APPROPRIATE ARCHITECTURE FOR SUSTAINABLE DEVELOPMENT: THE CREATION OF ECOLOGICAL FOOTPRINT AND HUMAN DEVELOPMENT INDEX CAPABILITY

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Abstract
Carbon emission scenarios are used as key inputs in the sustainability and built environment strategies and policies. Decisions and direction in these are based on carbon emission models which show the optimum mix of interventions required to achieve carbon emission reductions or stabilization.

Reducing carbon emissions however does not lead sustainability. Sustainability is more complex and requires the achievement of minimum quality of life standards as well as a balance between environmental and human systems. The danger with a focus on carbon emissions is that limited resources and timeframes may be exhausted trying to achieve reductions and valuable opportunities to build long term sustainable solutions will be being lost.

This paper argues that increasingly scarce resources, the timeframes for addressing climate change and the lifespan of infrastructure and buildings (50+ years) mean that we cannot address carbon emission reductions first, and then address sustainability later; we need to address both at once. We need to develop appropriate architecture for sustainable development and not just carbon emission reduction.

The paper draws on a definition of sustainability developed by the World Wildlife Fund to show how a sustainable development approach can address carbon emissions while building more sustainable systems. It proposes a built environment sustainability framework and shows how this can be used to assess built environments and identify appropriate mixes of interventions to improve the sustainability performance of built environments. It also provides an indication of the type of appropriate architecture for sustainable development envisaged by this framework.

INTRODUCTION

Carbon emission projections are widely used in both developed and developing countries to inform development strategies and policy. Projections are used to identify the most appropriate interventions required to achieve carbon emission stabilisation or downward trajectories to in order to meet global or national targets. Selected interventions then form the basis of key national development frameworks (Barker 2007) (Winkler 2007).

There are, however, problems with using carbon emissions as the key input into development strategies. Increasing carbon dioxide levels in the atmosphere are a symptom of imbalance in planetary systems and, as with the human body, a sole focus on addressing symptoms, may not lead to a cure.

A focus on addressing carbon emission symptoms often results in the selection of standardised technological solutions such as renewable energy or solar water heaters which can be easily modeled, and uniformly applied. These solutions however may not take into account pressing local social and economic circumstances. This results in the selected solutions not being implemented as these are not seen as a local priority and therefore are seen as inappropriate. Alternatively, if these are implemented, the technological solutions (often imported) consume valuable resources that are then not available to address local social and economic issues.

This approach is reflected in green building rating tools which emphasize technological solutions such as improved artificial lighting, efficient air-conditioning systems and renewable energy. This however assumes that this technology is available and affordable. It also assumes that there is the technical capacity and ongoing funding to install and maintain these types of installations. This is obviously not the case in many developed countries, as is demonstrated in the case study, later in the paper.

This paper argues that it is important to respond directly to local situations and build local systems with a view to long term sustainability. Instead of addressing symptoms of environmental imbalance with partial solutions, we must develop human and environmental systems which work together to achieve sustainability. For this, a definition of sustainability that both captures of the key characteristics of human and environmental systems and can be easily applied to the built environment, is required [1].

Defining Sustainability

A suitable definition of sustainability has been developed by the World Wildlife Fund (WWF). This describes sustainability as being the achievement of above 0.8 on the Human Development Index (HDI) and the achievement of an Ecological Footprint (EF) below 1.8 global hectares per person [2].

The Human Development Index was developed by the United Nations as an alternative to economic progress indicators and aimed to provide a broader measure that defined human development as a process of enlarging people's choices and enhancing human capabilities [3], The measure is based on:

- A long healthy life, measured by life expectancy at birth
- Knowledge, measured by the adult literacy rate and combined primary, secondary, and tertiary gross enrolment ratio
- A decent standard of living, as measure by the GDP per capital in purchasing power parity (PPP) in terms of US dollars

In order to measure the Human Development Index, minimum and maximum values (goalposts) are chosen for each of the above indicators. These goalposts are outlined below:

Dimensional indicator	Maximum value	Minimum value
Life expectancy at birth	85	25
Adult literacy rate (%)	100	0

Combined gross enrollment ratio (%)	100	0
GDP per capita (PPP US$)	40,000	100

The Human Development Index is the average of three dimensional indexes:

HDI = 1/3 (life expectancy index) + 1/3 (education index) + 1/3 (GDP index)

An Ecological Footprint is an estimate of the amount of biologically productive land and sea required to provide the resources a human population consumes and absorb the corresponding waste. These estimates are based on consumption of resources and production of waste and emissions in the following areas:

- Food, measured in type and amount of food consumed
- Shelter, measured in size, utilization and energy consumption
- Mobility, measured in type of transport used and distances travelled
- Goods, measured in type and quantity consumed
- Services, measured in type and quantity consumed
- Waste, measured in type and quantity produced

The area of biologically productive land and sea for each of these areas is calculated in global hectares (gha) and then added together to provide an overall ecological footprint [4].This measure is particularly useful as it enables the impact of infrastructure and lifestyles to be measured in relation to the earth's carrying capacity of 1.8 global hectares (gha) per person.

National Development Trajectories

National figures using the Human Development Index and Ecological Footprint have been combined in graph, shown below.

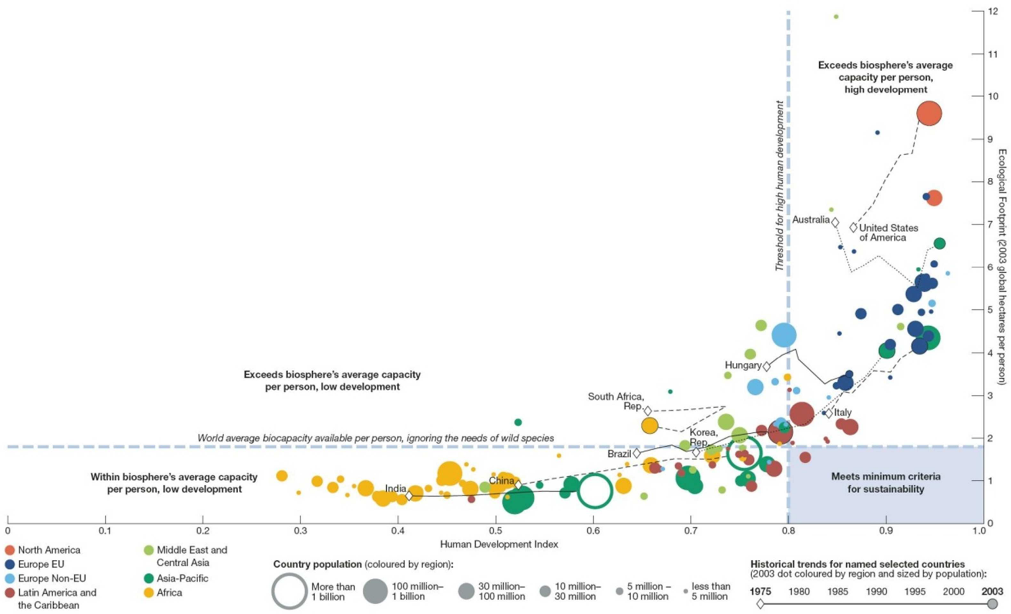


Figure 1 National Development Trajectories [3]

This shows that countries in Europe and North America very high Ecological Footprints and acceptable Human Development Indexes (above 0.8), while countries in Africa have unacceptably low Human Development Indexes (below 0.8) but have Ecological Footprints within the biosphere's allowable capacity per person.

The graph also indicates national development trajectories (the lines between the diamonds and dots). For example, the trajectory of the USA has been steep, with a large increase in their ecological footprint and relatively limited improvement in their Human Development Index in the last 20 years. In contrast, Hungary, over the same time period, has improved their Human Development Index to achieve the minimum sustainability criteria and, at same time, reduced their ecological footprint.

This suggests that strategies based on an understanding of current HDI and EF performance can support a shift towards sustainability [5].This is supported by Holden et al (2007) who argues, through reference to purchasing price parity and ecological footprint measures, that developing and developed countries require different strategies to achieve sustainability [6].

There is therefore a strong argument that built environment development strategies should respond to local EF and HDI performance and, through the provision of appropriate characteristics, support development trajectories aimed at achieving sustainability.

Minimum Standards and Built Environment Characteristics

The tables below interpret Ecological Footprint and Human Development Index criteria into minimum standards. The built environment characteristics required to achieve these minimum standards are then listed in the last column.

Table 1 Ecological Footprint, Minimum Standards and Built Environment Characteristics

Ecological Footprint Criteria	**Minimum Standards**	**Built Environment Characteristics**
Food: Measured in type and amount of food consumed	Occupants can meet their nutritional requirements through affordable, low ecological footprint means.	Local markets with low ecological footprint foods. Ability to produce low ecological footprint food.
Shelter: Measured in size, utilization and energy consumption	Occupants can meet shelter requirements through affordable, low ecological footprint means.	Appropriately sized, resource efficient accommodation.
Mobility: Measured in type of transport used and distances traveled	Occupants can access daily requirements using low ecological footprint means.	Daily requirements accessible within walking distance. Access to local public transport.
Goods: Measured in type and quantity consumed	Occupants can access required goods through affordable, low ecological footprint means.	Appropriate goods available locally. Facilities to support efficient usage / shared use of goods.
Services: Measured in type and quantity consumed	Occupants can access required services through affordable, low ecological footprint means.	Appropriate services available locally. Facilities to support efficient usage of services.

Table 2 Human Development Index, Minimum Standards and Built Environment Characteristics

Human Development Index Criteria	Minimum Standards	Built Environment Characteristics
Health: A long healthy life, measured by life expectancy at birth	Occupants can access facilities required for health.	Access to sports, health, leisure facilities. Access to healthy food and clean water. No local hazards such as violent crime and pollution.
Knowledge: measured by the adult literacy rate and combined primary, secondary, and tertiary gross enrolment ratio	Occupants can access facilities required for learning and education.	Access to primary, secondary, tertiary and ongoing learning facilities.
Standard of Living: A decent standard of living, as measure by the GDP per capital in purchasing power parity (PPP) in terms of US dollars	Occupants can access opportunities to enable a decent standard of living.	Access to employment opportunities. Self employment opportunities. Access to support for small enterprise development.

The Study Area

In order to understand the built environment characteristics listed in the Tables 1 and 2, these are translated into built environment sustainability criteria, shown in Table 3.

These criteria are then used to evaluate an area of Atteridgeville, a suburb of Pretoria. The study area is typical of many urban areas in South Africa and consists of self-built informal housing constructed in a loosely planned grid. Only basic infrastructure in the form of water (brought in by tankers) and some graded roads exists. Other infrastructure, such as street lighting, storm water drainage, piped water, electricity, parks, schools, health facilities, sports, leisure and retail facilities is limited or may not exist locally.

The built environment sustainability criteria were applied to a household (red rectangle) in the centre of the study area. Rings of 1km, 2km and 3km were then marked on the study area plan, indicated in Figure 2. A survey of the household and area using the criteria was then carried out.

Figure 2. Study area. Red rings indicate 1, 2 and 3 km distance from household location (red dot)

The results of this assessment using the Built Environment Sustainability Tool (BEST) are captured under the ‘Existing’ column in Figure 3 below, in accordance with the following key. An ‘0’ indicates the existence of the specified built environment sustainability criterion on site or within a 3 km radius of the site, a ‘5’ indicates that this does not exist and a ‘3’ that the criterion is partially fulfilled. For each set of built environment sustainability criteria, such as ‘Health’, an average value is provided in red; in this case it is 4.20. This average score provides an indication of the built environment capability within the respective areas, with a low score (near 0) indicating strong capability and a high score (near 5) weak capability.

The BEST results show that the site’s built environment capability to support EF and HDI targets is particularly weak in the areas of ‘Goods’, ‘Knowledge’ and ‘Standard of Living’, which all have an average of ‘5’. The best performing area was ‘Waste’ with a value of 1.67. These results are also shown in a spider diagram in Figure 2 (the blue line). These results can be used to diagnose gaps and prioritise interventions. In this case, built environment capability gaps exist in ‘Knowledge’, ‘Standard of Living”, and ‘Goods’ and interventions to address these should be prioritised.

Overall BEST measures of the HDI and EF capability can also be derived. Figure 3 indicates that the site has an EF capability of 3.43 and an HDI Capability of 4.73. The BEST also shows that the combined built environment capability is 4.08. This suggests that the site has a very low capability to support the achievement of HDI sustainability targets. It also shows that while the site has a better capability to support the achievement of EF targets, this is still very poor. These BEST capability measurements reflect South Africa’s location shown in Figure 1.

Appropriate Architecture for Sustainable Development

Given the baseline results, what would be suitable interventions to support sustainability in this area? What would be ‘appropriate architecture for sustainable development’ in this location?

In order to begin to develop and evaluate ideas a number of options were introduced into the tool and the impact assessed. These interventions are listed below:

- Urban Gardens: Provides access to local food gardens.
- Tool Hire: Provides access to local tool and equipment hire or sharing.
- Urban Market: Provides access to local markets for food and goods.
- Solar Water Heating: Provides solar water heating to houses.
- Local Multipurpose School: Provides access to a preschool, primary and secondary school and a learning resource centre with information and communications technology and support for ongoing learning.
- Rainwater Harvesting: Provides rainwater harvesting systems to houses.

Table 3 Built Environment Sustainability Tool (BEST)

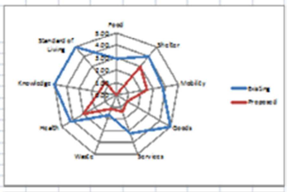
Key	Built Environment Sustainability Criteria	Existing	Urban Gardens	Tool Hire	Urban Market	Solar Water Heating	Multi Purpose School	RainWater Harvesting	Resilience	Proposed
Food		2.89							-2.22	0.00
FO1	Affordable / free water for irrigation	3.00						5.00	-2.00	0.00
FO2	2m2 per occupant of agricultural land	3.00	5.00						-2.00	0.00
FO3	Locally available affordable hand tools, seed and seedlings	5.00		3.00	3.00				-1.00	0.00
FO4	Access to clean drinking water	0.00						5.00	-5.00	0.00
FO5	Access to affordable fruit and vegetables	3.00	5.00		3.00				-5.00	0.00
FO6	Access to bread and bakery products	3.00			3.00				0.00	0.00
FO7	Access to affordable cereal products	3.00			3.00				0.00	0.00
FO8	Access to affordable beans and dry pulses	3.00	5.00		3.00				-5.00	0.00
FO9	Access to affordable dairy and poultry products	3.00			3.00				0.00	0.00
Shelter		4.00							1.64	3.00
SH1	Building area does not exceed 20m2 per person	0.00							0.00	0.00
SH2	Environmental control achieved through passive means	5.00							3.00	3.00
SH3	Water heating achieved through passive means	5.00				5.00			0.00	0.00
SH4	Cooking needs met through low energy / passive means	5.00							3.00	3.00
SH5	Lighting needs met through day lighting / low energy means	5.00							3.00	3.00
Mobility		3.75							0.77	2.50
MO1	Required education facilities within walking distance	5.00					5.00		0.00	0.00
MO2	Required health facilities within walking distance	5.00							3.00	3.00
MO3	Required retail facilities within walking distance	0.00		3.00	3.00				-6.00	0.00
MO4	Public transport within walking distance	5.00							3.00	3.00
Goods		5.00							0.50	1.00
GO1	Local access to high quality durable goods	5.00		3.00	3.00				-1.00	0.00
GO2	Facilities for shared use of goods: library / rental	5.00					3.00		2.00	2.00
Services		3.25							0.67	1.42
SE1	Local access to communication	3.00					3.00		0.00	0.67
SE2	Local access to affordable education facilities	5.00					5.00		0.00	0.00
SE3	Local access to affordable health care	5.00							3.00	0.00
SE4	Local access to affordable leisure facilities	0.00	3.00						-3.00	3.00
Waste		1.67							1.17	1.17
WA1	Available local facilities for recycling organic matter	5.00	3.00						2.00	2.00
WA2	Available local facilities for recycling paper and cardboard	5.00							3.00	3.00
WA3	Available local facilities for recycling aluminium	0.00							0.00	0.00
WA4	Available local facilities for recycling other metals	0.00							0.00	0.00
WA5	Available local facilities for recycling plastics	0.00							0.00	0.00
WA6	Available local facilities for recycling glass	0.00							0.00	0.00
Health		4.20							1.80	3.00
HE1	Locally available affordable nutritional food and water	3.00	3.00		3.00				-3.00	0.00
HE2	Locally available affordable sport and leisure facilities	3.00	3.00						0.00	0.00
HE3	Locally available affordable health care facilities	5.00							3.00	3.00
HE4	Locally available affordable healthy accommodation	5.00				3.00			2.00	2.00
HE5	No life threatening local hazards inc pollution, crime	5.00							3.00	3.00
Knowledge		5.00							1.40	1.40
KN1	Locally available affordable early childhood care	5.00					5.00		0.00	0.00
KN2	Locally available affordable primary education	5.00					5.00		0.00	0.00
KN3	Locally available affordable secondary education	5.00					5.00		0.00	0.00
KN4	Locally available affordable further / tertiary education	5.00							3.00	3.00
KN5	Locally available affordable ongoing learning (ie libraries)	5.00					3.00		2.00	2.00
Standard of Living		6.00							-0.33	1.33
SL1	Locally available employment opportunities	5.00					3.00		2.00	2.00
SL2	Locally available opportunities for self employment	5.00	5.00		5.00				-5.00	0.00
SL3	Locally available support for small enterprise creation	5.00					3.00		2.00	2.00
Totals			32.00	9.00	32.00	8.00	40.00	10.00		

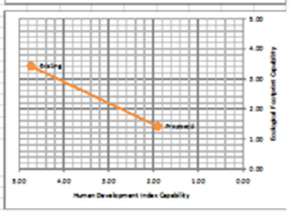
		Existing	Proposed
FO	Food	2.89	0.00
SH	Shelter	4.00	3.00
MO	Mobility	3.75	2.50
GO	Goods	5.00	1.00
SE	Services	3.25	1.42
WA	Waste	1.67	1.17
HE	Health	4.20	3.00
KN	Knowledge	5.00	1.40
SL	Standard of Living	5.00	1.33

	Ecological Footprint Capability		
FO	Food	2.89	0.00
SH	Shelter	4.00	3.00
MO	Mobility	3.75	2.50
GO	Goods	5.00	0.50
SE	Services	3.25	1.42
WA	Waste	1.67	1.17
EFC	Total Ecological Footprint Capability	3.48	1.43

	Human Development Index Capability		
HE	Health	4.20	3.00
KN	Knowledge	5.00	1.40
SL	Standard of Living	5.00	1.33
HDIC	Human Development Index Capability Total	4.73	1.91

		Existing	Proposed
ECFC	Total Ecological Footprint Capability	3.48	1.43
HDIC	Human Development Index Capability Total	4.73	1.91
BESC	Built Environment Sustainability Capability (ECFC+HDIC)/2	4.08	1.67





The overall impact of the interventions in terms of improved built environment capability was ascertained from BEST total scores. This indicates that ‘Urban Gardens’, ‘Urban Markets’, and ‘Multipurpose School’ have the highest BEST scores at 32, 32 and 40 respectively, and that ‘Tool Hire’, ‘Solar Water Heating’ and ‘Rainwater Harvesting’ have the lowest, at 9, 8 and 10, respectively.

The BEST results are surprising as show they indicate that conventional greening interventions such as the installation of solar water heaters, water efficiency programmes and energy efficient housing may have a lower impact on *local sustainability* than urban agriculture, multipurpose learning centers and local markets.

Conclusion

The paper concludes that the investigation into the implications of the HDI-EF definition of sustainability for the built environment in a developing country is a valuable exercise and leads to innovative and surprising results.

Translating the definition into a tool (the Built Environment Sustainability Tool) provides an innovative and original way of assessing the sustainability of urban environments. This tool can not only be used to assess the sustainability of urban environments but also the impact of potential interventions. This makes it highly valuable as a planning decision support tool.

The findings of using the tool are surprising in that they suggest that conventional greening interventions such as the solar water heater and water efficiency programmes may be less effective in improving the sustainability of a developing country communities than the development of urban agriculture, local markets and local multi-purposes community learning resource centres. While this is unexpected, a more detailed understanding of the local context and a deeper understanding of sustainability suggests that this finding is accurate and therefore the tool could be used to improve development planning and decision-making.

Further research on the tool and potential sustainability interventions should be carried out in order to understand how more responsive and appropriate architecture for sustainable development can be developed.

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