APPROPRIATE TECHNOLOGY FOR SUSTAINABLE HUMAN SETTLEMENT DEVELOPMENT.
THE CASE OF THE CONSTRUCTION OF THE NUST CAMPUS IN ZIMBABWE.

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Abstract
The vision of the National University of Science and Technology, NUST, in Bulawayo, Zimbabwe is to be a first world university in a third world country. Without doubt, the university has beautiful ultra modern architectural buildings. The Zimbabwe Architectural Quarterly, describes the campus as giving out a loud expensive noise and that it is an architectural demonstration of conspicuous consumption. The construction of the University started in the early 1990’s when the economy was stronger than it is now. The construction of the works was also supported through donor funding in addition to contributions from the tax payers. It is supposed to be complete by now. Currently the inflation level of the economy is the highest in the world. The construction of the university is far from complete because of among other issues, inappropriate technology used in the context of the prevailing economic environment. Thus the development is not sustainable as it does not address the needs of the communities on the ground. This paper describes the development of the university from appointment of consultants, the construction done to date measured against economic performance of the country in general. The paper looks at the philosophy of the designers in conjunction with world best practices and what Michael Porter would call sustainable competitive advantage.

INTRODUCTION
The Zimbabwean construction industry and hence the architectural related business and profession has been on the decline since the 1990s era and has worsened especially after the land reform exercise of the year 2000. Ten years prior to that year, the construction industry was relatively booming. Eight years after the exercise, the construction industry is virtually non existent. The campus at the National University Of Science and Technology is a major and perfect case study which reflects on the performance of the nation during the period in question.

Brian Edwards [6] defines sustainability as a process and sustainable development as a product. The Brundtland Commission of 1987 defines sustainable development as ‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs.’ Whereas Appropriate Technology (AT) according to John Tharakan [7] has the following attributes: local material use, labor intensiveness, small scale in nature, low capital expenditure, affordability, understandability, controllability, maintainability, adaptability, participation of local communities in innovation and implementation. AT is difficult to define. It can be summarized that it has both attributes of a process and a product. It infers that it is a product derived through processes. It can further be inferred that it is similar to sustainability and sustainable development although the latter takes consideration of
resources for future generations. According to the Webster’s 3rd International Unabridged Dictionary, architecture is both a science and art of designing buildings. It infers that it is a product from a process. So whereas architecture and AT are both products from processes, architecture relates specifically to buildings and AT to anything. In its definition for sustainable construction, Holcim Foundation [8], a Switzerland based organization uses the following five criteria:-
Balanced environmental performance, social performance, economic performance, creation of a good building and significant advancements that can be applied on a broad scale encompassing the following: ecology quality and energy conservation; economic performance and compatibility; ethical standards and social equity; contextual and aesthetic impact; and quantum change and transferability

**The Beginnings Of National University of Science and Technology.**

According to the NUST website [9], The National University Of Science And Technology, NUST, was established by an Act of Parliament in 1992 after there was a recommendation to do so in a report [10] of February 1989. The idea for a second university was mooted in 1982 after a Commission of Inquiry into the high failure rate at the first University of Zimbabwe during the 1981 and 1982 academic years. It was also observed that for economic growth of the country it was necessary for the University to be strongly science and technology biased. It was to be located in Bulawayo and was to admit its first students in 1993. The enrollment would rise from approximately 1000 students in 1993 to about 6 500 in the 2000. The faculties and schools of the University should include industrial technology, science, architecture and quantity surveying, environmental science, communications technology, commerce, arts and education. The orientation of the programmes should be towards applied studies and production etcetera. The University would have a strong research orientation, with an emphasis on the applications of science to technological development; a research and development centre would focus the activities of the University in research and consultancy.

The Commission indicated the action needed to establish the Second University including the legal steps, the appointment of the first officers, and the appointment of a Council to initiate planning. Early attention would be needed to staff development, given the serious shortages of academic staff then. The Commission estimated then that the total cost of the Second University as being in the region of $300 million to $350 million on the capital side, and in annual recurrent cost terms rising from about $11 million in 1993 to $71 million in the year 2000, all in 1988 prices.

It was argued that if the construction was carefully phased, the total financial burden was believed to be sustainable. It was emphasized that a vigorous fund raising campaign inside and outside Zimbabwe would be required. The effect of the university would be to improve the supply of professionals for the growth of the economy. It was also envisaged that after the second half of the 1990s, the opportunities for students to enroll in degree programmes would be much better than then.

According to a local publication [11], Mwamuka and Mercuri and Associates were the architects commissioned to develop the University after they won the master plan development. They were however in collaboration with American architects Davis, Brody and Associates and Planners as well as Ove Arup a British based international firm of engineers.

The architects informed the public that the design conceptionalises a ‘first world university in a third world country because of its ultra-modern architecture’.
There were to be three phases and the first two phases were estimated to consume $17 million in foreign currency component. According to the report [10, p.5], on April 18, 1980 one US dollar was equivalent to Z$0.64 and in January 1989 it was equivalent to Z$1.96 which shows a triple in economic fall.

**Zimbabwean Economic And Performance**

The advent of the 1990s saw the beginning of efforts initiated by the World Bank and the International Monetary Fund towards global integration of individual national economies through Structural Adjustment Programme. Its intentions were to among other issues; diminish the role of the state in economic affairs and increase the international movement of capital[1,p.20], this brought about improved foreign currency inflows into Zimbabwe through lines of credits and subsequently led to increase of exports. Earlier on, there were other efforts to improve the post independent Zimbabwean economy notably in 1981 through the Zimbabwe Conference on Reconstruction and Development (ZIMCORD) in tandem with the Transitional National Development Plan. In addition between 1982-1990 two Five Year Development Plans were implemented. The economy was doing well according to an international magazine [13,p61].

In 1997 a political decision to compensate liberation war veterans led to the beginning of the sliding down of the Zimbabwean economy. In year 2000 another political decision to redress the land imbalance which was still in status quo of pre-independent Zimbabwe state was speedily undertaken, through a belated land reform exercise. It is ironic that although the country experienced capital flight due to sanctions by donors such as World Bank (Structural Adjustments Loans) and International Monetary Fund (Balance of Payments Support), the same institutions were now pursuing lending policies linked to sustainability [1,p41] which route the country in hindsight also was now following but not to the satisfaction of everyone.

As of July 2008, the campus development has not been completed. Only the Administration Block and Commerce Buildings have been fully completed. The other operational buildings namely Chemical-, Applied Chemistry-, Students’ Hostels and Ceremonial Hall have been beneficially handed over but most of them already need maintenance.

The National University of Science and Technology is a glaring example of a project failing to complete although a budget has been set aside through Public Sector Investment Program, which is a government fund used to support public infrastructure development. A local publication [11], used the symbolism of a loud statement to describe the architecture and also alluded to the fact that the construction was very expensive and the design never evaluated. It is interesting to note that the late Sir Ove Arup, the structural design engineer of international repute and whose firm of engineers which now trades as ARUP designed the Nust campus buildings shared his opinion on architecture with architects in a journal [14,p526], that architects act and should act as the counsel for humanity and as such should speak out against the double forces of high finance and technology, otherwise, no one else will do so in an informed way. This therefore implies that ARUP and engineers in general would absolve themselves from the burden of protecting the public from high finances and technologies used on buildings. It then means that architects are the antennae for morality on designs of buildings and activities on construction sites. In Architecture, matters related to morality and professionalism are regulated by an Act of Parliament [15].

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Building
Level of
Table 2: Levels of completion of NUST Phase 1 (2008).

<table>
<thead>
<tr>
<th>Completion (%)</th>
<th>Administration Block</th>
<th>Library</th>
<th>Workshop and Laboratories</th>
<th>Lecture Rooms</th>
<th>Lecture Theatres</th>
<th>Halls of Residence</th>
<th>Staff Flats and House</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>30--40</td>
<td>40--45</td>
<td>50--60</td>
<td>70+</td>
<td>30--35</td>
<td>9--15</td>
<td></td>
</tr>
</tbody>
</table>

Prioritization Of Material Resources

Currently Zimbabwe, typical of many third world countries is facing unprecedented economic challenges in all fronts and in shelter delivery in particular. Public buildings, to be specific, which are state funded, have shown the greatest stress from the economic challenges. This is highlighted by snail paced, if at all, of progress of construction of such buildings. Granted, the economic environment is not conducive for many business initiatives to flourish, and some people blame the economic policies and politics of the ruling elite for such failure in delivering results.

However, some medical research on child mortality for instance according to news reports report in 2008 [16], has shown that relatively rich third world countries such as Angola with revenues from oil and petroleum and India which is a technologically rapidly developing country have higher child mortality rates than Malawi and Bangladesh. This shows that even though a third world nation might have the means to improve its people, its priorities might not be focused to other areas which are important. Locally, the question can be raised whether the priorities are right in terms of the architectural option being pursued currently in the construction industry. Knowledge is a resource which has to be used effectively.

The material technology resource has been found quite wanting as materials are no longer affordable as they should be imported. Materials such as wallpaper which is peeling off; aluminum sun-shading blinds, some of which have broken down; massive steel sun shading grills which allows light through; aluminum curtain walls in hostels, and polished granite on almost every building on site so far cause concern.

Ethical Standards And Social Equity

Brian Edwards et al.[12, p12], opined that professional institutes have a duty to serve society in the provision of decent, acceptable, maintainable, and low energy designed housing. He supports that local accountability be the first principle of sustainability and professional practices should put the community first instead of profit, fees nor speed of construction. He advocates that local accountability be the basis for decisions for designs, construction methods, tenure mix, management and crime prevention, p14.

The construction of the name display wall at the main entrance of the campus points out the professional challenges involved. The challenge with this wall is that it had three different architects commissioned to design it. This meant duplication of payments for a service and thus wasting financial resources. It also does not comply at face value with planning conditions of title deed of property [17] i.e. that it should be built either on the
boundary line or within the boundary as the wall is 35 meters outside of the campus boundary limits. However such an anomaly in development can be mitigated through the granting of a special consent by the local planning authority [17, Section 26 (3)(a)(2)], This therefore underlines the essence of professionalism, ethical conduct and competence in the implementation of AT.

According to Holcim Foundation a project should adhere to the highest ethical standards and support social equity at all stages from planning and building processes to long term impact on the communal fabric.

Since the construction began in 1998 the campus has not yet been completed. In fact if the right term be used, the buildings have not been handed over as having been completed. They have been beneficially handed over. They should actually be in the maintenance period. This is attributed to unavailability or insufficient building capital. As of July 20, 2008, monetary inflation in the country was at more than two million percent, the highest in the world. In an economically challenged country like Zimbabwe, sustainable construction means building to supply urgent and basic needs within the people’s means. Wastefulness and excessive consumption is financial irresponsible. Sufficient materials and resources should be left for others, including future generations. Sections of the Library Building whose construction is in limbo, shows excessive use of concrete and steel, elements which are very expensive. Such construction technology is associated with dam wall. Krause and Plewe [18, p.21,p.95,p.211] describe concrete framed buildings, column and beam and column & slab alternative construction methods which could be employed on a similar structure. The walls are then constructed by a brick in- fill. This then gives a cost effective solution.

The ablutions serving the Ceremonial Hall are a single story structure yet the walls have a 345cm thick outside wall. A normal outside wall for a habitable room has a thickness of 230cm. An ablution is not a habitable room [19] and is for short term use. This is excessive considering that the purpose of walls is for structural stability or for thermal or sound or privacy control etc. In addition to that it has a concrete roof.

The students’ hostels have façade portions with aluminum curtain walls. Aluminum is very expensive and has good aesthetic qualities but does not offer better thermal properties than brick. The hostels are therefore either extremely cold in winter or hot in summer. Thermal comfort is not achievable in the rooms. Inconsideration to materials’ physical properties lead to environmental problems just like Mies van der Rohe [20,p.92] had internal climate control problems with the Edith Farnsworth house, Illinois, 1949-1951.

**Energy Conservation**

One of the major critiques to the built environment concerns its inability to conserve energy. According to a source [21], energy is consumed mainly through processes in obtaining raw materials, manufacturing processes, transportation and distribution, construction processes, operations and maintenance, demolition, disposal or recycling. In an environmental conscious energy conservation guide [22], architects are recommended to consider using design techniques encompassing thermal insulation and heat storage using weighty porous material, appropriate building positioning in relation to the sun, natural lighting and ventilation, passive heating using the green-house effect whereby infra red light and hence warmth is converted from visible light, active water heating using the sun.

Africa has plenty of sunshine. Solar energy could be used to the benefit of all stakeholders. According to a news report[12], scientists estimate that every year a desert area of 1km square receives energy equivalent to 1,5 million barrels of oil. In reality the biggest
setback to solar energy use is the initial investment cost to buy polysilicon which is the main component of the energy generation mechanism. However since the competition to find the best solar technology is stiff, costs for silicon wafers are predicted to fall from US$300/kg to $100/kg in three years. Forbes magazine is quoted as saying that in the next 25 years solar will be the fastest—growing alternative source of electric energy. Other than hydro-power and fuel cell technology, it is the only zero-greenhouse-gas-emission technology that can rival the coal-fired power. Electricity generated could be routed into the local grid. An investment in solar electrical generation would be a good long term investment.

The concepts for natural light and ventilation have been used generously to most buildings and open spaces. According to Koenigsberger et al[5], the materials selected for Halls of Residences, Laboratories to name just a few do not save energy in buildings, hence they are so cold for habitation. Student residents have aluminum curtain walls. Buildings for Chemical engineering, library, the canteen have internal concrete walls although some have a coat of brick cladding.

<table>
<thead>
<tr>
<th>Material</th>
<th>Conductivity(w/mdegC)</th>
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<tbody>
<tr>
<td>Aluminum</td>
<td>220</td>
</tr>
<tr>
<td>Brick</td>
<td>0.806</td>
</tr>
<tr>
<td>Concrete</td>
<td>1.44</td>
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</table>

Table 3 Conductivity assessment of selected materials. Source [5].

One of humanity’s immediate and major challenge is caused mainly by modern greenhouse global warming according to BBC News [2]. In anticipation of the drastic effect of climate change, the brick is the most appropriate material to ensure that heat exchange between out- and in doors is minimized.

**Quantum Change And Transferability**

The architecture at NUST can be described as post modern. Post modernist architecture can fit anywhere in the world but it does not mean that it is always environmentally, socially or culturally acceptable. The architects’ architectural handwriting is post modernist. One attribute of post modern architecture building materials is the use of a lot of metals (steel), concrete and glass, which are generally more expensive compared to traditional materials like bricks and stones. The architects were the country’s leaders in post modern architecture as at the turn of the millennium. Michael Porter [3], would have pointed out that it was their formula or strategy for how their business was going to compete and win within the architectural fraternity. It was their competitive strategic advantage. Who would blame them? They both got educated from extreme capitalistic societies where success is measured by wealth. Funabashi Haruo [23] quoted former American Federal Reserve Chairman Alan Greenspan as saying the American CEOs have “infectious greed”. This appears like a bad disease yet but in that society it has deep social roots in that values are expressly capitalistic. Success is defined as becoming rich i.e. as having money. The architects business approach was to them appropriate. They do not deserve criticism for having got their reward.

Their other projects Southampton Life Center, Kopje Plaza Building, Construction House, Joina Centre in Harare and Bulawayo Centre in Bulawayo are testimony to this. Post
modern architecture is transferable and works in very strong economies as evidenced by the countries which have adopted them. Center Pompidou in France and Lloyds of London and Shangai Bank in Hong Kong.

In some aspects the design demonstrates innovation at the forefront of construction and quantum leap to conventional methods as evidenced by the curved ceremonial hall roof, the branch like roof supports to the administration buildings. However, were the roofs to need some repairs, the university would not be able to hire experts from South Africa and to buy the material and components used as they might be unavailable. Although the technology is innovative in the integration of materials, people would find it hard to copy it again and again. The innovative concepts are therefore currently not affordable, simple and broadly applicable.

The delta theater situated in the commerce building is naturally cool all year round due to innovative use of a void concrete basement which is naturally ventilated. The cooling system involves the cooling of air by the concrete. The air then naturally filters into the theater through vents below seats using the stack effect. In this way the comfort level in summer is good.

Balanced Environmental Performance
As a result of the construction of the NUST campus environmental change definitely took place. According to a survey report [4], considerations for evaluating the campus’ environmental change were categorized according to five major pressures namely: environmental, biotic, economic, cultural and aesthetic. The conclusion of the assessment found that initial and short term concerns to the construction were due to raw material extraction, construction waste materials, roads clearing; biotic threats resulted in wildlife movement and aesthetic performance was compromised by the following: construction noise disturbances, which were short term, visual impact due to non completed structures which is still persistent.

Conclusion
It is clear that the vision of a science and technology based university was taken as an appropriate tool for economic development. It is, however, an irony that the empowered technologists cannot save the country from economic perils using the knowledge gained from the same universities which gave them the knowledge in the first place.

It is clear from observation of built environment that the architecture for the provision of public buildings, in particular, is not sustainable in respect to the state of the economy. In other words it is not appropriate. At a closer analysis of the architecture and related disciplines applied to buildings, it is evident that sustainability should anchor the whole complex process. It is rare to find a situation like this in the African context. Value systems should be considered broadly in favor of the client. Sometimes national or institutional infrastructure delivery goals and objectives are not met, not because there is an economic constraint per se but probably because the principles of sustainability have not been followed. Impartial and professional construction project managers could best safeguard the interests of clients against the other consultants involved in the construction project. The university can also learn a leaf from the University of Pretoria whose vision “to be for South Africa what Oxford is for England” is similar to that of NUST and which it follows using the sustainable path [24].

Reference


[9] www.nust.ac.zw


[17] Regional, Town And Country Planning Act, Chapter 29:12, Section 26 b(ii).


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