quality had all emerged from just a bit more attention and a commitment to articulation and clarity on the site. Often, architects are not available for this type of consultation on site when working in remote areas like Butaro and thus quality, cost, and commitment to craft all suffer. In this case, the product, the architecture, the hospital, and the laborers all benefit. Recently, after hearing of the stone work of Butaro, these same masons were asked to build walls outside of Butaro, in both Ruhengheri and Kigali. The sustainable material and commitment to design produced a sustainable job force, a demand for higher quality standards, a means of developing craft excellence, and an outlet for displaying the enhanced abilities of the local craftspeople.

2.3 Impact of a natural ventilation strategy

Design solutions cannot emerge without a deep commitment to understanding local context. When designing a hospital, it is essential to study the key issues that dominate the region that the medical facility will serve. Since 2005, medical professionals affiliated with PIH had been working in Rwanda using a community-based approach to provide healthcare to impoverished areas. They were confronted by a deep problem in medical infrastructure where airborne diseases like Tuberculosis (TB) would emerge more potently over time, undermining their tireless efforts to treat patients.

PIH revealed that this was not just an issue in Rwanda, but also in the other countries throughout the world in which they had been serving since Dr. Paul Farmer founded the organization in 1985. Even as PIH expanded its services and shifted their policy and strategy for treating patients, TB infection continued to spread and the disease became even harder to treat as multidrug resistant strains of TB became prevalent. In Mountains Beyond Mountains, Tracy Kidder describes patients coming to health centers with one strain of TB and leaving resistant to another one. Even worse, some patients would appear at a rural clinic with broken legs and walk out with TB [2].

If diseases like TB are transmitted through the air, then the infection rate will steadily increase when the air is stagnant. However, if fresh air is constantly being circulated, then the infection rate will decrease, showing that ventilation is fundamental to an effective infection control strategy. In developed countries, hospitals have extensive mechanical ventilation systems to bring fresh air into the building to prevent airborne diseases from incubating. In Rwanda, such a high-tech ventilation system is not locally available and consumes extraordinarily large amounts of electricity thereby making the operational costs of such a system too high to be considered a realistic option for implementation. The goal of a mechanical ventilation system is to increase the number of times the volume of air in a room is replaced by a



1. Exterior Circulation - Reduces exposure to transmission
2. Ventilation - Combination well placed operable windows and fixed vents increase air changes
3. Large Industrial Fans - Increases air turnover while maintaining patient comfort

fresh volume of air, which is measured in air changes per hour. The Butaro District Hospital uses a natural ventilation system to attain the same ends by utilizing architectural techniques that do not rely on imported advanced technologies and that are cost effective, easily replicated, adapted to local constraints, and that consume minimal amounts of energy. According to research conducted by Roderick Escombe, using such strategies can increase air changes per hour up to twice the amount that mechanical ventilation can provide [3].

Drawing on the expertise of in-house professionals certified in Engineering Methods for Airborne Infection Control from the Harvard School of Public Health, MASS focused on integrating infection control standards into the early stages of the design process. Some of the first design decisions were driven by a desire to maximize natural airflow throughout the hospital in order to mitigate the transmission of airborne disease. The hospital itself is a campus of several buildings as opposed to a central structure, which helps to maximize the airflow through each building. The footprint of each building on the campus is oriented in the direction of the prevailing winds to maximize the speed of the airflow. While wind is never constant, efficient ceiling fans significantly increase air turnover. Meanwhile, the pitched roofs encourage and increase stack ventilation from higher to lower pressure to maximize the amount of natural airflow through the buildings. Additionally, the pitched roofs create the opportunity for clerestory windows thereby increasing diffused natural light inside and reducing electric lighting costs and needs.

The internal organization of each building reduces the likelihood of airborne infection. The typical hospital design of rooms on either side of a hallway will block airflow from one side of the building to the other side. This scenario, called a double loaded corridor, can incubate disease if hallways are not ventilated well. Since Rwanda is a warm climate, the buildings are designed in ways that require people to walk outside wherever possible, eliminating infection-prone interior hallways and large waiting areas. Additionally, by including isolation rooms for the most severe TB patients and by separating doctor and patient circulation as much as possible, the risk of infection is lower for people in the hospital who are not already suffering from airborne disease. In addition to these integrated architectural techniques, ultraviolet (UV) lights are used in waiting areas because UV lights help to kill airborne contaminates.

The measures taken in the Butaro District Hospital have contributed to raising the importance of infection control strategies in the design of medical facilities in Rwanda. The country director of MASS in Rwanda also works as the director of the Department of Architecture at the Kigali Institute of Science and Technology and integrates these ideas into the curriculum to educate and incubate the next generation of locally trained architects in such sustainable design principles. Because of the advocacy around this project, the Rwandan Ministry of Health now includes national standards for infection control and uses both PIH and MASS staff as consultants. Lack of standards is one of the root causes of poor performing buildings. The Butaro District Hospital addresses this by showing that high-profile, socially valuable architectural projects can change policy and have a significant impact on the development of effective local design practices.

2.4 Lessons Learned from Butaro

Eco-conscious sustainable design strategies have more than just environmental benefits. Using the locally sourced pumice stone had a substantial economic impact on the local economy sending funds directly to the region in which the hospital was being built. The process of construction became a laboratory for building capacity and improving skills, which had economic benefits for the masons' careers. Meanwhile, natural ventilation techniques lowered upfront and even maintenance costs. Natural ventilation will reduce the rate of infection in the hospital, reduce healing times, and thus eliminate unnecessary medical costs. Finally,

changes at the policy level for standards in the design of medical facilities are imperative to creating appropriate infrastructural solutions in public health. These strategies reveal that there can be a reverberant economic, social, and environmental impact from relatively low-tech concepts that are locally appropriate and distributed easily, inexpensively, and repetitively. Post-occupancy assessments are soon to be conducted to better evaluate the successes and shortcomings of the project based on the function of the intended passive systems and feedback from doctors and patients. With this in mind, the team has established a weather station and research project to assess the performance of the natural ventilation system, recognizing that adjustments and better understanding of its performance in practice will improve designs in the future.

3. Ecotourism: from green washing to sustainability

3.1 Exploitation under the guise of sustainability

The concept of eco-tourism emerged in the global "green" consciousness of the last decade and is now among the fastest growing subsectors in the tourism industry. For example, Costa Rica committed to an eco-tourist economy and subsequently tripled its number of tourists from 350,000 to 1.1 million from 1998 to 2001 [4]. The popularity of eco-tourism represents a change in tourist perceptions, increased environmental awareness, and a desire to explore natural environments. According to the Ecotourism Society, ecotourism is "responsible travel to natural areas that conserves the environment and improves the well-being of local people [5]." Eco-lodges proliferate and are a fundamental component of this interest surge, reflecting a growing change in the consciousness of travelers to have a lighter impact on fragile cultural and environmental ecosystems.

While ecotourism at first seems like the ethical way to engage a community and place, it can have negative and negligent impacts as well. One result, referred to as "greenwashing," involves the use of slogans and aesthetics to advertise a project's eco-consciousness without providing true impactful amenities. Greenwashing is in essence a disguise to mask typical and sometimes exploitative businesses as "sustainable" ones that in effect have helped to muddy and confuse what one should consider "green." In Ecotourism and Sustainable Development: Who Owns Paradise?, Martha Honey writes, "Much of what is marketed as ecotourism amounts to only ecotourism lite, which offers tidbits of nature or minor environmental reforms such as not changing sheets every day or, worse, 'greenwashing' scams that use environmentally friendly images but follow none of the principles and practices of ecotourism [6]."

Doing field research and analysis of local precedents near the Butaro District Hospital in Rwanda, MASS un-covered data showing proof of greenwashing and also confusion over what "green" actually refers to in the context of resource poverty. For example, there is one existing eco-lodge in Rwanda that is surrounded by fields of poor hillside communities yet charges $1000 per person per night. When an electrical grid could add a huge economic stimulus to a community without power, an eco-lodge proclaiming energy independence in a community that has little access to energy seems overly convenient if not unnecessary at the price range offered. Meanwhile, hundreds of local people could have potentially been employed in ways related to this project, yet only a few people benefit from the income reaching the remote village. Instead of the efforts to promote a true social engagement, exploitative cultural charades are performed at the often unnatural isolation of the guests. This "green-island" effect has taken hold in many economies. Ironically, the lodge professes a sustainability pledge, exposing a reality that the terms "sustainability" and "green" can be interchanged without much oversight and have been eroded of meaning. Without viable alternatives or rating systems, this trend will continue. A clarification and articulation is required to understand better the impacts, both negative and positive, that these interventions can engender.

3.2 Burera Eco-Lodge

When a client in Rwanda expressed interest in building an eco-lodge near the Butaro District Hospital, MASS was asked to help with the design and conceptualization of the project. The Burera Eco-Lodge concept comes from principles learned over years living in the Butaro District. These principles are based on furthering expertise, creating new jobs and job markets, using local materials as much as possible, and using the community design process to realize the building. Because this project is for paying tourists, thinking could be expanded to include the influence of the lodge's profit on agronomy, land rights, as well as education and trade development.

Set high above Lake Burera, the Burera Eco-Lodge is conceptualized as an alternative to greenwashing and as an example of tourism models that will advertise, rate, and benefit communities as much as or more than it benefits the customers. Working with a unique client and a spectacular site, the Burera Eco-Lodge seeks to generate a new model of tourism, with the aim of directly benefitting local communities. In working closely with Public Nature, a non-profit organization with expertise in social justice tourism, the design provides an alternative to the pervasive model of a high end hotelier working in complete economic and social isolation from the local context. Instead, the lodge stands on a moral imperative to create unique new and active tourism opportunities for the community to own, replicate, and benefit from. Acting as a venture philanthropist, the Lodge is seen as an engine to engage new markets and allow for communities to build business around its investment potential. Ideas include walking and biking networks, outreach centers featuring experimental plots for new farming and silviculture techniques, a cooking exchange academy, and the development of commercial centers in more remote communities to support the guests' outreach. The result will be a high end eco-lodge experience that is rooted, supported, and made more valuable by its relationship with the surrounding communities.

In addition to these proposed amenities, this project will be evaluated by strict benchmarks of environmentally and socially conscious sustainability. Rated through a set of metrics highlighting social impact, cultural value, education, job creation, new economic opportunities, impact on health, and community design outreach, the Lodge will allow guests to see their impact directly as well as understand how such an investment can become a fixture of a thriving and healthy civic community. This project has the potential to help redefine, using metrics, what "green" and "sustainable" should and should not refer to in the context of rural Africa.

4. A new rating system is required

4.1 Martha Honey's metrics for ecotourism

Because greenwashing has become so common, Martha Honey has proposed the creation of a rating system in which eco-lodges and other ecotourism projects can be vetted by and for customers to assess community impact and experience. She argues that "real ecotourism must involve seven vital and interrelated characteristics: travel to nature destinations; minimizing negative environmental impact; building environmental awareness; direct financial benefits for conservation; financial benefits and empowerment for local people; the respect of local culture; and the support of human rights and democracy [7]."

Honey's rating system is a good start but it suffers from a definitive way to quantify impact. Like many "green metrics," the social and environmental criteria in this rating system are intertwined, making quality hard to determine. Furthermore, Honey's expansive metrics do not clarify "sustainability" as much as they could. Her use of the term still acts as a catch-all for "good impact" instead of as a concept that refers to cyclical input and output divided among legible categories. In essence, sustainability and greenwashing emerge because of a lack of quantifiable metrics for the social impact of buildings. This is a primary reason why sustainability has been focused primarily on green buildings and not the more holistic potential of definitive environmental, social, and economic sustainability.

A parallel can be seen in the agriculture industry, in which so-called sustainable practices are ineffective because they have an inappropriate focus on capital-intensive standards and the private sector [8]. A study by Philipp Aerni shows that effective sustainable agriculture can be achieved in a more bottom-up solution in which farmers have agency to be entrepreneurs in a multifunctional context [9]. Aerni writes, "Farmers that feel to be in charge of their lives and able to successfully participate in the global economy may contribute to social empowerment in rural areas (social dimensions), generate more income and employment in the region (economic dimension) and become more interested in managing their scarce environmental resources in a sustainable way (environmental dimension) [10].” Similarly, locally incubated architecture communities in developing countries need such agency to have innovative roles in initiating sustainable change. While Honey’s metric system is an improvement from the standard metric system in resource rich countries ignore such aspects of sustainability by focusing on limiting the consumption of environmental resources, her system eludes the importance of considering such ways in which local entrepreneurship can facilitate multifaceted sustainable initiatives that lead to systemic change.

4.2 Bryan Bell’s Social Economic Environmental Design (SEED) Network

To change the status quo of this defensive approach to architectural sustainability, a metric system must be developed in tandem with exceptional projects that seek to showcase architecture’s dormant social responsibility. Bryan Bell, a leader in articulating the social impact of design, has been developing a metric system to rate a buildings social environmental and economic impacts. The SEED Network was developed as a compendium to the environmentally focused certification program, LEED, which is the standard American metric system that rates the sustainability of an architectural project. SEED is an effort to showcase the larger impacts that infrastructure has on societies, cultures, environments, and economies. Bricks and mortar are just the end result to a dynamic and complex matrix of environmental, political, economic, social and cultural engines that could, if driven right, greatly benefit places of need. Bell’s network focuses on the following five principles [11].

- SEED Principle 1: Advocate with those who have a limited voice in public life.
- SEED Principle 2: Build structures for inclusion that engage stakeholders and allow communities to make decisions.
- SEED Principle 3: Promote social equality through discourse that reflects a range of values and social identities.
- SEED Principle 4: Generate ideas that grow from place and build local capacity.
- SEED Principle 5: Design to help conserve resources and minimize waste.

Bell’s system is based on the belief that architecture is a valuable way in which communities and individuals can address economic and social change. Crucially, he separates the two into different categories. Design and implementation are promoted as a collaboration between professionals and locals who are naturally experts on the needs of the community. While the LEED system is a series of checklists focused on the architectural design, the SEED Evaluator is a series of essays focused not only on the design intent, but also the effectiveness of economic, social, and environmental sustainability strategies from schematic design through post-occupancy. This is intended to hold the designer and the client to a higher level of accountability. Each project is evaluated in the context of the community that it serves.

Bell’s work addresses the larger impacts of the building without muddying the concept of sustainability as vague synonym for positive impact. Without such refined metrics, it is difficult to articulate why one project is successful over another, as well as why one project has some successful and some unsuccessful elements that could be improved without losing its integrity. However, a rating system is not infallible: the success of an individual project, or indeed of a social system, depends upon levels of social commitment and engagement to maximize impact over the long term.

5. Conclusion

These Rwandan case studies show that expensive and foreign technologies are not needed to make significant contributions to sustainable design. In fact, by using local materials, local labor, and informed architectural strategies such as natural ventilation, it is possible to expand the impact of design to areas of health, education, and policy. In addition, choreographing the economic impacts of infrastructure development could allow for new economic opportunities, better environmental performance, and positive social change. This holistic vision of sustainability has as much relevance in resource rich countries as resource poor settings. Unfortunately, greenwashing is corroding sustainable design projects and even people with the best intentions get caught up in specific aspects of design that have minimal and isolated impacts at best. A more rigorous system of metrics is needed to evaluate a design’s holistic, integrated approach to sustainability not only to reveal the falsity of projects obfuscated by greenwashing, but to develop guidelines for affecting community-based change at the local level.

Environmental sustainability alone cannot be considered as the primary means by which architecture can revolutionize development. While low-cost and locally available techniques like natural ventilation represent an eco-conscious approach to design in resource constrained settings, projects like the Butaro District Hospital show how a holistic design process can positively impact public health while socially and economically transforming a place. If architecture serves the poor, then building and the building process must do more than construct walls and roofs. When one member of the MASS team was asked the reason for building one first rate hospital instead of two second rate hospitals, he replied, “Rwandans don’t deserve a second rate hospital. Plus, we can build a first rate hospital for the price of a second-rate hospital.” Good design matters in establishing dignified spaces for individuals and communities and good architects are practitioners at using the built environment to propose new models of social, economic, and environmental sustainability in the context of constraint based design.

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NESTown: New Ethiopian Sustainable Town
A Real Life Experiment

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Abstract:

By 2030 almost five billion people or 60% of the world population will live in urban areas. Even though urbanisation can be considered a positive development there are also major challenges that have to be addressed – especially in Africa where cities are ill-prepared to absorb the large-scale migration from rural areas. The Ethiopian government has recognized these challenges and is supporting the development of new urban centres that would help diverting migration away from Addis Ababa, the overcrowded capital city. In this article we use the example of the New Ethiopian Sustainable Town (NEST) to illustrate how existing vital challenges in Ethiopia could be addressed by means of an interdisciplinary model of urban development.

Keywords: Nestown, Buranest, sustainable town.

I Introduction

The founding of *Buranest*, the new Ethiopian town, was celebrated on June 27, 2010. The name is chosen by the local authorities. It is composed of *Bura*, the local kebele or territorial corporation of about 8000 inhabitants, and of *NEST*, the code for New Ethiopian Sustainable Town, a design for more than 20'000 inhabitants.

The new town *Buranest* was declared the *Amhara Model Town* by the regional government. It is situated close to *Yifag*, close to the Eastern shore of Lake Tana. and about 70 km north of *Bahir Dar*, capital of the Amhara Region where about 23 million people live, about a quarter of the Ethiopian population (fig. 1).

Buranest is a real life experiment with the goal of creating a *Self-sustaining Town.* This is to be achieved by transforming the highly dynamic relationship between the growth of the population, the cultivation of the territory and the settling in the landscape within the time of about half a generation. New capacities are to develop on the site which can re-establish and periodically renew the ecological and cultural equilibrium, which today is highly at risk.

The experiment is executed based on collected data, defined goals, commitments for the transformation and working hypotheses. All experiences will be recorded and serve in starting additional *Self-sustaining Towns* in Amhara. The laboratory for this experiment is shaped by three main elements:

the natural landscape on Lake Tana with its resources which have been culturally changed and in parts gravely depleted or lie fallow;

a farming population, sedentary or recently arrived, that only knows few promising forms of work, production and exchange for a sustainable future;

the area of a commons (10.6 ha), formerly used for grazing and now rededicated for building the first stage of the town for about 4000 inhabitants.

Two more urban centres – *Yifag and Adis Zemen* – are easily reached from *Buranest* so that a tripolar city of more than 100'000 inhabitants could develop relatively fast.

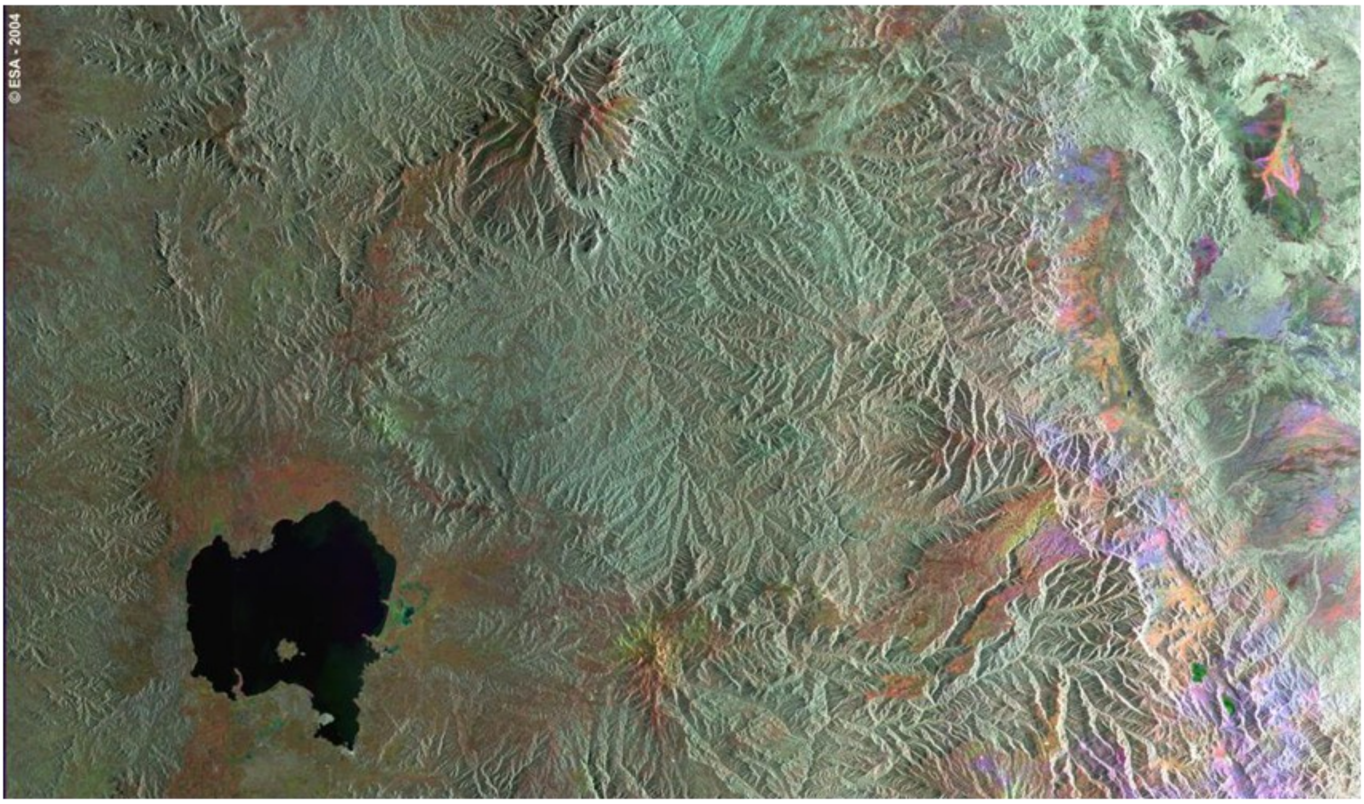
Why build self-sustaining new towns in Ethiopia?

Building new towns will change the traditional single homestead lifestyle of the farmers. Urban living and urban agriculture will improve output, in quantity as well as quality, with the help of autonomous cooperation, technologically enhanced work, a diversity of trades and exchanges. Thus, everyday life, based on division of labour, can become differentiated and productive, reduce the pressure for migration and further solidarity across generations without harm for man and environment.

In addition, through building new towns a cyclically operated metabolism will be created in order to secure the long-term regeneration of the town environment which often is ecologically depleted and highly endangered. The adequate care for the metabolism of urban environments requires the transformation of traditional patterns of cultivation.

Self – sustaining describes the relationship between available regional resources and the resources that the region requires to meet its needs, such as water, food, energy and construction materials. Self-sustaining, however, encompasses more than a technical or technocratic feature: it encompasses cultural, social, economic, and political values and the exchange of knowledge, skills, and technologies, all requiring careful design and policy decisions.

Figure 1. Lake Tana, source of the Blue Nile



From a systems theory point of view, self-sustaining urban environments are a dynamic construct consisting of borders, dense or lose stationary stocks (e.g. congregation of people, buildings, waste or data storages), dense or lose flows (e.g. people, water, air, energy, goods, data) and processes that lead to the transformation of stocks, flows and other urban dimensions. A balanced system of exchange establishes an equilibrium between immigration and emigration, as well as exports and imports.

Approaching the term self-sustaining from multiple angles, a composite of solutions encompassing citizens, services, infrastructure, construction, transport, and energy production are intertwined.

Against this backdrop, the real life experiment *Buranest* is founded on basic characteristics of the local environment, decisive goals, commitments in the process of transformation and working hypotheses.

Basic characteristics of the local environment

The basic characteristics do not only apply to Ethiopia, but can be observed in most developing countries, with similar disadvantages and risks. We divided the basic characteristics into 8 great challenges that need to be addressed in the design of a self-sustaining new town in Ethiopia:

Demography: population growth averages around 3%. For Ethiopia's 80 million inhabitants this means an additional 2.4 million people per year.

Ecology and Agriculture: Soil erosion, deforestation, increasing livestock density, lack of technology to control for drought and flood and the shrinking size of arable land per inhabitant are threatening agricultural and environmental sustainability.

Water & Health: water resources are sufficient but unbalanced, health care insufficient with periodic outbreaks of illnesses.

Energy: producing heat by burning wood is inefficient and contributes to deforestation. Electrical power supply is essential and can increasingly be provided by the new hydro plants in the area. Energy potentials (geothermics, sun, water, wind) are underused.

Schooling: analphabetism lies around 60%, mostly for older inhabitants and girls. Higher education and technical training are scarce and often of poor quality.

Working techniques, tools, machines and organization: more than 80% of the population live on subsistence agriculture, with traditional, but inefficient tools, little mechanization, in single homesteads.

Mobility: physical strength of man and animal are mostly used for transport. Mobile communication and paved streets are rapidly extended. The numbers of trucks, bicycles and public transport are growing.

Migration: day labourers, whole families are looking for work or markets, settle informally at the edge of streets or under power lines, migrate to the next bigger city.

Decisive goals

These challenges must be addressed by setting the right priorities: First of all there needs to be more public and private investment in agriculture in order to improve the quantity and quality of agricultural products and services. Second, investment in skilled labour needs to increase in rural and urban areas. It crucial for endogenous development because it enables people to specialize in a particular craft that is in demand and build up local markets based on the division of labour and earn an income that may improve people's living condition and attract more investment. This again will help to reduce the push-factor of rural-urban migration and, at the same time, stimulate the mobility through trade and exchange.

Commitments in the process of transformation

These goals can only be achieved through complex processes of transformation that assist people in their efforts to move from traditional towards habits of self-improvement that combine a better use of local knowledge with a readiness to adopt knowledge in efforts to improve local products and services. These processes require guidelines and commitments. For *Buranest* they are:

Active and autonomous participation of all stakeholders is guaranteed by bottom-up and top-down processes of realization, already involving the regional government and planning authorities as well as the local community and the individual farmers.

High rate of supply from locally available resources for local needs leads to marginal dependence on imported goods. This applies to building material, to energy as well as human resources like labour and knowledge.

Transfer of new technologies is provided, including education and advanced training. The new local technical and vocational school will be directly involved in the building process. The school is financed by the Amhara Development Association.

Production and innovation of value-added chains are derived from independently developed traditions and adopted technologies: planting of bamboo, production of building material, production of furniture, production of yarn, weaving or growing of grain, introduction of electricity, introduction of grain mill, milling grain for the neighbourhood, selling flour, setting up a bakery store.

Working hypotheses

For the goal of self-sustainability we have formulated four working hypotheses: (I) the loop of urban practices, (II) the security in filling basic needs, (III) the increase of living standards for individuals and the group and (IV) the rules of urban cohabitation. In *Buranest* these hypotheses will be implemented step by step and are periodically evaluated if they help to achieve the goals.

II: The loop of urban practices

Buranest becomes self- sustaining by creating an infrastructure that can be maintained and operated by the local people. It requires education and technical training of its inhabitants, the facilitation of local energy production and trade and exchange with other communities, as well as a balanced flow of basic natural resources within defined perimeters. Thus, *Buranest* means implementing the 4E: Education, Energy, Exchange and Ecology (fig. 4). They are the base and the driving force for the development of the town. Already at the outset, they are integrated in and adjusted to the life of the town and are used to enhance urban capacity building, i.e. the formation of vocational skills, economic and electronic exchange, mechanized and electrical power, re-cycling paradigms and practices.

The local economy of Buranest is dominated by Urban Agricultural Manufacturing. It is located within and on the fringe of the town, which grows, processes, and distributes a diversity of food and non-food products, using and reusing human and material resources, products and services found in and around that urban area. The hinterland in turn supplies the unprocessed harvest as well as human resources to the urban area. By integrating the rural people into the urban economy mobility and exchange is enhanced while permanent migration is reduced.

III: Secure fulfilment of basic needs, resource management in the public interest

Urban forms of living have always been based on public interest and the solidarity of many individual households that are integrated into the town. The inhabitants gain a secure chance for food and water, for example by cooperative production and storage. Resource management in the public interest of the town is able to provide food, health care, education, provision of materials, communication, transport, construction and maintenance of buildings and streets without outside help by local entrepreneurship. Certain services may be handled by private enterprise and further the competence in business organization. This includes the market and the management of electricity, garbage and sewage and recycling.

IV: Increase of living standards, added value from co-operation

The site of Buranest was chosen by the regional authorities in collaboration with the local administration. It lies on higher ground, with no flooding in the rainy season, close to a paved road and a power line runs through it. Added value and the resulting increase in living standards can be gained from agriculture, husbandry, forestry, urban agriculture including fish farming, water management and health care and sanitation. Power supply and application, transport and communication, the production of tools and machinery, already started through start-up initiatives financed by a Swiss sponsor, also contribute, and not least construction and construction financing.

It is not intended to use any newly imported metal sheets or freshly cut wood for the construction of the living and working closes of *Buranest*. Therefore, even buildings of more than one story will be built without scaffolding and from locally gained materials like stone, pressed earth, waste, bamboo, grasses combined with industrial waste like tin cans, metal parts and with recycled imports like plastic containers, tires or cables. The lots with their buildings for living and working are designed in such a way that they can be adjusted to new needs by self-construction. Building is handled cooperatively: the private households receive a lot including a primary structure as a loan and are obliged to collaborate in the construction of the neighbouring buildings without compensation. They can dispose of their lot and building at the earliest when the second building is finished.

The building by the inhabitants themselves, the development of alternative materials like pressed earth help to increase competences and promotes trades like carpenters and electricians. In-kind contribution leads threefold to added value: private extendable living quarters, technical know-how and vocational qualification for further demand.

V: Urban Charter & Townplan

How does a town emerge in Africa? It may start with a place in the shade of a tree. Here, people gather to devise their own history. Tree and town square mark the centre of the urban core. They embody the town charter as prepared by the town council and decided by the majority of the town's people.

Town charter and town core are the urban answer in Ethiopia to the never-ending and permanently extending settlements by the roadside. They represent the formal vs. the informal way of collective living. Formal living is complementarily structured in public and private legal realms and physically constructed by public and private space offering security of ownership and pride of achievement.

Buranest consists of three main areas (fig. 5). The areas of public institutions: town core with concentric ring roads and radial avenues; the town quarters with their closes; the hinterland with agriculture and forestry. The dimensions and proportions will allow all areas to change, become denser and adjust use and form so that changing needs can be met and the spatial quality of living stays intact at the same time.

The town core is the first place for the new town. It consists of the town square with 4 nuclei. This is where the interaction with the hinterland starts, the exchange of resources and products. The 4 nuclei mirror the activities which are required to build a town. The technical-vocational education and experience in the vocational school in nucleus 1 and the building experiments in the building yard in nucleus 2 are of particular importance (fig. 6).

The close and the dwellings are the pulsing spaces of everyday urban life. They are built, equipped and enlarged by the inhabitants themselves. The pattern of the spatial lay-out is preset. It determines the area for vegetable gardening, the circular wall with storage, stables, shops and repair shops, the rows of houses with their domestic gardens, places for shared activities like sports and games, the infrastructure for building services and transport.

In the closes and dwellings the desired changes will take place, from traditional resource dependence to recycling by technical resource management, from uniform to diverse income production, from man or animal driven to mechanized labour, from wasteful and conventional construction to durable and sustainable construction out of local material.

Concluding remarks

Planning and building a new town is based on centuries of experience and knowledge accumulation: outstanding larger and smaller examples are known in the Roman Empire, in Europe from the early Middle Ages, in the Americas from the 16. Century onward, in Africa and in India in the 20. Century.

Building a town is a process of learning by doing. The town remains unfinished, a product of learning and teaching by the young and the old, women and men, trial and error, building up and taking down. The town is a permanent workshop, a tools factory and storage of materials, energy production with repair services, exchange of goods and money, and, not least, participation of the inhabitants.

Reference: Website: NESTown.org

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Since 1974, own office for Architecture and Urban Studies (AUS) in Bern CH. Projects, Buildings, Participatory Workshops and Studies in Urban Planning, especially on Urban Housing and City Development. Various awards, e. g. Deutscher Betonpreis für Wohnen der Zukunft.

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Numerous publications on: Architecture, Design and Teaching, Urban Design and Urban Planning; e.g.: “NETZSTADT – Designing the Urban” by Franz Oswald and Peter Baccini, (Basel, Berlin, Boston, 2003).

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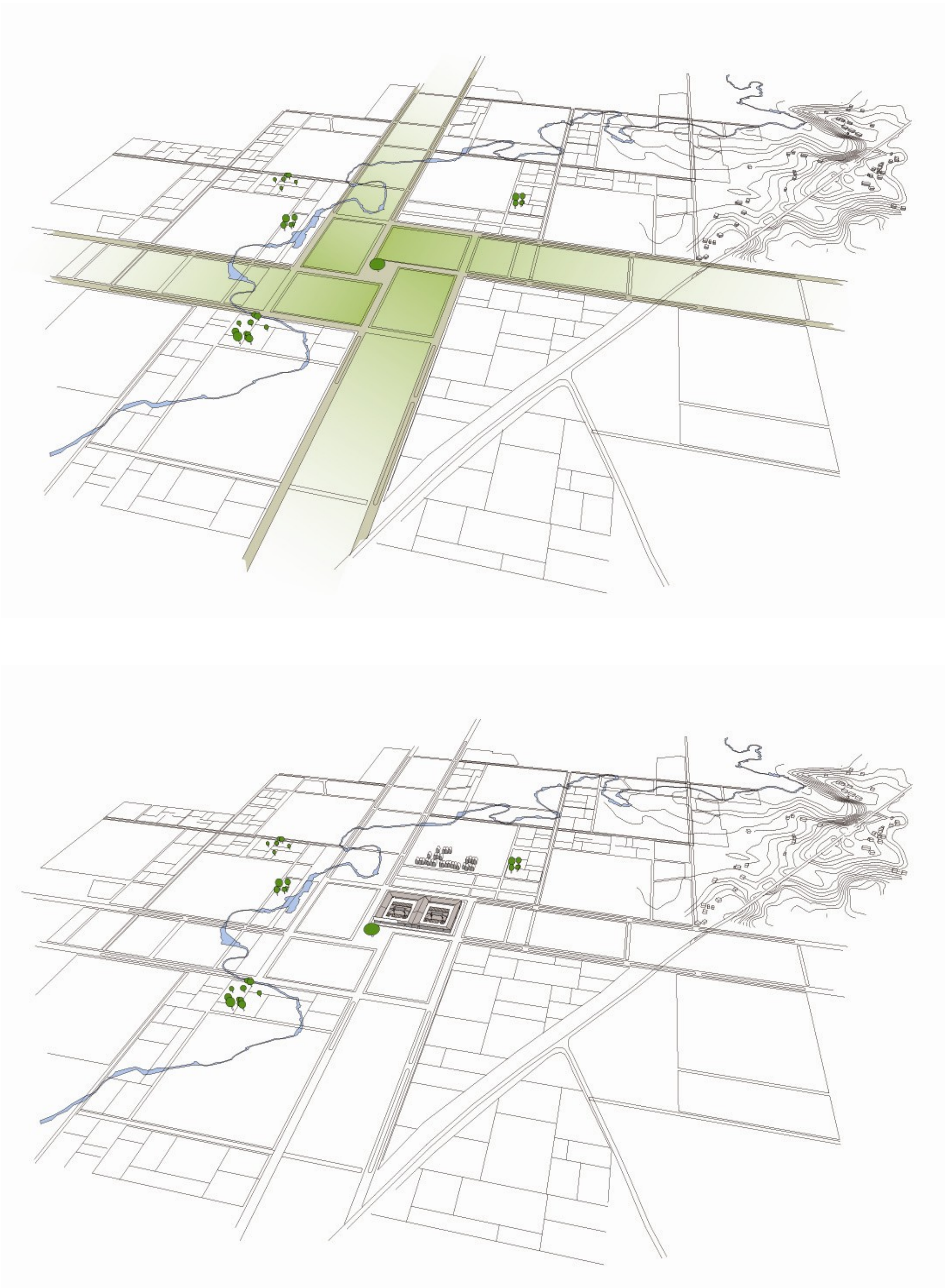
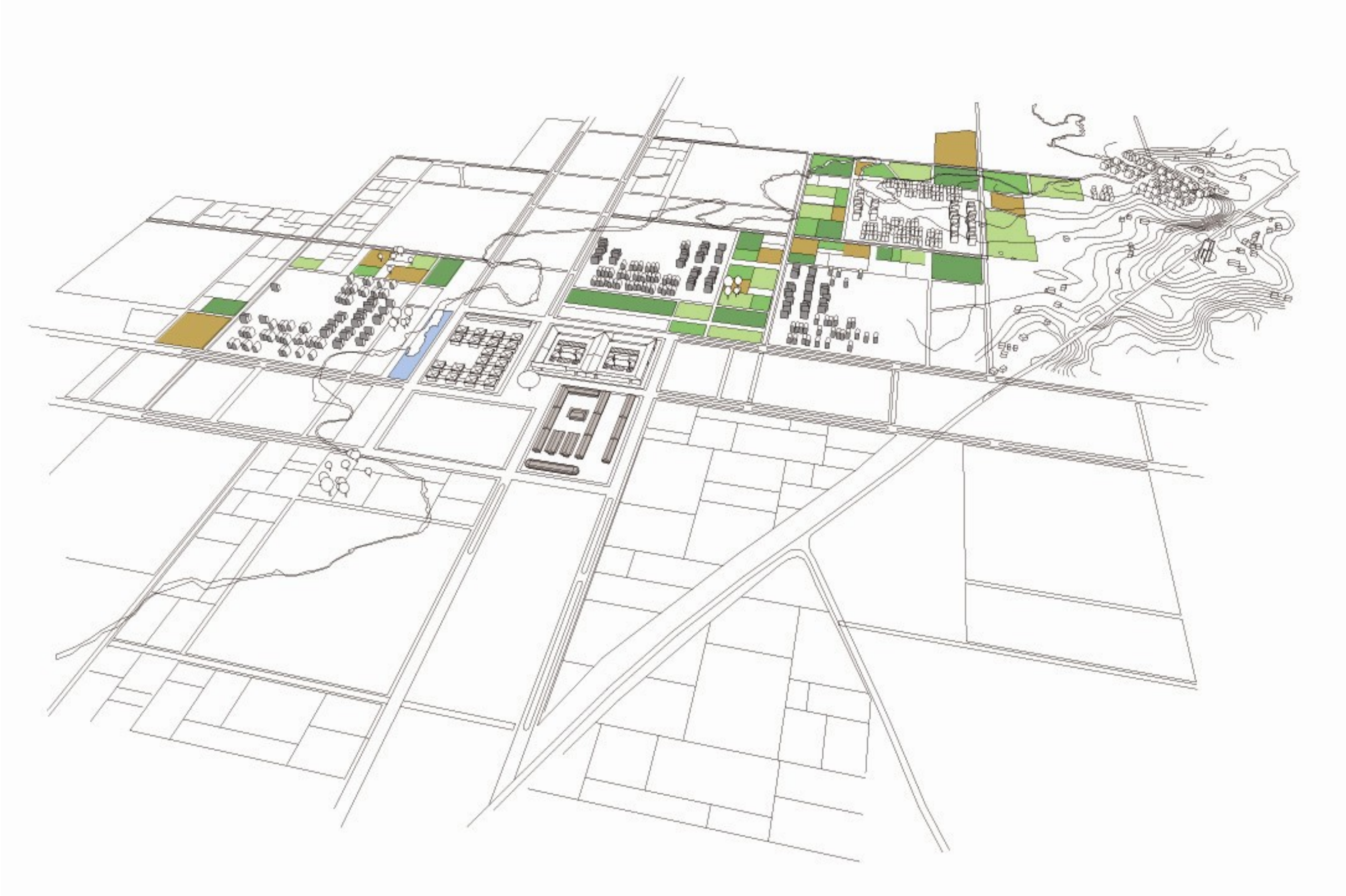
ATDF JOURNAL Volume 7, Issue 1/2 2010

Fig. 2: – NESTOWN model—phases of town development





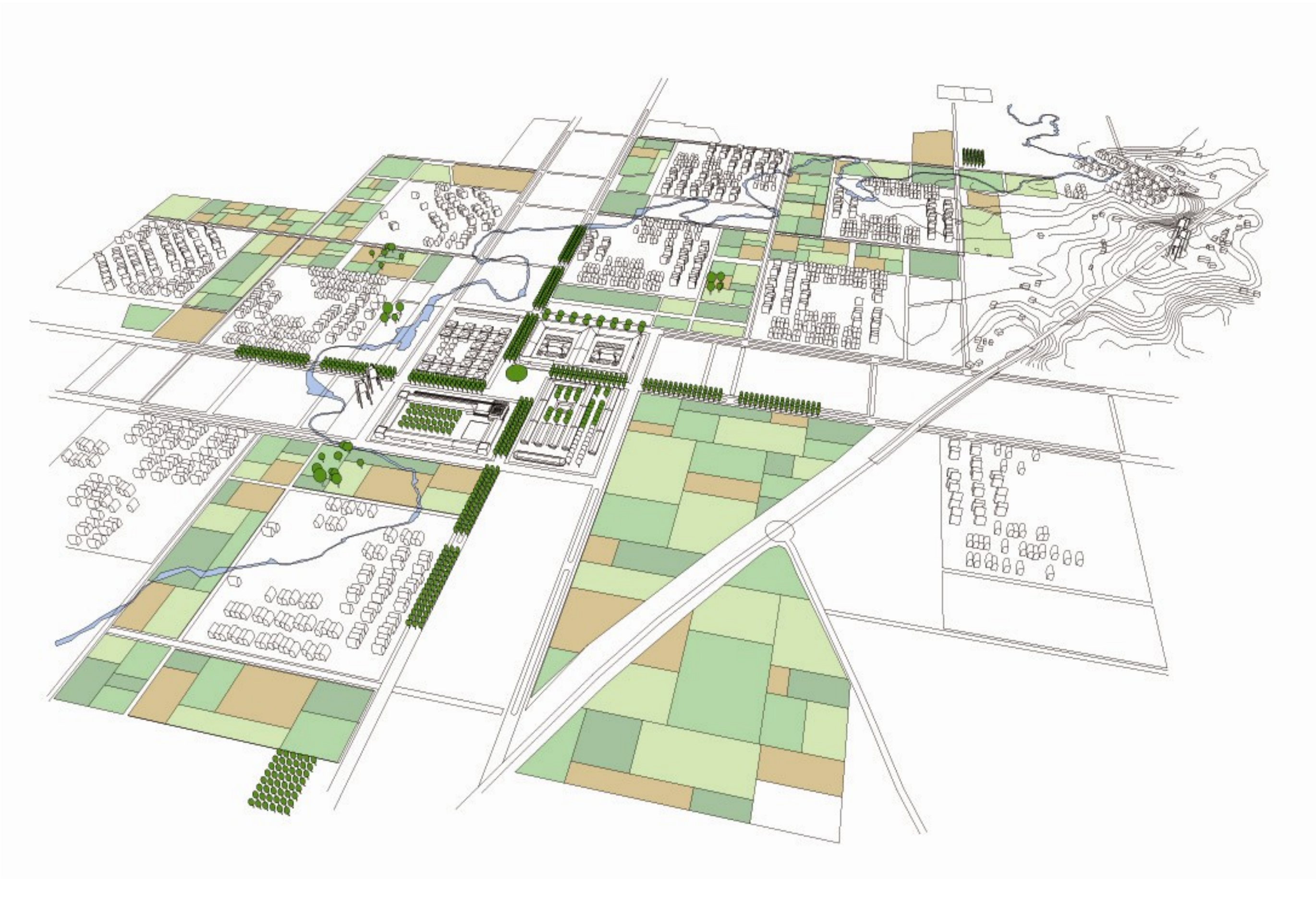


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Figure 3. BURANEST town plan - NESTOWN model adapted to real site

Appropriateness is a moving target
The re-invention of local construction technologies and materials in Ethiopia

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Abstract

Urbanization is a generally positive factor in overall poverty reduction but it needs careful urban planning and innovative housing design that makes better use of local resources and practices. Efforts to do so have largely failed in the fast growing cities of Africa. Rather than enhancing the value of existing local resources and practices by combining them with innovative new designs and technologies, governments tend to prefer foreign contractors that import most of their materials to construct energy-intensive and expensive high-rise buildings. This paper uses the case of the SUDU (Sustainable Urban Dwelling Unit) to illustrate how things could be done differently in the case of Addis Ababa.

1. Introduction

Africa is urbanizing faster than any other continent and, at the same time, it is least prepared to accommodate the large number of new residents that arrive every year. This is particularly true for Ethiopia and its capital Addis Ababa [1, 2].

Ethiopia will be confronted with an additional 45 million people within the next 15 years with the basic needs of food, water, safety, and also shelter in not yet existing, or already overstressed, mostly urban settlements. The decades to come will certainly be formative in the further long-term development of the country. Given this challenge, Ethiopia has to invent its own modes of 21st century urbanization rather than relying on outdated models of the so-called developed world. It has to re-invent its indigenous building methods, construction technologies, material use and reduce its dependence on imported materials, if it wants to escape its satellization role in the process of economic globalization [3].

What are the methods, instruments, and ideas that will be needed to structure the necessary development? The capital of Ethiopia, Addis Ababa, is a dynamic urban large-scale laboratory where urban phenomena of growth, expansion, and densification can be experienced and investigated first hand.

Currently, with a population of around 2.8 million people, and 78 ethnic groups, Addis Ababa is the undisputed metropolis of the country. This will remain so for the coming years, as experts predict the population will reach 6 to 8 million people by 2025. So far the city is ill-prepared for this looming migration from the rural areas. Most crucial questions related to urban density, care, safety, social coherence, economic development, and, above all, ecology are hardly addressed. Appropriate building materials and techniques, local participation in the design and implementation of new urban settlements and a supportive urban infrastructure are of crucial importance. Yet, newer developments in Addis Ababa show the contrary: it has been infected with the so-called 'Dubai Fever'. It is the desire to copy or import an image of economic growth and link it with political power. Glass and steel towers are a manifestation for this development and are meant to give a modern look to the city [3].

2. The Dubai Fever

The Dubai Fever, manifested in seductive flashy high-gloss magazines, reached all African cities and with it also Addis Ababa. A city, where more than 60% of the population lives below the poverty line and where power cuts are the rule rather than the exception. The copy and paste of architectural role models brings huge problems with it. Instead of using locally available material, more than 80% of construction material in Ethiopia is imported, mostly from East Asia like cement steel and glass. Capital and foreign currency, which would otherwise be needed to invest in the sustainable growth of local markets, is spent for foreign contractors, mostly keeping the country out of the value chain process. Most big construction sites are run and managed by foreign experts, Ethiopians are mostly seen in lower daily laborer ranks.

But the glass towers have also a big impact on the energy consumption of the city and with it on the ecological footprint of the whole country. Instead of designing and building in accordance with the ideal climatic conditions, which fall between 10° Celsius minimum and 30° Celsius maximum, the glass facades require technical cooling systems, using one of the goods Ethiopia doesn't have in abundance: energy [3].

3. The Grand Housing Project

Ethiopia needs to develop regulations and visions, on how to make better use of its rich culture and its reliable resources such as natural stones, loam brick technology or rammed earth techniques. The population increase of 20% over the last decade in Addis Ababa has dramatically shown the need for such a reconsideration of locally available techniques and materials, next to imported design and construction models. As a first "solution" for the desolate housing situation, the Low Cost Housing Technology (LCH) was developed with German support. In 2002, it was introduced into the local construction sector – with visible results. Over 40,000 accommodation units for approximately 200,000 persons have been built. At the same time, almost 40,000 jobs were created in the local construction sector, which is mostly organised in the form of small business enterprises. Based on the LCH-principle, the government is trying to promote this development with the recently launched "Addis Ababa Grand Housing Program" – an ambitious project aimed at the construction of further 50,000 accommodation units per year until 2014. But again, the construction technologies used for the program are based on a concrete pillar and slab system. Enormous amounts of cement and gravel are used on construction sites, hollow cement blocks are meant to fill the structures. The underlying principles were developed in the re-building period of post-war Germany but can they be applied to Ethiopia or even whole Africa?

4. The cost of ignoring local people and resources

On closer examination, these kinds of measures such as the Grand Housing Project reveal several shortcomings. The much praised top-down strategy of generating houses, infrastructures as well as jobs for the poorest within one individual program and one construction methodology proves to be an economic pseudo-cycle. When the resources of the local economy go mostly into a foreigner-led superheated construction sector, the question must be asked: Who can afford to build these structures in the future, moving from a government owned program to a private one? It would be considerably more promising and sustainable to develop diverse economic and also construction models, which would allow dealing with poverty and infrastructure problems of one's own accord. It would also be preferable to apply techniques and knowledge, which originate from local habits, materials and cultures and not necessarily from a global market. The use of prefabricated cement materials and mass production of them (or rather: mass importation) has been implemented in the production of housing in the Grand Housing Project in order to facilitate and shorten the construction time. However, the construction projects had to face many unpredictable problems such as shortage of materials, improper use of both material and technology, and unskilled manpower that led to very costly delays. These problems are likely to manifest themselves again in the operation and maintenance of the buildings because the local people were just asked to execute orders. They were not involved as experts of local knowledge and materials or trained in how to maintain the buildings.

The use of eucalyptus trees as a support for the formworks, used in the precast beams that hold the ribbed slab blocks and are usually also used as scaffold, were initially seen as a local solution. Yet, it is not a sustainable solution. An average of 800 eucalyptus tree logs were consumed by building a single block of the Grand Housing Project. For the 60,000 housing units completed so far, taking an average of 30 units per block structure, 1.6 million eucalyptus trees have been consumed so far. The large-scale consumption of trees for such purposes is likely to aggravate the already fragile environmental conditions in Ethiopia a country that is struggling against poverty and unpredictable climate change. Here, alternative techniques and methods have to be applied in order to achieve sustainable construction.

5. Integrative Thinking in Building, Architecture and Urban Planning

Sustainability requires an integrative approach that includes various disciplines in the fields of design, construction and urban infrastructure. Ethiopia needs to rethink current tendencies of just copying misleading architectural images from abroad, which increase the country's dependence on imported materials and know-how. There is a need to enhance indigenous construction capabilities and the use of local materials and knowledge to cope with the dramatic need for urban dwelling. This knowledge must be based on an integrative thinking of design, construction, building physics, sociology, energy, ecology and also take into account microeconomic considerations. New methods of low-cost housing and sustainable neighborhood infrastructure and management must be explored. In this context, Ethiopia could even draw from its past interaction with Italy. Streets radiating from grand central buildings are conducive to social exchange and community-building and maybe well in line with existing social habits in Ethiopia. A mixity of ideas and building technologies may offer a chance to better manage community services and tackle traffic problems [4]. There are also many possibilities to combine low-cost housing with existing know-how and resources in the region and build sustainable operating double-story building techniques as they can be found in many African cities. These would allow to double the urban density of the current territory without wasting valuable territories for agricultural land use.

6. The SUDU Project

In the summer months of 2010, the Ethiopian Institute of Architecture, Building Technology and City Development (EiABC), together with the Swiss Federal Institute of Technology in Switzerland (ETH Zurich) started to build on its campus a double-story Sustainable Urban Dwelling Unit (SUDU), based on the current urban conditions and needs. It is used as a show case for integrative thinking and an experimental laboratory to convince decision makers, economists, environmentalists, urban planners and also architects to rethink traditional building methods and social space requirements in order to find new ways to build a city.

For less than 1000 Ethiopian Birs (60 EUR) per square meter, the EiABC constructed a SUDU prototype to illustrate how an integrative design and construction process could work that involves local and foreign experts as well as students from the ETH in Zürich and the EiABC under the umbrella of Addis Ababa University. Students from different backgrounds, cultures and disciplines worked closely together to plan, design and build the project in full scale and experienced first hand the need to listen to and learn from each other in order to accomplish a joint project successfully. It enabled transdisciplinary and cross-cultural thinking and acting. In addition, it was also a test-run for building-up innovative organizational structures in the field of sustainability at the University of Addis Ababa as well as within ETH Zurich. Under the guidance of ETH Sustainability and the ETH North-South Center several departments at ETH Zurich managed to develop institutional relationships that allow to handle such projects in the future and use the connections to EiABC and Ethiopia for further research activities.

7. Sustainable Urban Dwelling Unit (SUDU)

The need to reduce global emissions, energy consumption, and material waste requires the systematic development of sustainable buildings in large, as well as small scales. Materiality, social space, water management, waste management, energy production and consumption, operation, and maintenance have to be designed and coordinated so that the economic, social and environmental objectives are achieved in the most effective way. In this context, the project served as a first experiment that helped identify the opportunities and challenges associated with the translation of theory into action. Based on the concrete experience with the prototype, performance standards will be established emphasizing innovation and integrated design.

Ethiopia, once called the corn chamber of Africa, has a rich soil, which contains high levels of clay particles. Almost every excavation material in the city of Addis Ababa is a possible source for the material needed to build new structures. The SUDU project used a "rammed earth" technology to construct the first level of the building with a 60cm wide wall structure. With a formwork, which was designed for multiple use, the loam soil is brought in form and densified with small metal rammers. Each layer is 120 cm high and when the first layer of the formwork is filled, the form is lifted up so that filling and ramming can start again. Openings for doors and windows are just speared out. A small ring beam was constructed on top of the last layer, to ensure the structural strength needed to accept the ceiling, done in a specialized technique.

The first ceiling of the SUDU project was done in a tiled vault technique, designed and introduced for the first time in Ethiopia by Prof. Dr. Philippe Block from the ETH Zürich, who gathered some practical experience already in the 2008/09 project for the Mapungubwe Museum in South Africa together with architects Peter Rich and Henry Fagan and John Ochsendorf and Michael Ramage as structural engineers (see article in this ATDF issue). The technique, also known as Guastavino or Catalan vaulting, was introduced already in the end of the 19th century in many public buildings in New York, such as the Central station or City Hall Subway Station. The system was patented in 1885 by the architect Rafael Guastavino. It supports robust, self-supporting arches and vaults using interlocking tiles and layers of mortar to form a thin skin. The tiles are usually set in a herringbone layout with a sandwich of thin layers of Portland cement. Unlike much heavier stone construction, these tile domes or barrel constructions could be built in space without additional support. Each tile cantilevers out over the open space during construction, relying only on a quick drying cement, known as "Plaster of Paris", produced in Ethiopia. With this technique, no scaffold is needed to construct the ceiling or dome, just a string guide system is used to make sure the form is kept in an ideal structural line.

The second floor of the SUDU project was constructed with loam stone produced in a hand-operated loam stone press, with an output of several hundred stones per day, operated with local know how and work force. The first layer of stone is put in a loam mortar bed enriched by 5% cement, all other layers are just placed on top. This technique also allows for additional structural support if needed by spearing out an internal formwork for small columns, securing the building against lateral forces, since the area around Addis Ababa is seismic active. The argument here is once again, that no additional formwork is needed and a combined technique of interlocking loam stones and a possible pillar structure allows for a heterogeneous construction method, according to location and regional requirements regarding seismic activities.

The roof construction followed again the "Catalan Vaulting" technique, this time covered on top with a special 10cm thick waterproof mortar, produced out of prickly pear cactus juice, salt, lime and loam soil. Since 2008, this method is introduced again by an Ethiopian born artist, Meskerem Assegued in a project in the village of Aslam, near by the city of Dire Dawa, in the very east of Ethiopia. She investigated the technique in Mexico and brought it back to Ethiopia, where she found proof, that it was used for centuries and forgotten over the years. Out of this loss, the inhabitants of the village could not repair their roofs anymore and replaced them over the last decades with corrugated metal sheets, producing unbearable conditions in the overheated homes. Through her project, more and more of the villagers are replacing their roofs again, coming back to the old techniques and traditions. Micro enterprises and know how developed fast in Aslam and it was brought through the SUDU project to Addis Ababa. The technique uses prickly pear cactus, cut in small pieces and let set for 5 days with water in a dark barrel. After this period, the slimy juice is then filtered and mixed with salt, loam and lime, and thus ready for use. The villagers use the juice already to paint all of the exteriors of their homes to seal them against rain and also started a loam stone production, with astonishing results in strength and durability. The plastering of the SUDU project was done in the same technique, easy to handle and to produce, without any imported materials.

In total, SUDU uses only 5% of the cement, which would have been needed compared to a hollow cement block construction as it is the most common construction method right now in Addis Ababa. Local materials such as loam, local know-how and local workers led to a first case study building, which will be used to gather more information and will hopefully lead to its first implementation phase very soon on a larger scale. The project may encourage the local industries and small-scale enterprises to think more and more about alternative construction methods than concrete. Less than 100 years ago, Ethiopia had the tradition of constructing seven story loam buildings, but almost forgot about it. New technical infrastructures in connection with those traditional methods will help to develop a sustainable construction for future generations, in urban as well as rural conditions. EiABC was already granted another research project to investigate the possibilities to build a rural counterpart commencing in 2011.

The SUDU project represents a catalogue of possibilities, it is a combination of different possible techniques, available and appropriate in Ethiopia. Those appropriate technologies can and will change in Ethiopia over the next decades, when its population will shift from rural to urban. Appropriateness is a moving target and it can only be understood in a certain moment in time. Different regions in Ethiopia have different material resources, which have to be exploited and combined with other, even maybe foreign techniques and technologies. Those heterogeneous technologies could be an answer to one of the most urgent questions in Ethiopia: how to house an additional 45 million people in the next 15 years to come.

A city is maybe one of the most complex systems, human mankind ever came up with. The SUDU project can just be a particle of such a system, but it can enhance the understanding of how urban infrastructure and the quality of materials as well as spaces can lead to a project which is adopted by the people living in it and becomes their own, rooted in their own history and culture.

Acknowledgements

SUDU SummerSchool Project:

EiABC: Herbert Schmitz, Dr. Elias Yitbarek, Tibebu Daniel, Melak Moges, Zegeye Cherenet, Fasil Giorghis, Meskarem Zewdie, Joseph Hennes, Dirk Hebel

AAiT: Getachew Bekele

AAU: Elias Berhanu

SNV: Willem Boers

Department of Architecture ETH Zürich: Dr. Philippe Block, Dr. Marc Angélil, Lara Davis ETH Sustainability: Dr. Christine Bratrich, Cathrine Lippuner North-South Centre ETH Zürich: Dr. Barbara Becker, Astrid Smitham, Emma Lindberg Eawag ETH Zürich: Chris Zurbrügg Institute for Environmental Decisions ETH Zürich: Dr. Philippe Aerni , Institute for Developing Economics ETH Zürich: Dr. Isabel Günther and all participating students from ETH and EiABC

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Sustainable urbanization: The missing bottom-up dimension

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Introduction

Sustainable urbanization in developing countries will be one of the major challenges of the 21st century. Especially in Africa where the current rate of urbanization is fastest and cities are least prepared to offer poor migrants decent living conditions through innovative solutions in housing, urban design, education and infrastructure. Sustainable urban planning in African cities requires a willingness to learn from past mistakes and greater recognition of all the privately organized public services that make living in the overcrowded informal settlements bearable. Supporting the informal activities of these local entrepreneurs and helping them to gradually improve their management practices as well as the range and quality of their services would not just improve the livelihood of the urban poor but also create new economic opportunities. Such public-private partnerships represent the bottom-up dimension of urbanization because they tend to be inclusive and sustainable. But they must also involve innovative academic institutions in the design and implementation of sustainable local solutions in cooperation with local private and public actors. In this context, incentives must be designed for universities to make them more responsive to the needs of the local urban economy. This would require the integration of the science and practice of entrepreneurship into the student curriculum especially in the area of architecture and urban design. Such academic institutions have the potential to facilitate effective collective action in efforts to improve environmental and health conditions in informal settlements and helping local entrepreneurs to get access to public funds and better connect with the formal economy. The following article will illustrate how that might work in the case of the city of Addis Ababa in Ethiopia.

The challenge of urbanization in Africa

Goal 7, Target 11 of the Millennium Development Goals (MDGs) is to achieve significant improvement in lives of at least 100 million slum dwellers by 2020. In response to this challenge UN-Habit developed in close collaboration with the UN Statistics Division and the Cities Alliances an operational definition of slum dwellers. The definition is largely based on what people lack in these settlements rather than what they have [1]. It includes (1) access to improved water, (2) access to improved sanitation facilities, (3) sufficient-living area, not overcrowded, (4) structural quality/durability of dwellings and (5) security of tenure. One could argue that the problem can be solved by making it a human right to have access to all these necessities. But who would have the means to ensure the basic provisions and who would manage and sustain them? Human rights with respect to decent livelihood conditions cannot be met unless institutional incentives are put in place that make it more attractive for all stakeholders in the public and the private sector to invest in people, goods and services that contribute to the improvement of the living conditions in poor urban areas. Since such incentives are based on the mobilization of market forces for development, many urban planners are still reluctant to create them. They assume that planning is merely meant to regulate and control markets and not to facilitate new markets that better serve the needs of the poor. The UN Habitat report [2] reflects this attitude quite well in its introduction. Seeing the market as the problem rather than as part of the solution creates however a typical collective action problem because, as even the UN Habitat reports admits, current institutional arrangements are unable to address the fundamental problems in many African cities. Most stakeholders seem content to endorse human rights but do little to make it more than a wish list. The sustainable improvement of poor urban settlements lacks priority and relevance in the public sector agencies and the private sector alike. No wonder then that the proportion of the urban poor continues to grow faster than the rate of urbanization in most African cities [3].

What can be learned from urbanization in Asia and Latin America?

The situation in African cities stands in strong contrast to the one in cities in Asia and Latin America, where the share of slum dwellers has decreased thanks to large-scale investment in urban infrastructure, public-private partnerships in the provision of local public goods and the promotion of technology transfer and higher technical education [4, 5]. Against all doomsayers of public-private partnerships, these actions have led to less and not more inequality because all the knowledge available is mobilized and tapped to find appropriate solutions. As a result, a shift of the city economy from informal to formal has occurred, and once this is happening, long-term urban planning becomes more effective and less harsh for the poor who have now formal property titles. They therefore start to see the opportunities of change more than its risks. It helps explain why 72% of the urban population in Sub-Saharan Africa still live in slums as opposed to 58% in South Asia, 35% in East Asia and 30% in Latin America [2, 3]. The improvements in East Asia and Latin America are reminiscent of a similar development that occurred in Europe during the 19th century, which was actually the century of public-private partnerships (PPPs) [6]. At that time, PPPs helped to cope with the first wave of economic globalization fuelled by the revolutions in science, agricultural technologies, transportation (railways) and communication (telegraph) [7]. PPPs can be defined as arrangements in which private parties participate in or provide support for the provision of public goods. In most cases the public sector remains the owner of the physical assets and defines the terms of the arrangement in a way that provides sufficient economic incentives for a company to invest in, operate and maintain the good or services it is providing [6]. Unfortunately today people don't remember anymore about the past developments and tend to associate PPPs with privatization and deregulation rather than joint financing public-private partnerships that provide for public goods [8]. While most Europeans do not remember anymore how they developed economically, Asians still do and value PPPs as a vehicle for development correspondingly. That is why Asian investment in African cities may be part of the solution rather than part of the problem considering that the share of informal settlements in Africa has mostly increased over the past decades despite numerous Master Plans. These plans were mostly by designed by urban planners from Europe that always had the best intentions but never wanted to see the challenge of implementation assuming that the public sector can run things just as smoothly as it does in Europe.

The fear of public-private partnerships

The lesson from this divergence happening between Africa and the rest of the developing world shows that the ability of the international community in general and UN Habitat in particular to successfully implement Goal 7, Target 11 of the MDGs is very limited. The UN-Habitat headquarters in Africa are located next to Kibera in Nairobi, one of the largest informal settlements in Africa. Kibera is also the slum that gets most attention from outsiders. Countless projects sponsored by foreign governments and NGOs aim at improving its living conditions for decades but despite all these efforts, Kibera continues to share the same problems and misery of any other African slum. One problem is that the more money that is spent by charities and NGOs on informal settlements, the more likely that governments stop care about them. In fact, many governments seem to benefit from their activities as well as the ongoing existence of informal settlements. They cost them nothing because basic services, schools, hospitals, water and sanitation, waste disposal are mostly privately run by locals - if they are run at all - while the government can collect fees and rents from its people for all kinds of permits [5]. Yet, these short-term benefits are obtained at the expense of long-term disaster because informal settlements operate by definition largely outside the formal legal business environment and therefore offer few possibilities to lift its inhabitants out of poverty through economic growth. Unfortunately, many charities and NGOs operating in slums tend to increase incentives for locals to remain in the informal sector because how would they be able to out-compete professional foreigners in the provision of local public goods and services [9]?

Endogenous economic growth is bottom-up by nature and therefore cannot be achieved by social planning alone but must include local entrepreneurs that serve unmet needs and innovate to out-compete their local competitors [10]. Yet these entrepreneurs face numerous obstacles in their efforts to make profits that would allow them in invest in the improvement of their business and hire people. With no formal title, no formal address and no collateral of any acknowledged value there is little chance to attract investors and get access to financial services such as insurance, credit, loans, saving accounts, etc. Moreover, business in the informal economy is burdened with high transaction costs due to the absence of formal legal contracts, bad infrastructure and health hazards due to a polluted environment and inadequate health care that affect economic capacity [5]. Last but not least, UN agencies as well as donor agencies are reluctant to support local entrepreneurs even if they provide useful public services since they believe that this should be the exclusive job of ordinary civil servants according to textbook knowledge – no matter if the public sector fails to deliver [11].

In other words, most people in informal settlements are locked in poverty and there are few resources available to invest in a better life of their offspring, which makes it unlikely that the next generation will be better off. There are however efforts even by large donors and government agencies to unlock enterprise despite these obstacles. Microcredit and microinsurance schemes proved successful in easing access to financial services. Moreover, vocational training centers for the poor have at least helped poor settlers to acquire some skills they can use in their search for work; and granting collective development rights and issuing land certificates have also stimulated entrepreneurial initiatives to a certain extent [12].

Yet, all this is not sufficient to facilitate growth-oriented entrepreneurship that is based on the creation and successful commercialization of new products and services. This requires much higher amounts of investment and cost-effective regulation in the formal sector [13]. Unfortunately, regulations of private sector activities in Africa, mostly copied from developed countries, are costly and complex. The complexity of the formal business environment is a huge barrier to market entry for resource-scarce informal entrepreneurs. It is not just sufficient for them to be literate, as many development NGOs continue to believe, to attract investment and set up a successful business. They have to master the formal language and practice of business. This comprises the ability to write a business plan that convinces potential investors, to know the basics in management and accounting, to make effective use of new knowledge and technology to improve the offered products and services, to reach out to customers through different marketing channels, to ensure access to the latest business and market data, to build up a network in the private sector and government, etc. Most of these things cannot be learned by merely going to high school or even university. They require careful mentoring and the eventual development of tacit knowledge that enables them to make better use of available codified knowledge and build up a business network [14].

UN Habitat should recognize and support private initiatives in the provision of public goods

The Global Report on Human Settlement 2009 by the United Nations Human Settlements Programme [2] acknowledges that current approaches to urban planning in African cities must change because they continue to use old-fashioned master plans that fail to address the needs of the local people as well as the global challenges such as the depletion of natural resources and climate change. Urban planning systems, especially in Sub-Saharan Africa, are increasingly aggravating urban problems rather than helping to improve human and environmental conditions. Even though the report acknowledges that urbanization is generally a positive phenomenon because concentration creates economic and social opportunities, makes the provision of public goods more cost-effective and helps to restore ecosystems in abandoned rural areas, its recommendations are less convincing. It tends to blame market forces rather than flawed urban development theories for the failure to implement sustainable urban planning. Bottom-up solutions are only recognized as long as they are guided by presumed far-sighted and well-educated social planners that use strategic spatial plans as well as the latest tools of monitoring and evaluation. In fact, one often gets the impression that urban design experts are more excited about the visual power of geographic information systems (GIS) to locate problematic areas than to actually solve the problems. In response to the failing Master Plans they suggest more plans such as site plans, subdivision plans and neighbourhood plans and so on that are likely to further limit the freedom of local entrepreneurial activities and make more difficult to ever manage the transition from informal to formal through economic empowerment. In fact, the authors of the UN Habitat report seem to regard urban informality as a solution rather than a problem, considering it to be an alternative to the market-oriented formal system – as if informal settlements would be devoid of markets. They seem to believe that an informal entrepreneur has made a deliberate choice to have a value-based rather than profit-based business. They see it as a sort of life-style choice or even an anti-capitalist statement.

The fact is however that these entrepreneurs have no choice. They are simply stuck because the informal sector prevents them from having a growth-oriented business that would ensure a better future for the next generation. This undervaluing of the situational context by the authors of the UN Habitat report is related to the so-called 'fundamental attribution error' [15, 16] meaning that they have mostly an elite background and tend to ignore different situational contexts. Having grown up in affluence, they never had to live in the harsh environment of slums and were never confronted with existential threats related to natural risks and lack of technological means to address them. Yet they firmly believe that their views are related to their superior education and not to their social status. They think that if only slum dwellers would be as well-educated as they are they would immediately share their preferences and life styles for sustainable development and abandon the desire for material growth. Slum dwellers that make no attempt to get out of poverty and abide to traditional habits are therefore considered to be wise and somewhat educated. Often they are then lucky to get hired as local project leaders for a foreign NGO due to their alleged like-mindedness. This sort of negative-selection [9] has also been noticed by entrepreneurial slum dwellers who realized that it can be more profitable to adopt the anti-capitalist jargon of the Western do-gooders in order to get a well-paid and well-cared job in a foreign development organization than to actually build up a risky business in a market with no real support infrastructure for entrepreneurs.

The well-meaning but paternalist view of many urban planners ignores that they could actually learn something from local people in the informal sector as well as from local research institutions. After all, they are quite innovative in finding solutions for local constraints because they have experience on the ground; they would very much like to upgrade their businesses or low-cost technologies to serve a larger customer-base – if only they would receive institutional support in their endeavour to run a formal growth-oriented business or university spin-off firm. In a UN Habitat Working Paper called 'Slums of the World' [1] the capacity of the poor to find the best solutions to local problems is actually duly acknowledged in the concluding remarks. But they would never call these innovators 'entrepreneurs', instead they describe them as being 'meaningfully involved in the process of improving the slum conditions under which they live' (p48). Considering this great concern for political correctness in the choice of language, it is not surprising that effective public-private partnerships that are based on well-designed incentive schemes (as described by Grimsey and Lewis [6]) are hardly ever mentioned in the UN Habitat report [2]. The reluctance to look closer at the potential of public-private partnerships may be related to the fact that most contributors have academic degrees in disciplines such as geography, economics and urban planning where they mostly learned theories from the 1970s that are hardly applicable to the global knowledge economy of the 21st century. They welcome interdisciplinary and participatory approaches as long as 'uncooperative' troublemakers that do not share the preferred view, strategy or theory are excluded.

The Case of Addis Ababa

Addis Ababa is Ethiopia's political and economic capital. It is located in the center of the country and covers 54'000 hectares of land with an estimated population of 3.2 million. Despite a relatively low urbanization rate due to various regulations to slow down rural-urban migration and a preference of most foreign NGOs to work in rural rather than urban Ethiopia, Addis Ababa is expected to become one of the fastest growing cities in Africa over the next couple of decades – and it is ill-prepared. The housing-related infrastructure of Addis Ababa has suffered from decades of neglect and misguided urban planning and policy. The large majority of settlements continue to have no access to sanitary infrastructure and services, paved roads, formal waste disposal as well as water treatment. This is especially true for the inner parts of the city which have the greatest concentrations of slums [17].

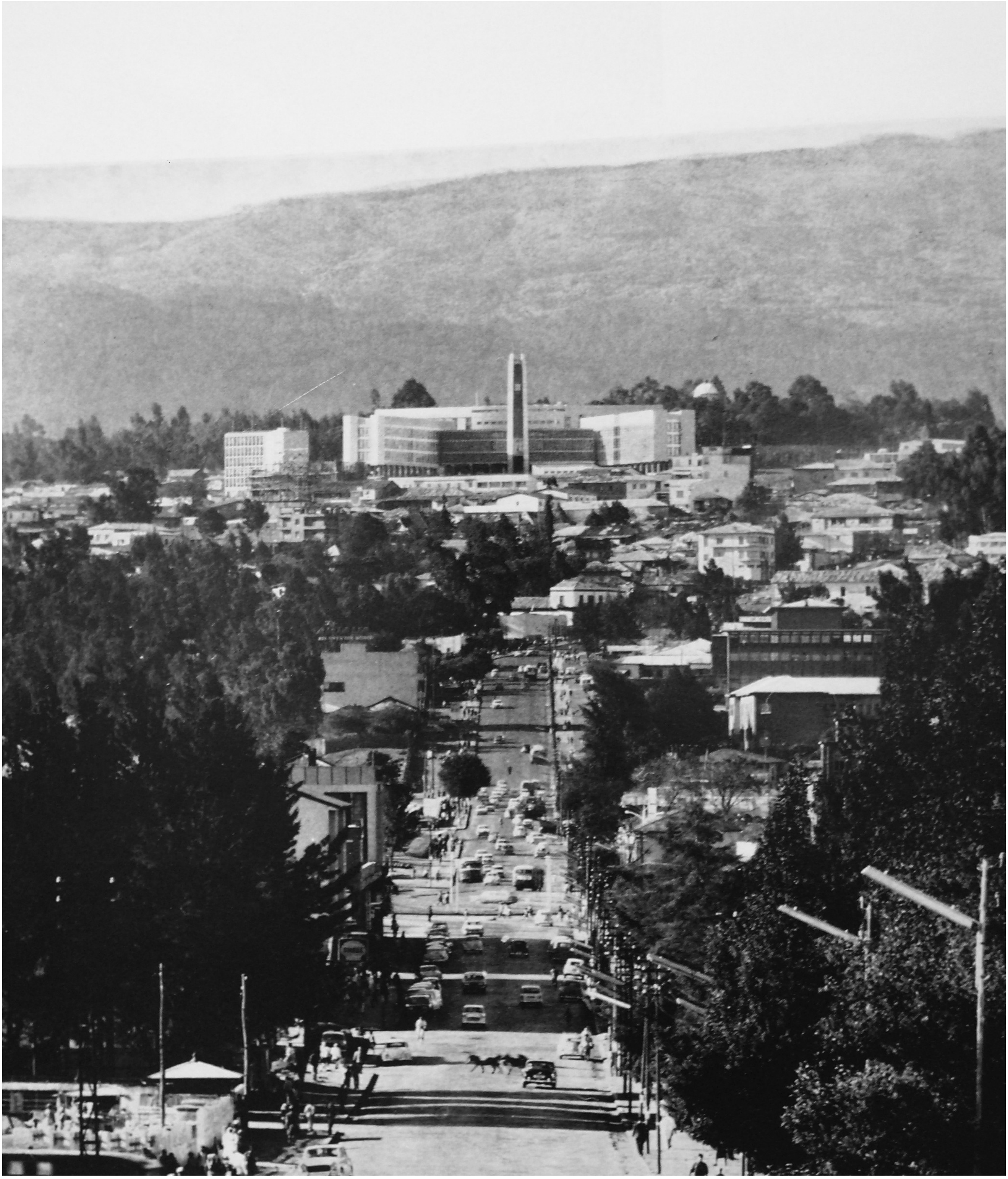
Most international estimates put the proportion of the city's population living in run-down slum settlements, as one of the highest in the world. An alarmingly high percentage of houses in these settlements are roofed with corrugated iron sheets, have mud or earthen floors and are devoid of basic amenities such as toilet or kitchen. The majority of the makeshift houses is single story and attached to row houses. They only consist of two or fewer rooms whereas the average household size is 5.3 individuals. Overcrowding and congestion in these informal residential areas is putting further strain on the neglected infrastructure [18]. Yet, investment in the upgrading of houses or infrastructure by local people and businesses has almost come to a halt because of burdensome and expensive government regulations, unreasonably high down-payments (20% of the construction costs) for house building and extremely high mortgage interest rates. On top of it, private ownership of land is still not possible. City authorities are the sole suppliers of land and the government retains a high degree of control over land use and design. It leases land to private developers and regards this as a major source of revenues. Only plots that do not exceed 73 square meters and form part of a housing cooperative are free of charge. Since most of these plots are however exceeding a minimum of 90 square meters they are also charged. Finally, plots that exceed 175 square meters are available at market prices through public tender. They may involve leaseholds of 50 to 99 years. This rather odd and arbitrary leasing system explains to a great extent why modern privately-financed capital- and energy-intensive skyscrapers, also seen as an expression of 'the Dubai fever' [19] are mushrooming along with poorly maintained informal settlements in the inner city. The result is a dual economy that results in growing social and economic inequality because one part is taking full advantage of economic globalization while the other part is completely excluded [18].

Overall, the Ethiopian People Revolutionary Democratic Force (EPRDF) that came to power in Ethiopia in 1991 and continues to rule the country ever since has achieved little in improving the conditions of the poor in Addis Ababa, despite good intentions. Some would argue that this is not the fault of this government but the result of either neglected or misguided urban planning policies since Italian occupation in World War II. Apart from the great plan for urban development designed by the Italian occupiers, four master plans were designed by European leaders in urban planning between the end of World War II and 1974 when the Communists came to power. The communist regime (Derg) then designed the most flawed urban development policy (again guided by Europeans). They nationalized all urban land and rental dwellings in Ethiopia through a proclamation in 1975. Yet, in the course of its implementation, they did not make any distinction between poor and rich property owners. As a result, thousands of poor owner-occupiers who leased portions of their already cramped dwellings were expropriated of the very rooms for which they were receiving low nominal rent payments. All rental accommodation in poor urban areas was placed under the administration of newly-created institutions, namely, the neighbourhood associations that are known as urban dwellers' associations or kebeles. In addition to the creation of countless new institutions and regulations, the Derg facilitated the preparation of two more master plans for Addis Ababa. Largely guided by ideological reasons, the revolutionary government strongly encouraged the production of housing through cooperatives. Despite generous preferential treatment throughout junta rule, the net outcome of the junta's housing policy was a near complete disruption of the urban housing market [18].

The lesson of all this is that the city probably suffered from too much rather than too little urban planning. The latest attempt to revive old Master Plan ideas is the Grand Housing Programme (GHP) also popularly known as condominium housing (related to the condominium regulation that was passed in 2004). It was meant to be a response to the huge housing shortage in Addis Ababa and as an alternative to makeshift kebele housing. The aim of the GHP is to build 50'000 housing units a year using Low-Cost Housing (LCH) technology designed by the German Gesellschaft for Technical Cooperation GTZ. The construction of these houses also involves training of locals to carry on the programme themselves later on. However, the construction of these houses consists mostly of imported materials, technologies and know-how and only cheap labor-intensive products and services are provided by local people (most trained in vocational training centres). It is unlikely that locals will be able to continue to run their businesses once the funding for GHP will run out. Their business is unlikely to be able to compete with Chinese firms that may be more capital-intensive but are still cheaper due to specialization and the ability to take advantage of economies of scale. Once again the GHP design is based on a top-down philosophy combined with some Newspeak on the need for participatory approaches. That is why few of the existing condominiums are actually occupied by the poor who are unable to afford and maintain it. Instead those who have obtained one tend to rent it out to generate revenues for themselves [19]. Apart from that it encourages the city once again to leave responsibility for urban renewal and design to foreign actors and neglect their responsibility for the provision public goods.

Overall, the government-driven effort to upgrade housing and urban living standards looks not very convincing. It is already quite odd to assign responsibility for the upgrading of urban infrastructure to the Environmental Development Office (EDO). Its mission and activities are based mostly on catch words such as 'community-led development', 'participatory approach', 'developing a sense of ownership', etc. maybe in the hope of attracting money from foreign donors. The scope of its activities comprises everything from constructing roads, water drainage, toilets, communal water posts and small bridges to creating employment and building schools, public libraries, health stations and market places [17]. One wonders however if the office should rather focus on the few things where it really has competence and otherwise engage in joint financing public-private partnerships not just with specialized firms and private contractors but also local entrepreneurs. In this context, local content requirements could have a great potential to induce foreign contractors to collaborate with local companies and

Addis Ababa: Churchill road in mid 20th Century.



help them improve their goods and services up to a standard required to become a local supplier for the large firm. Instead the government plans everything without really consulting the local private sector. It prefers to leave the implementation to neighborhood and kebele development committees reflecting the city administration's effort to decentralize governance. In this scheme all the funds allocated by the government have to be matched by contributions from the dwellers. But since the allocation of the matching fund was decided top-down it is not surprising that the dwellers felt a sort of imposition and no sense of real ownership. The lack of upkeep and maintenance of upgraded roads and other infrastructure is a result of this [17].

Addis Ababa: Churchill road in 2008 .

Community-based infrastructure upgrading has nevertheless achieved a lot over the past ten years to improve drainage and other infrastructure necessities in the city but mainly thanks to private initiatives within the slums. One interesting development in this context is the increasing participation of the private sector in collection and disposal of solid waste. It is based on door-to-door collection of solid waste for households that are willing to pay a nominal charge (about one US dollar per month). They pick up the waste and bring it to the nearest municipal garbage dump so that it can be picked up by municipal trucks [18]. This type of business creates employment for the locals and makes a substantial contribution to the provision of a public service. Since 90% (by volume) of the solid waste is organic matter the business could even further be developed by the composting of such waste and sell it as organic fertilizer to the numerous urban dwellers that maintain a garden in the backyard to grow food. Moreover it could address the problem of overflowing landfills not just by introducing composting and better forms of recycling but also the generation of biogas. This would however again require the experience and ingenuity of local entrepreneurs combined with technological know-how from foreign companies. The government could then be the broker to facilitate such collaboration.

The problem of liquid waste is even more serious in the poor areas of the city because they lack a functioning sewage system and 25% of the dwellers have no private or shared toilets. The contents of pit latrines or septic tanks are supposed to be collected and dumped by municipal suction trucks but their numbers and services are inadequate leading to overflowing of pit latrines in areas with limited access to roads. Again private operators have jumped in to address the problem but since this business is capital-intensive they charge more than those who dispose solid waste [18]. It would be odd to describe these local operators as people 'meaningfully involved' [1, p48]. They are simply responding to a need and hope to be able to carve out a living from it.

Such private sector activities remain in an embryonic stage unless the government acknowledges the public value of these services and contributes to their upscaling and improvement in the form of public-private partnerships that attract more investment. Moreover, it could enhance affordability of these services by using and extending conditional cash transfer and voucher schemes for poor households that allow them to pick the best service provider for the basic public services - just as it allows to better care for their kids and select an appropriate school. Since contaminated water is the main source of childhood mortality improving water sanitation services and having more budget resources for child nutrition would be mutually reinforcing [21].

ETHiopia Urban Laboratory

In view of all the flawed previous attempts to manage and improve urban livelihood in Ethiopia there is an urgent need to learn from best practices elsewhere and encourage the adoption of more innovative and effective forms of collaboration between universities, the private sector, civil society and governments. Considering the alarming fact that Ethiopia's population is projected to grow from 82 million in 2005 to 170 million in 2050 and that most of this growth will happen in cities (UNFPA Report 2007) planners and policy makers can simply not afford to ignore past mistakes and following business as usual.

There are currently too many duplications in the aid business, too much waste of valuable scarce resources, too much competition where there should be cooperation and too much cooperation where there should be competition [22, 9]. Optimal forms of collaboration as well as possibilities for urban economic growth from the bottom up must be explored. At the same time, new ways must be found to benefit from global economic and technological change by adjusting and combining it with the rich cultural heritage of Ethiopian civilization and its great natural and human resources [19].

In this context, an innovative and fruitful form of interdisciplinary and cross-cultural collaboration has emerged from a joint academic initiative between the Department of Architecture and Urban Design of ETH Zurich and the Ethiopian Institute of Architecture, Building Construction and City Development (EiABC). The main objective of the jointly established summer school for architecture and sustainable development (also called ETHiopia Urban Laboratory) is to bring Swiss and Ethiopian students together in a joint effort to create joint sustainable solutions to problems related to housing, water treatment and business in Addis Ababa. The long-term success of this undertaking largely depends on the appropriate training and support of graduate students who want to add value to their local experience and knowledge by combining it with the newly gained practical knowledge in the joint course on modern business methods and user-friendly new technologies. If it encourages them to design new products and services that better meet the needs of the local low-cost housing market and get investment to convert it into a viable business model then a great step towards a sustainable bottom-up solution in low-cost housing would be accomplished. Their business initiative will be crucial to ensure that the prototypes that are jointly designed in Design Research Laboratories on campus are not just remaining on the shelf. If they manage to eventually reach a level of quality and price that allows for the entry into the booming construction business of Addis Ababa, then new home-grown entrepreneurs will emerge that employ people and attract investment from outside. All this would require an entrepreneurial infrastructure that is still not existing for graduate students in Ethiopia. Venture Funds, Technology Transfer Offices and Technoparks for spin-off firms are rather unknown at public universities in Addis. But the growing Chinese influence and their efforts to build up special economic zones SEZs to facilitate competitiveness, foster export-oriented production, and promote wider economic reforms, might hopefully also inspire the government's attitude towards a business-friendly environment at universities [23]. Experience shows that universities that engage with the local private sector are not just becoming engines of economic and social change but also improve the quality of research and teaching [24].

How to make a business out of innovative prototypes in housing?

One purpose of the ETHiopia Urban Laboratory was to encourage Swiss and Ethiopian students to think about viable business models related to the so-called Sustainable Urban Dwelling Unit (SUDU). SUDU is a low-cost housing prototype that tries uses local substitutes for expensive imported building materials in Ethiopia. It is to prove that there are competitive and sustainable alternatives that rely on cheap local resources and forgotten traditions in Ethiopia. In order to minimize the use of concrete for example, the SUDU uses a deep foundation that is based on a very thin slab construction in a donut shape. The student group was asked to focus on two innovative components of the SUDU (which was being built on campus at that time) and investigate their potential to be successfully commercialized in Addis. These two components low-cost block production using loam as the basic building material, and tile production and vault construction, a technology that is able to reduce reinforcement material.

Based on the theoretical and practical insights gained during the course of the summer school, the two groups consisting of Ethiopian and Swiss students were asked to explore the market for loam bricks and vault technology respectively in the booming construction market of Addis Ababa. The task was very challenging considering that there were only two weeks to write a business plan that also includes field research and the use statistical data.

Both groups followed the usual structure of a business plan. They looked at the construction business environment in Ethiopia and the major players involved. In the housing market there are architectural offices that deal with real estate agencies and their private and public sector customers. Once a contract is signed the architectural offices conduct a market bid to determine the general constructor. The general constructor may again subcontract some parts of the construction to specialized companies doing masonry, electrical installations, and floor and roof finishing, for example. In order to successfully commercialize the innovative components the two groups realized that they need to win general constructors as clients for their products. Both groups also learned that business expenses need to be as low as possible at the beginning when big customers still need to be convinced that products can be delivered on time and at a certain price and quality. At this stage it is important to keep almost all costs as variable costs (vehicles, tools and machines are usually fixed costs but by renting this equipment they can be kept as variable costs at the beginning). Once a first big contract has been won and successfully accomplished, fix costs can slowly increase together with the variable costs required to upscale production (more labor). Both groups realized how difficult it is to obtain reliable statistical data on the housing market. By means of interviews with the major players involved they could however get a rough idea of how the rules of the game work in the market. Knowing more or less the prices for similar products offered by their competitors they made their cost calculations accordingly. In this context, labor-intensive brick production may sometimes bring a cost-advantage but only if the orders are of a relatively small in scale so that it can be handled within a certain period of time. Once the orders become larger and quick delivery is expected there is increasing pressure to acquire machines that are able to respond to these demands and increase production accordingly. The demand for improved labor skills will increase correspondingly and with it the cost for labor. The group that was concerned with the commercialization of the innovative vault technique realized that this product could also be marketed to rich and individualist customers who search for a new aesthetic housing design that is connected to the latest trend in architecture. They would then offer a premium or first class quality product that is also linked to the award-winning architects that are involved in the SUDU project who would ensure the quality by paying a visit to the customer before the house is inaugurated. The high profits gained in the upscale market could then be used to cross-subsidize the market for cheap vaults in the low-cost housing market. Price differentiation would thus allow an increase in scale as well as scope in the production of innovative vaults.

Despite all the great ideas developed on how to create a successful business out of these innovative components there was also a high amount of frustration in the two groups because it was difficult to really get hold of reliable information and the business network relations of the established players can hardly be challenged unless there is support from government.

Another opportunity to create a market - not just for the innovative components but for the entire SUDU prototype- could be the plan of the Ethiopian government to build new self-sustaining cities in other parts of Ethiopia in collaboration with Urban Designers from ETH Zurich that have great knowledge about the local circumstances as well as the appropriate new technologies. In this context the Ethiopian government could draw on the Chinese experience in efforts to increase the economic importance of small- and medium sized towns on the country side [25]. If this plan is able to win public and private investors it would create a high demand for well-educated architects, planners and construction managers that are able to design models compatible within the Ethiopian context. Low-cost housing typologies will be required for these new towns with new public space and new public facilities, including urban landscape and recycling. If the government would decide to build the new houses based SUDU technology and choose to collaborate with EiABC, then this would substantially increase business as well as learning opportunities for the university and its students. It would also increase interest of established players in the construction market (including GTZ) to intensify collaboration with the university. The demand for graduate students and professors at EiABC would correspondingly increase and their expertise would be crucial in the resulting public-private partnerships. The quality of teaching and research at EiABC would also increase correspondingly because the a high demand for scientific and, most of all, applied research concerning indigenous construction material, building technology, housing and infrastructure will force the school to regularly update and renew teaching material and make research more focused on solving concrete and practical problems in Ethiopia; based on the experience gained in the implementation of the projects new schemes of good governance and best practice could lead to more cost-effective regulations in planning, construction and building. The ultimate goal is to enhance the local capacity to operate and maintain the stocks of energy, water, materials, capital and space of these new cities.

Concluding Remarks

Economic Globalization is accelerating the process of urbanization especially in the developing world. Judging from the past experience in the developed world, urbanization caused a lot of problems in the short term but turned out to be a natural and positive development on the long run that created new employment opportunities, led to deindustrialization and a new service-oriented economy, produced agglomeration effects that led to more innovations and ideas and helped to alleviate pressure on the natural environment by enabling a transition of labor from agriculture to other more productive economic sectors [3, 4, 10, 23]. A similar development is currently taking place in Asia and will eventually take place in Africa; unless large donors and international development agencies, including the United Nations Human Settlement Programme (UN-Habitat), that focus on the prevention of the negative short-term effects will unintentionally endanger the natural and positive long-term benefits of urbanization. Even though UN-Habitat publishes very valuable country-based situational analyses of urban development (e.g. [18]), its flagship reports (e.g. [2]) reveal a general despise of private sector activities, no matter if these are small entrepreneurs in informal settlements that provide basic services that the public sector fails to deliver, or large international construction companies that are mostly busy building fashionable but energy-intensive skyscrapers. Generally, these reports stick to the old-fashioned assumption from the 1970s that all things related to urban planning, urban design, urban infrastructure and the proper management of urban flows need to be in the exclusive domain of the public sector, no matter if it is able to deliver or not. This assumption would have astonished urban planners in the 19th century that heavily relied on public-private partnerships when addressing the growing challenges of urbanization that were linked to the first wave of globalization due to improvements in public transportation and communication networks. After two World Wars and a long Cold War most of these public-private partnerships (PPPs) were replaced by large government bureaucracies that wanted to have control over the use of technology for reasons of national security. Once the Cold War was over, public-private partnerships became again an option to address problems in the provision of public goods more effectively. Yet, the vested interests against this institutional change are large and powerful because many established organizations and bureaucracies still benefit from the old system. The organized opposition against PPPs schemes was quite effective by linking them in a negative way to terms such as privatization and deregulation that would benefit large companies at the expense of the poor. Yet, fact is that in most cases governments did not pass on ownership of public infrastructure and other public assets to the private sector. Moreover, regulatory frameworks were not abolished but designed in a way that was more cost-effective and therefore more acceptable to the taxpayer. There are certainly many examples where PPPs did not have the expected positive effects but that is part of the learning process. Many large emerging economies such as Brazil and China have embarked on this learning process and experimented with new models of PPPs. Their experiences largely contradict the doomsday scenarios of the opponents. It has resulted in most cases in improved efficiency and better quality of public goods and services and in the case of Brazil it also helped to reduce social inequality substantially and improve environmental management especially in the crowded cities. A lot can be learned from experiences not just in the large emerging economies but also the smaller developing (e.g. Columbia, Chile) and developed countries (New Zealand, Sweden). UN Habitat should not ignore these incubators of PPPs and their positive development on the process of urbanization.

Ethiopia and its capital Addis Ababa have been a great victim of socialist and modernist experiments in urban planning since the end of World War II mostly guided by Europeans with little understanding of the different needs of the urban population. Considering that many regulatory constraints still prevent entrepreneurship and sustainable innovation in urban design and low-cost housing, a more bottom up-oriented approach to urbanization would be highly desirable. Once things work on a smaller scale the government might then think of scaling it up and give more support to the researchers and entrepreneurs that made it happen.

This approach of starting things on a small-scale and then test the market for the potential of larger investments to upscale production has been chosen by the joint summer school for architecture and sustainable development created by the Ethiopian Institute for Architecture, Building and Construction (EiABC) and the ETH Zurich Department of Architecture. This so-called ETHiopia Urban Laboratory is a first attempt to unite knowledge and experience in architecture, building and urban design to jointly create viable solutions to urban problems, promote local business activities and thus enable sustainable technological and economic change in the city of Addis Ababa. Even though it is too early to assess the impact of this partnership there will definitely be a lot of lessons to be learned from this experience that can then be taken into account by other joint initiatives elsewhere. Development is a process of trial and error and there is no perfect social planner that can avoid this, as the history of urban development in Addis Adaba illustrates well.

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People in slums do not always work in the informal sector nor is the informal sector exclusively for slum dwellers, but generally, slum dwellers are more likely to be employed in the informal sector than non-slum dwellers.

http://www.sustainability.ethz.ch/lehre/ETHiopia_urban_laboratory/index

The SUDU prototype consists of two stories and a sustainable, autonomous operating water cleaning facility. The first story of the SUDU is based on ramped earth technology. The second story consists of tiles and blocks. The blocks are used for the 2nd floor construction and the tiles for the vault ceilings.