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Environmental Sustainability and Policy Implications of Urban Building and Construction in Kenya

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THE KENYA INSTITUTE FOR PUBLIC POLICY RESEARCH AND ANALYSIS (KIPPRA)

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Environmental Sustainability and Policy Implications of Urban Building and Construction in Kenya

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Abstract

The trend of urbanization and population growth has exerted excessive pressure on natural capital, with scientific evidence showing an overshoot beyond sustainable limits. Ensuring ecologically sustainable cities and metropolitan regions with a high quality of life is a prime development goal, in Kenya and worldwide. The proportional contribution of the construction sector to environmental degradation has been estimated at a global average of 30 per cent to 40 per cent. This study reviewed existing best practices, conceptual frameworks, and empirical evidence of the benefits of environmentally sound and sustainable building and construction. It applied a weighted summation model and additive utility concepts in Multi-Criteria Decision-Making (MCDM) to analyze the views of Kenyan stakeholders on the relative importance of nine selected environmental criteria and ten commonly applied strategies for environmentally sustainable building and construction. Slum upgrading, regeneration of brownfields, the 3R philosophy of waste re-use, recycling and reduction, and harmonizing new construction developments with neighbourhoods emerged the four leading strategies in environmental sustainability in the urban building and construction sector. Health and safety, and air quality were the criteria most highly ranked by the stakeholders. Ecology received a uniform weight as an important criterion. Noise pollution, energy efficiency, and air quality emerged to be the factors impacted on least by a combination of all the strategies considered. In Kenya's scenario, the results implied a greater need for participatory development of policy and technology for sustainable urban built environment, and ensuring strict implementation of spatial planning and environmental policy agenda, economic incentives that can motivate research, and innovative measures to achieve high environmental standards, by particularly improving strategic performance on the criteria of noise pollution, air quality, and energy efficiency. Policy recommendations focus on facilitating the four identified leading strategies and role of education in increasing environmental awareness and efficiency in the management of water, waste, and energy in building and construction activities.

Abbreviations and Acronyms

AHP	Analytic Hierarchy Process
CBA	Cost Benefit Analysis
CBDs	Central Business Districts
CBS	Central Bureau of Statistics
CSO	Central Statistics Office
DfID	Department for International Development
DMSED	Department of Micro and Small Enterprise Development
EF	Ecological Footprint
EIA	Environmental Impact Assessment
ELECTRE	*Elimination Et Choix Traduisant la REalite*
ERSWEC	Economic Recovery Strategy for Wealth and Employment Creation
EPI	Environmental Performance Index
ESI	Environmental Sustainability Index
FAR	Floor Area Ratio
FSI	Floor Space Index
GDP	Gross Domestic Product
GFN	Global Footprint Network
HDI	Human Development Index
ICEG	International Centre for Economic Growth
ICT	Information and Communication Technology
IISD	International Institute for Sustainable Development
ILO	International Labour Organization
IRR	International Rate of Return
ISDIS	Integrated Sustainable Development Indicators System
IT	Information Technology
JBIC	Johannesburg Business Information Centre
JPOI	Johannesburg Plan of Implementation
KEBS	Kenya Bureau of Standards
KIE	Kenya Industrial Estates
KIPI	Kenya Industrial Property Institute
KIRDI	Kenya Industrial Research Development Institute
KNBS	Kenya National Bureau of Statistics
KPI	Key Performance Indicators
LPE	Law of Proportionate Effect
MCDM	Multi-Criteria Decision Making
MDG	Millennium Development Goal
MFI	Micro Finance Institution
MSE	Micro and Small Enterprise
NCSE	National Council for Small Enterprises
NPV	Net Present Value
OLS	Ordinary Least Squares
SAW	Simple Additive Weighting

SDI	Sustainable Develoment Indicators
SME	Small and Medium Enterprise
SMEA	Small and Medium Enterprise Agency
SSI	Small Scale Industry
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNEP SBCI	United Nations Environmental Programme Sustainable Building and Construction Initiative
UNU	United Nations University
USA	United States of America
WCED	World Commission on Environment and Development
WGBC	World Green Building Council
WWF	World Wide Fund

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1. Introduction

Human-induced environmental degradation is a serious global concern in an era that has fittingly acquired the neologism *Anthropocene* due to the dominant and stressful human influence on the planet. The extent of humanity's demand on the biosphere in terms of providing ecological resources and services, referred to as Ecological Footprint (EF), is escalating. By 2003, EF had exceeded the Earth's biological carrying capacity by about 25 per cent (WWF, 2007). Unsustainable human activities, however, continue to degrade the vital life-support functions that a healthy environment offers humanity and all forms of life. The life-supporting natural capital, which yields the flow of priceless ecosystem goods and services, is being degraded and liquidated by wasteful use of energy, materials, water, fibre, and topsoil. This global environmental problem has challenged research to address key policy questions on environmental sustainability. The seventh Millennium Development Goal (MDG) aims to ensure environmental sustainability through specific targets on sustainable development policy and provision of decent housing, safe drinking water and adequate sanitation.

Developing countries rely heavily on natural resources to meet national development goals, and experience rapid population growth and urbanization. To effectively address the numerous environmental problems that arise from this scenario and growth dynamics, they need to integrate sustainability principles into their national development policies. The popular term "greening" is now widely used to describe strategic development measures meant to reduce environmental degradation or reflect it as costs in national accounts. Urban ecology, a new subject, specifically targets high quality of life in urban environments, where most of the current world population is going to live. Similarly, ecological economics as a recent multidisciplinary field addresses the dynamic and spatial interdependence between human economies and natural ecosystems and, therefore, it is central to the modern concepts of greening.

The internationally growing "green building industry" is evidence that these modern concepts can be applied to achieve environmentally sustainable built environment (Pintér *et al.*, 2005; Darmstadter, 2006; Tepe, 2007; UNEP SBCI, 2007). But how important is the building and construction sector to the sensitive issues of environmental sustainability? This and broader questions on the operational feasibility of sustainable development in a stochastic socio-economic system are probably the most common questions that research on environmentally sustainable built environment must answer. There are practical findings that the building and construction sector is globally responsible for 30 to 40 per cent of all deposited waste, of all energy uses in our society, and of all material flows (UNEP SBCI, 2007; Tepe, 2007). Empirical evidence has lately shown that environmentally friendly building design, strategic construction planning, and energy-efficient operations in the building and construction sector worldwide can reduce greenhouse gas emissions by a substantial 1.8 billion tonnes of carbon dioxide, while providing other environmental health benefits and cost savings (UNEP SBCI, 2007).

Nairobi has doubled its population in the last decade and Kenya's urban population currently stands at about 40 per cent of the national population (Government of Kenya, 2008a). In Kenya's Vision 2030, for instance, the natural environment is treated as part of the social pillar. Under housing and urbanization, the Vision 2030 targets an "adequately and decently housed nation in a sustainable environment" (Government of Kenya, 2008a).

Urban planning and associated spatial development policies have to take place within a multidisciplinary and multi-stakeholder setup, characterized by diverse public expectations and competing or conflicting views and interests. The study shows the resultant high-priority strategies for achieving a sustainable and decent urban environment in Kenya. The desired environmental policy direction needs the support of sector-specific sustainability indicators and economic incentives.

The proportion of global population living in urban areas is progressively overtaking the rural equivalent. The 2007 Revision of World Urbanization Prospects by the UN (2008) showed that 50 per cent of the world population would live in urban areas in 2008. The rapid expansion of urban areas with rising populations in developing countries and ever-increasing depletion of natural resources complicates urban environmental problems. Kenya's ecological sustainability is also at stake, given that it is an ecological debtor according to resource accounting estimates for the year 2003.

The building and construction sector is critical to meeting the Kenya Vision 2030 development blueprint. Land use changes from rural to urban character largely involve massive building and construction activities with far-reaching environmental consequences, common among them being pollution of water, soil and air; noise pollution; habitat fragmentation leading to biodiversity loss; and degradation aesthetics. The operational phase of buildings involves extensive energy and water resource consumption as well as waste generation.

In Kenya's scenario, the urban population is projected to hit the 60 per cent mark by 2015 (Government of Kenya, 2008a). Using urban space and resources in a way that ensures adequate spatial distribution of people and their activities in a healthy environment poses a big challenge to spatial planning and environmental policy formulation. Inadequately informed planning frameworks and lack of strategic planning hinder the identification of, and focus on, priorities for sustainable building and construction. Over 5 million Kenyans live in slums and at least 60 per cent of Nairobi's 4 million inhabitants settle on only 5.5 per cent of its total area (Government of Kenya, 2006b); this scenario calls for effective strategies for sustainable building and construction.

A major decision problem is how to arrive at the most suitable criteria and best-compromise options in a sector characterized by multiple attributes and stakeholders with different environmental perceptions. Kenya's building and construction industry is a case in point, with urban centres as the epitome of the cited environmental pressures and disorder. Though a few common interests may be realized in health and safety aspects, different stakeholders naturally underscore different criteria as shaped by their training, experience, and local interests. To be effective, participatory public policy processes must seek ways of effectively addressing and harmonizing any conflicting stakeholder perceptions.

Building and construction is a basic sector recognized by government policy agenda worldwide. The Kenya Vision 2030 underscores infrastructure development. There is also an increasing trend of investment in real estate, and land banking is being viewed as a viable instrument for investment and urban renewal. Building and construction activities are central to these goals. Two major factors that influence an increase in building and construction activities in Kenya are:

- Rapid urbanization and demographic shift to urban areas and urban lifestyle, with more than a half of Kenyan population projected to live in urban areas by 2015.
- The aim of Kenya's Vision 2030 for the building sector, which is to increase the annual production of housing units from 35,000 to 200,000 by 2012.

The global goal of ensuring environmental sustainability is embodied in the seventh MDG, of which Target 11 desires by 2020 to improve the lives of at least 100 million slum dwellers globally and avoid new slum formations. The government has responded by carrying out a needs assessment towards meeting this target (Government of Kenya, 2006b). This environmental target has government policy backing and can gain from research on best practices and key environmental performance indicators, informed by various stakeholders.

The National Environmental Management Authority (NEMA) has similarly responded to modern environmental challenges by embarking on a multi-stakeholder process aimed at enhancing access to environmental information in Kenya and making informed investment choices. Effective monitoring of environmental changes requires NEMA to develop and validate indicators of environmental sustainability adapted to local needs and priorities. It takes time to influence attitude and change choices and priorities in building and construction. For Kenya to achieve the goal of providing adequate infrastructure with "decent housing in a sustainable environment" according to Vision 2030, high environmental standards for the building and construction sector based on analysis of priorities amidst conflicting and competing interests are required.

A pragmatic outlook supported by global evidence shows that the sector is critical to environmental sustainability. Building and construction decisions highly affect the environment, but decision makers have the social responsibility to bequeath sustainable environment as a highly valued public good to posterity. Environmentally sustainable building and construction is essential to achieving sustainable development. The question is, therefore, how to sustain high quality of life and environmental safety by addressing priorities agreed upon through a multi-stakeholder and consultative processes, thus promoting informed consent and compliance with policies. Multicriteria evaluation models based on quantitative and qualitative value judgements are central to sound environmental decision making (Gomes *et al.*, 2008).

The following research questions respond to the problems outlined above and seek to address existing research gaps:

- How practically significant is the building and construction sector to the critical goal of ensuring environmental sustainability?
- Globally, which indicators, strategies and decision models are effective in facilitating sustainable infrastructure management solutions within multiple criteria and multi-stakeholder environments?

- Using decision models based on urban planning and environmental management concepts, best practices, and local stakeholder views, which criteria and strategies can lead to effective policy decisions on environmental sustainability in Kenya's urban housing and construction industry?

The main objectives of this study are therefore to:

- Demonstrate, using quantitative and qualitative estimates, how the building and construction sector is crucial to environmental sustainability agenda
- Identify the key indicators, targets and models suitable for evaluating environmental performance in housing sectors and construction processes
- Apply a multiple criteria decision model based on user-weighted criteria and user-rated strategies to recommend best-compromise policy options for Kenya towards meeting the goal of environmental sustainability for the building and construction sector.

2. Overview of Building and Construction Activities

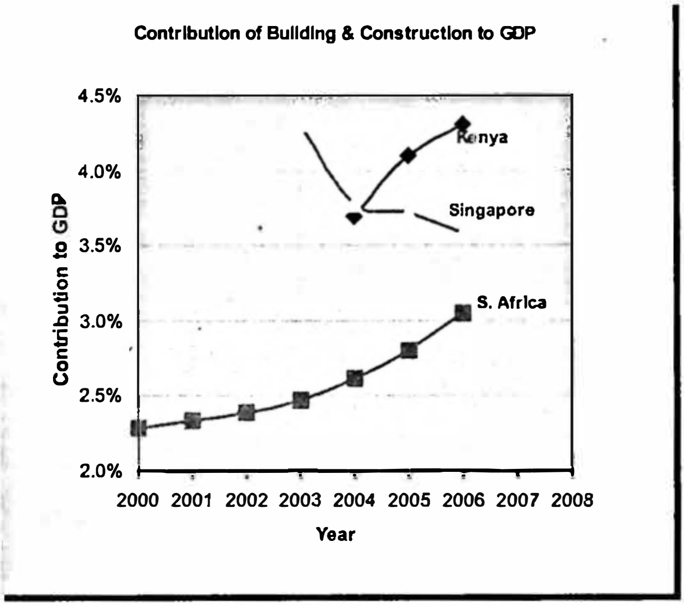
The building and construction sector generates significant social and economic benefits. But the sector also contributes significantly to the use of raw materials globally, energy consumption, solid waste generation, and greenhouse gas emissions. Building and construction projects sometimes face opposition due to conflicting environmental interests, hence calling for compromise solutions to ensure social justice and economic development as well.

2.1 Socio-economic Significance

Buildings that do not meet proper quality standards are a threat to both people and the environment. The building and construction sector employs over 111 million people worldwide and contributes approximately 10 per cent to the global Gross Domestic Product (GDP) (UNEP SBCI, 2007). Kenya's Vision 2030 underlines the housing and construction sector due to its labour-intensive nature, which gives it high potential to create more employment and utilize Kenya's comparative advantage in labour abundance. Construction has strong linkages with other sectors of the economy. The housing sector has a local content of more than 90 per cent, and therefore investment in housing and integrated planning can deliver direct positive effects on national income by triggering forward and backward linkages through additional investments in manufacturing of building materials, transport, marketing, and infrastructure development (Government of Kenya, 2008b).

The macro-economic significance of this sector has been appreciated in countries Kenya can emulate, such as South Korea where it contributed 7.8 per cent to GDP in 2006, and rising contributions at constant prices in South Africa, as shown in Figure 2.1. The Central Business Districts (CBDs) of these countries account for the highest density of the sector's activities, and Nairobi represents this case in Kenya. The constraint of land scarcity has instead been used as an opportunity for innovative solutions in Singapore, a small country about the size of Nairobi, through densification and IT-based services. In Malaysia and Mauritius, building and construction has provided a relatively high proportional contribution

Figure 2.1: Contribution of building and construction to GDP of various countries



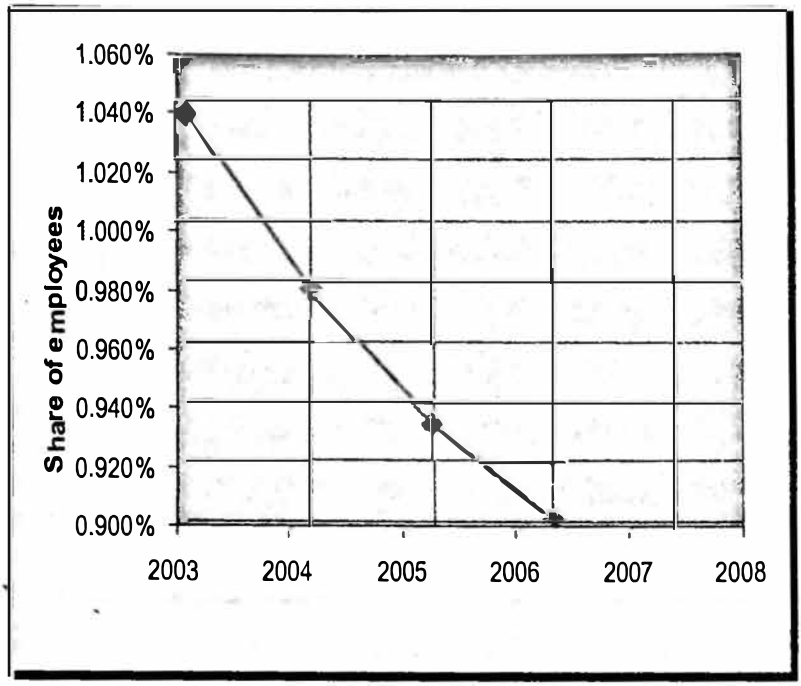
Source: KNBS, 2007; Statistics Singapore website; and Statistics South Africa website

to employment by sector, where about 10 per cent of all employment in major sectors has been in this sector alone.[1]

The percentage population of Kenyans employed in this sector has remained around 0.2 per cent between 2003 and 2006 (KNBS, 2007). This percentage has been rising in South Africa, Mauritius, and Malaysia for the same period. Its contribution to employment as a percentage of all the major sectors in Kenya has been on a downward trend from 1.05 per cent in 2003 to 0.92 per cent in 2006 (Figure 2.2). Lessons drawn from city development strategies in South Africa, Singapore, Mauritius, and Malaysia show that large government spending in this sector, public-private partnerships, enhanced professionalism in the construction industry, and integrated services in facility management are the crucial drivers of the high standards sustained in their building and construction sectors. A building authority that collaborates with research

[1]Information based on data from these official websites: Korea National Statistics Office, Department of Statistics Malaysia, The Central Statistics Office (CSO) of Mauritius, and Statistics South Africa.

Figure 2.2: Share of building and construction in sectoral employment in Kenya



Source: KNBS (2007)

and development institutions is central to the success of Singapore's building developments.

2.2 Environmental Significance

There is extensive literature explaining the correlation between the built environment, driving, vehicle emissions, air quality, physical activity, and public health (LEED-ND, 2006). The construction industry contributes to environmental degradation by modifying and denuding existing landscapes and habitats, and mass production of noise and construction waste. Habitat destruction or fragmentation, soil erosion, pollution of water, soil and air, and climate change arising from deforestation and energy uses are among the serious non-localized environmental consequences. Residential buildings account for most of the energy used in this sector, sometimes exceeding 90 per cent in developing countries (UNEP SBCI, 2007).

Land use change from rural to urban character increases impervious surfaces such as pavements and rooftops, which increase storm water runoff and reduce groundwater recharge. The open pits left after extraction of construction material create a serious health hazard. Poor housing planning and waste management practices lead to increased waste discharge, especially in informal settlements and slums. The causal pathways are interrelated with positive feedbacks that impair ecological integrity and endanger human health and safety.

Kenya's urban centres face major problems in spatial planning and waste management, most of which fall within the housing and construction sector. The recommended *3R philosophy* of re-using, reducing and recycling waste is hardly implemented. Much waste consequently remains on open ground or ends up in water courses, jeopardizing public health. A recent public opposition to the construction of a cement factory in Kitengela due to fear of air pollution and conflict with the surrounding land use shows how the Kenyan public has become conscious of environmental issues and harmony of new developments with their neighbourhoods in the built environment (*Daily Nation*, 24 January 2008).

2.3 Urban Planning and Environmental Policy Issues

Land use and zoning policies determine the location, quantity, and distribution of stationary pollution sources such as industrial corridors away from residential centres. The 2006-2011 Strategic Plan of Kenya's Ministry of Housing (Government of Kenya, 2006a) decries the limited capacity of research institutions to conduct research on building materials and technologies. Also highlighted is the lack of an all-encompassing legislation for coordination, guidance, regulation, monitoring, and evaluation of the housing sector and the lack of incentives for private sector investments in housing. The ministry has acknowledged environmental degradation as a threat to the housing sector, against the backdrop of rapid urbanization and spread of slums and informal settlements.

Kenya's Vision 2030 states: "Kenya's cities and towns are poorly planned. There is an acute need therefore for an effective capacity for regional and urban development planning" (Government of Kenya, 2008a). Lack of professionalism is evident, since over 90 per cent of buildings in Nairobi are not designed or supervised by professionals, and the city lacks a master plan. The last master plan updated in 1973 expired in 2003 and, therefore, cannot reflect present realities. Only a third of Kenyan towns are planned and only four municipalities have planning departments at present (Government of Kenya, 2008a).

The Vision 2030 is limited in strategies to secure the intended "sustainable" environment, which should in essence be a healthy environment providing sustainable ecosystem services. Given the low adaptive capacity of Kenya and other developing nations, precautionary measures against environmental degradation are fundamental. Planning of human activities in space and time is central to this requirement, while creating awareness of new concepts and sharing practical lessons can inform local policy agenda.

Kenya's Environmental Management and Coordination Act No. 8 of 1999 provided for the establishment of the National Environment Management Authority (NEMA). The Act details procedures and rules meant to reduce adverse environmental impact of human activities. Indicators that reflect current sectoral realities are needed to enrich the assessment of various environmental parameters and also facilitate the recognition of knowledge and implementation gaps.

NEMA enforces the standard procedures of Environmental Impact Assessments (EIA) for construction processes by "screening" to categorize projects according to the level of assessment they require, and "scoping" to identify key environmental issues and impacts, ending up with a plan for public involvement and Terms of Reference for the EIA.

3. Review of Concepts and Practical Cases

3.1 Theoretical Concepts on Sustainability and Multiple Criteria Decision Models

The concept of sustainability and its practical feasibility takes a key position in global development debate. Famous early writings such as the *Tragedy of the Commons* by Garret Hardin (1968) and *Limits to Growth* by Donella H. Meadows *et al.* (1972) had warned of the possibility that human lifestyle would exceed the capacity of the natural environment to sustain. The confirmation of these fears has been documented by Meadows *et al.* (2004) in their book *Limits to Growth: The 30-Year Update,* and the comprehensive Living Planet Reports by the World Wide Fund for Nature (WWF). The Brundtland Commission Report of 1987, World Commission on Environment and Development (WCED, 1987) added weight to the concept of sustainable development, making it a universal concept shaping the world's development agenda for social equity, economic efficiency and ecological sustainability.

The sustainability agenda have motivated rapid developments in multidisciplinary academic fields that tackle sustainability, for example *Ecological Economics* and *Urban Ecology*, both addressing the issues of sustainability in systems where humans are principal change agents. The domineering role of humanity in modifying the environment has led to the introduction of a new geological era called *Anthropocene*, a term introduced in 2000 and formally adopted in 2008.

The Millennium Development Goals address the development priorities for developing countries, with ensuring environmental sustainability as the seventh goal. The science of sustainability is relatively new. Sustainable development is gaining popularity but its concept and realization still leave many knowledge gaps.

Concept of sustainability

Ongoing research on *Sustainability Science* proposes the development of indicators that can help transform macro-policies and national sustainability goals into decision making variables at the project level (Ugwu and Haupt, 2007). Efforts towards achieving the targets under the social pillar of Kenya Vision 2030 can, therefore, be informed and enhanced by research on sustainability indicators. The definition of *sustainable development*[2] given by the Brundtland Commission Report (WCED, 1987) is broad and has become the standard. It stressed the growing need for effective international cooperation to manage economic and ecological interdependence, and called for a change in policies and institutions to ensure linkages between institutions that manage the economy and those that manage the environment.

Economists tend to view sustainable development as a steady state within a natural resource or macro-economic growth model, while sociologists may view it as a socio-economic system that evolves slowly and non-destructively with its supporting ecosystem (Conrad, 1999). The global consensus on the concept of sustainability is that sustainable development is founded on three pillars: environmental, social, and economic pillars. These pillars together form the so-called sustainability triangle. Conrad (1999) concurs that the notion of sustainable development as a steady state is inappropriate because ecological and socio-economic systems display structural dynamics that seem inconsistent with a stationary set of deterministic difference equations. He proposes a definition of sustainable development that fits stochastic and evolving environments, referred to as the *adaptive development* concept.

Pintér *et al.* (2005) have pointed out the ambiguity in the popular definition of sustainable development and, particularly, the lack of detail on what to sustain, to what extent, and on what time scale. They interpret sustainable development to mean "the maintenance of aggregate stocks, inventories or qualities of economic, social, ecological or institutional assets over time". Indicators are used to provide information on these stocks and hence help to define key aspects of sustainability in specific contexts.

The concept of *Ecological Footprint* (EF) is used to measure the extent of humanity's demand on the biosphere in terms of providing ecological resources and services. The universal unit used is the *global hectare* (gha), which is one hectare of average global productivity, considering biologically productive land and water in a given year. It is therefore not equal to the physical hectare, due to spatial variability in biological productivity (GFN, 2007). The concept of *biological carrying capacity* or

[2]Defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED 1987, The Brundtland Report).

biocapacity is applied to estimate the long-term capacity of an ecosystem to support a given material standard of living.

Ecological Footprint (EF) analysis uses the life-supporting natural capital, or *ecological capital*–defined as the stock of living ecological assets that yields goods and services on a continuous basis (GFN, 2007). Based on this concept, human EF had by the year 2003 exceeded the Earth's biocapacity by about 25 per cent (WWF, 2007). Cities have significant ecological footprints varying according to population size, average material standard of living, productivity of the land-water base, and technological efficiency in resource management. Nairobi's EF has been estimated to be 32 times its area (GFN, 2007). According to 2003 estimates, Kenya had an average EF of 0.8 gha/capita, which was already above its biocapacity of 0.7 gha/capita, down from a biocapacity of 1.9 gha/capita in 1961 (Goldfinger *et al.*, 2008). An individual's ecological footprint can be calculated using data on lifestyle, including the transport means used and distances travelled. Annex Tables 2 and 3 show a sample of EF analysis results for two KIPPRA employees, both of which exceed the country's average.

Natural ecology shows the ultimate efficiency of biological systems, where no resource is wasted due to a closed loop of system functioning. This is the basis of new concepts in economic efficiency and environmental sustainability. Ecological economics examines the dynamic and spatial interdependence between human economies and natural ecosystems. Research efforts have yielded a system of Sustainable Development Indicators (SDIs). Pintér *et al.* (2005) highlight various attempts to create "aggregate" measures of sustainability aspects for a more "nuanced perspective on development than economic aggregates such as GDP". They cite the Human Development Index (HDI), the Environmental Sustainability Index (ESI), and the Environmental Performance Index (EPI) as proper examples.

Challenges of measuring sustainability

Conceptual and technical challenges hinder efforts to implement sustainability concepts. Sustainability is routinely assessed using weighted indicators that facilitate comparative evaluation. An overall sustainability score is calculated as an aggregate index of measurement (Romaya, 2002). Sustainable Development Indicators (SDIs), though popular in public and private sectors as strategic policy tools, have limited actual influence on policy. The International Institute for Sustainable Development (IISD) singles out the following challenges:

- **Institutional challenge**: Need for strong environmental institutions that can champion integration of SDIs into key policy decisions on budgets, sectoral policy, long-term plans, and sustainable development strategies.
- **Methodological challenge**: The difficulty and lack of consensus on indicator measurements in terms of what to measure, how to measure it, and linking specific indicators to time-bound targets and thresholds. Comparability of indicator systems is needed to harmonize the standards used to measure the same variables.

A 2005 discussion paper prepared by Pintér *et al.* (2005) for a UN expert group proposed pragmatic ways for choosing sustainability indicators, key among them being:

- The adoption of an evolutionary approach that utilizes a small set of 3-5 indicators that touch on high-priority policy issues
- Linking the SDIs to policy goals and targets, as demonstrated by the MDGs (hence crucial to Kenya Vision 2030)
- Non-monetary environmental and social indicators that are compatible with macro-economic indicators and budgeting processes

Indicators enable countries to assess progress towards sustainable development and MDGs. The Johannesburg Plan of Implementation (JPOI) also calls for work on indicators of sustainable development by countries at the national level.

Sustainability and construction concepts

"Green building" refers to the shift from standard building practices, typically guided by short-term economic considerations, to "best practices" emphasizing quality construction, energy efficiency, indoor air quality, conservation of water and other natural resources, and thoughtful planning and design for human productivity and health. It employs a life-cycle approach, estimating the cumulative environmental and social impacts of a building throughout its lifespan, from construction through use to demolition (Tepe, 2007).

New concepts on "greening" the building and construction sector have been advanced by the World Green Building Council (WGBC). Its mission is "to accelerate market transformation of the global property industry towards sustainability". India, Mexico, United Arab Emirates, Australia, Japan, North America, and the United Kingdom already have "green building councils". New councils are already forming or gaining consideration among developing and transitional economies such as Ghana, Nigeria, South Africa, China, and Brazil (WGBC, 2007). As urbanization increases, so does the need for ecologically sustainable cities and metropolitan areas. This has motivated conceptual frameworks informed by academic fields, especially urban ecology and ecological economics. These integrated concepts facilitate collaborative and interdisciplinary research by both social and natural scientists (Pickett *et al.*, 1997; Nilon *et al.*, 1999). Models for studying urban ecosystems and sustainable building and construction have also been devised (Nilon *et al.*, 1999; Charlot-Valdieu *et al.*, 2004; Ugwu and Haupt, 2007). Such models need to ensure that:

- Sustainability and environmental justice provide the context for the studies or model
- Participatory research involves the residents
- Public education on urban ecosystems is tailored to use both informal and formal methods to reach diverse groups of city dwellers

Multicriteria decision support models

The tools in resource economics used to evaluate investment choices include Cost-Benefit Analysis (CBA), Internal Rate of Return (IRR), return on invested capital, and dynamic optimization. These mainly single-criteria approaches are limited in evaluating non-monetary benefits, amenity values, or services of nature (Conrad, 1999). Multiple criteria methods are more effective since they apply different approaches to seek the best-compromise solutions.

Multi-criteria Decision Making (MCDM) methods are widely applied as a branch of operations research. MCDM is the "study of methods and procedures by which concerns about multiple conflicting criteria can be formally incorporated into the management planning process", as defined by the International Society on Multiple Criteria Decision Making (2008). MCDM methods can address different problems: choice-based, ranking-based, or sorting-based methods. Traditional single-criteria decision making methods focus on maximizing benefits while minimizing costs (Morais and Almeida, 2006).

The purpose of MCDM is to help improve the quality of decisions by ensuring decision-making is more explicit, rational, and efficient. Decision alternatives are evaluated on a set of measurable criteria within a decision matrix made up of rows of rated or scaled alternatives and columns of weighted criteria. This technique is usually applied to facilitate decision-making in scenarios involving numerous decision options, many criteria, and conflicting perspectives. Multicriteria Decision Analysis (MCDA) provides a way of structuring complex decision problems for positive outcomes in situations that involve uncertainties with multiple stakeholders and criteria (Morais and Almeida, 2006). MCDA as well takes into account political priorities (Ruiter and Sanders, 1998).

In decision making theory, a criterion may represent either an attribute or an objective. In this sense, therefore, MCDM problems are either a Multi-attribute Decision Making (MADM) or a Multi-Objective Decision Making (MODM) problem, or both. MADM is more related to problems whose number of alternatives has been predetermined. It is used when the decision maker (DM) has to rank a small finite number of strategies or courses of action. MODM is used for problems of continuous space and MADM for discrete problems. Hobbs and Meier (2000) outline the basic functions of decision analysis as follows:

- To structure the decision making process
- To display trade-offs among criteria
- To help reflect upon, articulate and apply value judgments on acceptable trade-offs, resulting in recommended alternatives
- To help make more consistent and rational evaluation of risk and uncertainty
- To facilitate negotiation
- To document how decisions are made

Alternatives are different choices of action or entities available to the decision maker. Attributes are also called "goals" or "decision criteria", commonly understood as parameters or characteristics (Schinas, 2007). Weights assigned to the attributes are usually normalized to add up to unity. Scores of alternative actions on the decision criteria can be transformed to range from 0 to 1. This helps ensure comparability between different units by a process called standardization. According to Ruiter and Sanders, (1998), the two common standardization formulae are:

Standardized score = ("raw" score$_i$)/(Σ "raw" scores)

and

Standardized score = ("raw" score$_i$)/(maximum "raw" score)

The latter is more suitable for comparing more alternatives because the results obtained are not too close to one another. Ordinal expressions are often used to represent qualitative value judgment of criteria weights in terms of the average priorities of interest groups (Ruiter and Sanders, 1998).

Decision analysis tools and weighting of criteria

The common models used for MCDM are:

- Simple Additive Weighting (SAW)
- Analytic Hierarchy Process (AHP)
- Multi-attribute Utility Theory (MAUT)
- Multi-attribute Trade-off System (MATS)
- *ELimination Et Choix Traduisant la REalité* (ELECTRE) (translated as Elimination and Choice Expressing the Reality)

Weighting of criteria is based on technical calculations or value judgments that reflect the relative importance of established objectives. MCDM methods like ELECTRE and AHP use the technique of *outranking* to choose alternatives ranking higher. MCDA approaches usually assign undesirable attributes (costs) negative utilityvalues or a reserved ordering system for scalar values. Desirable attributes (benefits) are then assigned positive values that ascend according to the perceived utility.

3.2 Empirical Findings on Sustainable Building and Construction

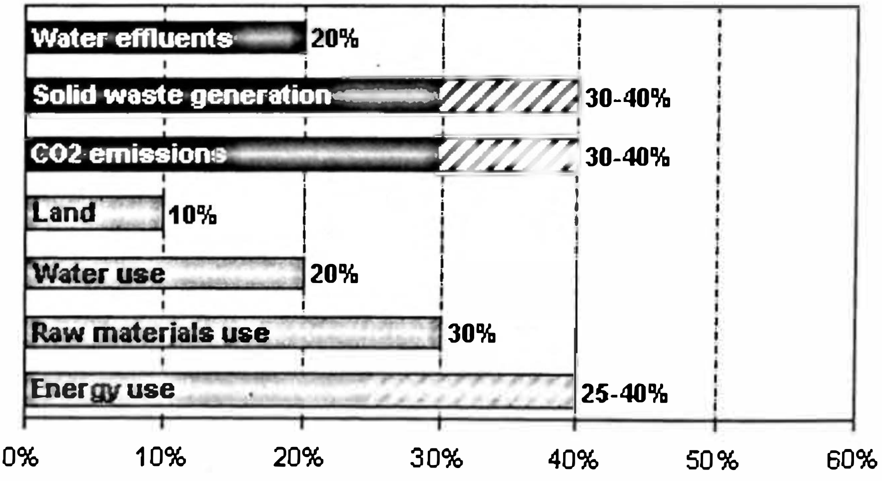
Research has shown a positive link between green office spaces and employee productivity, employee retention, and health. "Green" buildings derive these benefits mainly from design adaptations, as opposed to new technologies. Studies also link environmental attributes like proximity to recreational facilities, aesthetic qualities of streets, and perceptions of safety to overall physical activity levels (LEED-ND, 2006). Environmentally conscious design in the building and construction sector can immensely reduce global environmental degradation.

Environmental costs of building and construction

Conservative estimates show that the building and construction sector worldwide can help realize emission reductions of 1.8 billion tonnes of carbon dioxide, hence boosting the Kyoto Protocol obligations (UNEP SBCI, 2007). This sector is globally responsible for a significant 30-40 per cent of all deposited waste, of all energy uses in society, and of all material flows (Figure 3.1) (UNEP SBCI, 2007; Tepe, 2007). It is therefore a key sector in sustainable development debate (UNEP SBCI, 2006).

Using recycled building materials, installing energy-saving appliances, and maximizing natural lighting in building design typically reduce energy use by 25 per cent to 35 per cent, and up to 80 per cent in some of the best performing buildings. These strategies yield significant long-term cost savings and reduced greenhouse gas emissions. Studies estimate that using recycled building materials saves 12 per cent to 40 per cent of the total energy used during materials production (UNEP SBCI, 2007).

Figure 3.1: Share of the built environment in resource use and pollution emission



Source: UNEP SBCI (2007)

The upfront cost of green construction tends to be higher than that of conventional construction. Studies indicate that the difference is minimal (only 2% according to a 2003 study sponsored by the US Green Building Council), and that the long-term payoffs quickly offset this initial investment. The typical payback period for projects in India, for example, is estimated to be between three and seven years (WGBC, 2007). A 20-year net benefit of $50 - $65 Net Present Value (NPV) per square foot has been confirmed in the USA through a comprehensive analysis of financial costs and benefits of green buildings (Kats *et al.*, 2003).

Country examples on sustainable building and construction

Norway and Germany present good examples of environmental management in the housing and construction sector. German spatial planning policy ensures a strict adherence to spatial planning parameters: site occupancy ratios, floor-area ratios, and green area allowance for various building categories. Success has been realized in creating spatially balanced quality housing infrastructure to ease pressure on major centres (Müller and Karsten, 2001). *Brownfield redevelopment* is preferred as an inner city development strategy to avoid land wastage and preserve sub-urban greenfields (Koll-Schretzenmayr, 1999).

In Norway, there are concerted efforts to ensure environmental awareness creation within municipalities and promotion of densification principles. Norway's Urban Environment Prize is a research incentive. Priority action includes enhancing spatial efficiency, attention to biodiversity conservation, reducing energy consumption in the building stock, and sustainable waste and building management practices (Norwegian Ministry of Local Government and Regional Development). There are plans that promote land-saving construction and forms of settlement as well as re-utilization of urban wastelands (*brownfield redevelopment*) as in Singapore's densification programme to redress land scarcity.

Models applied to sustainable building and construction

A comprehensive methodological framework for assessing sustainability in building and construction resulted from a 2001-2004 combined research and demonstration project of the European Union, referred to as "Sustainable Renovation of Buildings for Sustainable Neighbourhoods" or HQE²R project.[3] The six principles of sustainable development, shown in Table 3.1, form its theoretical basis at the neighbourhood scale. The objective of the project was to develop a new methodology or approach, together with the necessary methods and tools to promote sustainable development and the quality of life in urban areas.

With its integrated approach, the HQE²R methodology provides a framework applicable to European cities. The project used case studies as neighbourhood models. The comprehensive methodological approach is based on five main sustainable development objectives, 21 targets for sustainable neighbourhoods and buildings, and 51 key issues with their 61 "indisputable" indicators– the Integrated Sustainable Development Indicators System (ISDIS) (see Appendix Table 1). The three assessment models in the framework of HQE²R are:

Table 3.1: Issues addressed in sustainable development principles underpinning the HQE²R model

- *Economic efficiency*: Common good while including all social and environmental costs
- *Social equity*: Meeting the needs of all within the neighbourhood; tackling poverty and social exclusion
- *Environmental efficiency*: Ensuring equal access to resources while protecting and conserving them globally and locally
- *The principle of long term*: Decisions based on long-term impact, not overstressing short-term benefits
- The global principle (includes the principle of subsidiarity)[4] Considers how actions affect different geographic scales
- *The principle of governance*: Residents empowered to participate in their own governance

Source: Outrequin, 2003 (for HQE²R)

[3] HQE²R is a combined research and demonstration project, partly funded under the "Energy, Environment and Sustainable Development" programme, Key Action 4, "City of Tomorrow and Cultural Heritage", with the Fifth Framework Programme of the European Union.

[4] A key principle of EU law, whereby the European Community will only take action if its objective cannot be better achieved at a more local level (European Commission Glossary of Justice and Home Affairs).

- Indicators impact model (INDI model) on sustainable development indicators for assessing and choosing projects
- Environmental impact model (ENVI model)
- ASCOT model (Assessment of Shared global Cost and externalities/Assessment of Sustainable Construction and Technology Cost), a simulation model that allows comparing global costs of a sustainable building (new or rehabilitated) with a reference (or traditional) building.

In assessing urban sustainability in Brazil, Fehr *et al.* (2004) have proposed parameters and corresponding indicators of sustainability, citing municipal situations where bottom-up management procedures with participation of organized society are instrumental. Their research acknowledges that indicator quantification can be difficult, and social units must therefore develop reasonable definitions of concepts such as low, high, adequate, and deficient. The proposal of indicators should be a consultative and multi-stakeholder process. Bojo´rquez-Tapia *et al.* (2005) applied AHP and compromise programming methods to harmonize conflicting expert and political opinions on a controversial airport project in Mexico (Mexico City International Airport).

ELECTRE method has been applied by Morais and Almeida (2006) to identify priority cities for water supply investment in Brazil against limited financial resources. The approach ensured collective and well-understood decisions that are also more explicit, rational and efficient. Pietersen (2006) applied MCDA as a tool to support sustainable management of groundwater in South Africa by identifying critical alternative courses of action and developing a decision model to propose strategies aligned to legislative requirements. The study involved field investigations, community workshops, and consultations with decision makers and professionals.

Ugwu and Haupt (2007) identified Key Performance Indicators (KPI) and assessment methods for infrastructure sustainability in the South African construction industry. They proposed an analytical decision model for sustainability appraisal in infrastructure projects within the context of developing countries. They applied the techniques of "weighted sum model" and "additive utility model" in an Analytical Hierarchy Process (AHP) for Multicriteria Decision Making (MCDM) to compute a *sustainability index*. The index is used to evaluate infrastructure design proposals.

3.3 Synthesis of Reviewed Concepts and Practical Cases

Though the concept of sustainable development is still evolving, ecological sustainability remains at the heart of the concept. The reviewed literature shows the growing need for effective international cooperation to manage economic and ecological interdependence, and points to a change in policies and institutions to ensure linkages between institutions that manage the economy and those that manage the environment. Reviewed examples of research on sustainability indicators for cases in Brazil, South Africa, and the European Union display similarity in the indicator systems–with common themes in economic, environmental and social pillars of sustainable development (Fehr *et al.*, 2004; Charlot-Valdieu *et al.*, 2004; Ugwu and Haupt, 2007). Aggregated indices will require high quality data to ensure consistency, comparability, and completeness in indicator sets. Political consensus on indicator weights, however, remains difficult to achieve (Pintér *et al.*, 2005).

The importance of the construction profession in economic development and related challenges of sustainability have been pointed out by various contemporary researchers. Ugwu and Haupt (2007) rightly observe the conflict of options, especially in developing countries, because of the need for immense infrastructure development to boost economic growth, put against the pressing need for poverty alleviation, capacity building, and social justice. The authors converge on the point that translating sustainability objectives into concrete action at the micro level is a major challenge that has left many knowledge gaps, making sustainability appraisal difficult.

There is acute lack of structured methodology and information at various levels in developing countries. MCDA offers the most suitable methodology for attaining effective solutions in this scenario. Integrating “sustainable” or “green” building practices into construction processes provides considerable financial, health, and environmental benefits.

4. Methodology

The methodological approach takes into account the fact that the building and construction industry is very broad and highly diversified. Considerable variations from one type of construction to another makes it difficult to derive generalized indices applicable to the industry as a whole. Local definitions must ensure conformity to specific local conditions and spatial idiosyncrasy. The research framework and methodology relied on a review of sustainability research and existing guidelines on environmental assessments and sustainable construction. Locally, relevant indicators of environmental sustainability in the built environment were identified, and an analytical model for multiple criteria analysis of various stakeholder views and strategies was formulated. The approach closely followed the procedure used by Ugwu and Haupt (2007) in developing key performance indicators for infrastructure sustainability in South Africa, but with modifications.

4.1 Data Sources

Secondary data on spatial planning parameters for Nairobi were obtained from the Ministry of Lands and used to evaluate the existing policy on space economy. *The Karengata Local Physical Development Plan* and Kenya Vision 2030 provided secondary information on policy goals for Kenya's housing and construction sector. Primary data on key environmental criteria were obtained from interviews of stakeholders in the sector. They were required to assign weights to selected indicators depending on their perceived relative importance in achieving environmental sustainability objectives in Kenya's urban built environment. The stakeholders were experts in professions dealing with building and construction, environmental science, economics, and two persons from none of the above to represent the public. Out of the total 25 stakeholders, 17 responded within the time frame of this exercise.

The assessment of indicators was informed by the Integrated Sustainable Development Indicators System (ISDIS) of the HQE²R methodological framework and cases from literature review, borrowing mainly from previous research on sustainability indicators by Fehr *et al.* (2004) for Brazil and Ugwu and Haupt (2007) for South Africa. The models were modified in definition of parameters, weighting, and scaling.

4.2 Conceptual Basis

The literature review exposed the need for a comprehensive local framework of indicators and models for monitoring sustainability in Kenya's building and construction processes. Rationally, this study therefore borrows concepts from previous comprehensive research on sustainable building and construction, as demonstrated by the reviewed models in the European Union (HQE²R model), South Africa, and Brazil (Charlot-Valdieu, 2004; Fehr *et al.*, 2004; Ugwu and Haupt, 2007), with adjustments to match local scenarios and stakeholder perceptions. Strategies that can effectively inform the relevant environmental policies were identified based on evaluation matrices that give ranked outputs based on weighted criteria. This multicriteria decision method is widely applied to decision support in resource management. The reviewed conceptual frameworks and best practices informed the criteria and strategies for reducing environmental degradation in this sector. They were then rated based on the science of environmental sustainability, principles of urban planning, and expert opinion.

There is no theory that can arrive at the best alternative directly; many alternatives therefore had to be explored based on decision criteria. Based on planning theory and environmental management principles, the criteria and possible actions or strategies shown in Table 4.1 were identified for evaluation. Slum upgrading was considered for Nairobi as one of the local strategies. A slum-upgrading project has been undertaken in Nairobi to respond to the problem of slums, and is adapting to meet the seventh MDG, Target 11.

The case of Nairobi, where 60 per cent of the population lives in informal settlements at high densities, points to inadequate land use planning. Vegetation and dust-reducing techniques in urban construction help enhance air quality. Natural criteria, especially topography, determine air circulation potential and therefore influence how high urban buildings should rise. Energy-use efficiency can be achieved largely during the operational phase of buildings. Energy-saving lamps (compact fluorescent light) last ten times longer than normal tungsten lamps and emit 70 per cent less heat, hence the preferred choice.

Aesthetic quality of the built environment influences customer preferences, attracts higher rates, and inspires invaluable health benefits. Landscaping and mitigation against visual intrusion, reducing noise pollution, and spatial harmony of new construction with the neighbourhoods are recommended planning measures. Sustainable water and waste management has indisputable effects on human health and ecology. To enhance ecological integrity and ensure water sustainability, engineers propose porous pavements, which increase infiltration of rainwater to recharge groundwater and reduce the amount, speed and adverse effects of storm water runoff. These concepts are fundamental to sustainable building and construction. The assignment of weights to these planning criteria needs experts. Expertise and fundamental principles minimize bias within a given panel of experts.

4.3 Analytical Basis

The MCDA approach used is based on a composite value function $V(X_1, X_2, X_3 ..., X_n)$ using a weighted sum of functions over each individual evaluation measure.

Therefore:

$$V(X_1, X_2, X_3 ..., X_n) = w_1 V_1(X_1) + w_2 V_2(X_2) + w_3 V_3(X_3) + ... + w_n V_n(X_n)$$

where w_i = weight of evaluation measure X_i and $\sum w_i = 1$ with $0 < W_i < 1$. Standardizing the sum of weights to be equal to unity yields normalized weights.

From the many MCDA methods reviewed, the one applied by Ugwu and Haupt (2007) to appraise infrastructure sustainability in South Africa was selected. It is suitable, being a hybrid of the *weighted sum model* and *additive utility model*. Moreover, its computational approach and structured methodology are adapted to situations in developing countries. The resulting decision matrix for sustainability appraisal is represented as follows:

$$SI_i = \sum_{j=1}^{N} d_{i,j} W_j \quad \text{(for i = 1, 2, 3, ...M)}$$

where SI_i is the final sustainability index, D_i is the *decision alternative* given M alternatives, and $d_{i,j}$ is the stakeholder-assigned utility (scalar value) measuring the performance of D_i on given sustainability criteria N (for i = 1, 2, 3, ...M; j = 1, 2, 3, ...N). w_j is the weight assigned to the criteria, where $w_j \leq K$ and K is a user-defined integer scalar quantity. The weight should depend on country-specific priorities on sustainability agenda.

$SI = \sum SI_i$ (for i = 1, 2, 3, ..., M) is the overall index for the entire project. Different sustainability projects are therefore comparable using this measure.

Model modification

The mathematical model above was given new definitions in ***i*** (to represent the array of strategies: i = 1, 2, 3, ...M)) and ***j*** (to represent the vector of criteria guiding the evaluation of strategies targeting environmental sustainability in Kenya's urban building and construction sector). The terminology "strategies" was used instead of "alternatives" because the latter tends to mean a single option can be chosen out of many options to address the problem, for instance, in selecting the most effective waste recycling method presented earlier in the case of Brazil by Gomes *et al.* (2008). The index *(SI)* for this model represented a *suitability index* for evaluating all the strategies analyzed.

The scaling of weights, unlike the case of South Africa by Ugwu and Haupt (2007), was reduced from 5 to 3 levels. Using fewer semantic differentials is less confusing to respondents and facilitates categorization. Nine criteria and ten strategies were identified to be suitable for this case study (Table 4.1). The strategies were scaled to four levels depending on perceived effectiveness. The model captured the perceptions of the various stakeholders on the relative importance of the given spatial planning and environmental management criteria (j = 1, 2, 3, ...N). This is based on the fact that different interest groups represent different objectives and criteria, as Morais and Almeida (2006) observed in their case study of water supply management in Brazil. These interests are usually competing or conflicting. Interaction with experts also acts as a validation process.

4.4 Data Analysis

For qualitative analysis, the zoning policy based on the Local Physical Development Plan for Nairobi (zones 3, 4, 5) was evaluated based on best practices in space utilization and allowance for environmental functions. A collaborative multi-stakeholder report by Ministry of Lands, Nairobi City Council, Karen and Langata District Association, Ministry of Water and Irrigation, and NEMA (The Karengata Local Physical Development Plan) was analyzed to reveal the level of environmental awareness and sensitivity to land management issues among the stakeholders in the sector. The spatial planning indicators for space economy analyzed were: "Site Occupancy Ratio", expressed as the percentage of the total area of a plot occupied by the footprint of a building, and "Floor-Area Ratio" (FAR) or "Floor Space Index "(FSI), expressed as the total floor area in a building block divided by the total area of the land parcel.

Weighting exercise

First, the analyst assigned weights to the decision criteria in the matrix shown in Table 4.1. These were referred to as modeller-assigned weights. The key to the weighting technique is shown below.

Key:

1 = Criteria of minor importance to environmentally sustainable building and construction

2 = Important criteria to environmentally sustainable building and construction

3 = Critical/very important criteria to environmentally sustainable building and construction

Kenyan stakeholders drawn from both the public and private sector as follows did the second weighting exercise:

- 2 practising civil engineers (French BCEOM Consulting Engineers)
- 2 environmental scientists (KIPPRA and Kings Consultants)
- 2 architects (Ministry of Public Works)
- 2 surveyors (Survey of Kenya)
- 3 urban/physical planners (Ministry of Lands and Ministry of Housing)
- 2 economists (KIPPRA)
- 2 GIS experts (Oakar Services Ltd)
- 2 persons representing the public

The perceived scores of the different strategies on the selected environmental criteria were scaled from 0-3 as follows:

Table 4.1: Decision matrix of environmental criteria and strategies

Strategies \ *Criteria*	*Land management*	*Water management*	*Waste management*	*Energy efficiency*	*Visual impact*	*Noise pollution*	*Ecology*	*Air quality*	*Health & safety*
Criteria weights	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8	W_9
Strategy scores	$d_{i,1}$	$d_{i,2}$	$d_{i,3}$	$d_{i,4}$	$d_{i,5}$	$d_{i,6}$	$d_{i,7}$	$d_{i,8}$	$d_{i,9}$
Waste re-use, recycling, reduction									
Water-saving measures									
Energy-saving measures									
Porous pavements									
Slum upgrading									
Harmonizing new development with neighbourhood									
Noise pollution reduction measures									
Space economy									
Regeneration of brownfields									
Landscaping									
$\sum_{i=1}^{10} d_{i,j}$									

0 = Has no visible effect on the corresponding criteria

1 = Has some remote/weak effect on the corresponding criteria

2 = Is effective on the criteria

3 = Is highly effective on the criteria

Since assigning the scores needs technical knowledge of the impact of the activities on the chosen criteria, only groups consisting of experts in the areas of environmental management and building and construction were consulted. A negative score was assigned where a strategy is perceived to be influencing the given criterion negatively, as is common practice in MCDA scorecard analysis. In cells where there were major score differences, the scores were discussed among the stakeholders to reach a consensus on the values. Except for the environmental scientists who, due to distance, could not discuss their weights together, all the other stakeholders were interviewed together and asked to discuss their assigned weights to reach a consensus.

Computation of Suitability Indices (SI)

The mean weights were taken to represent an overall balanced stakeholder judgement on the relative importance of the criteria. The modeller-assigned weights (integers) and the mean weights representing balanced stakeholder views (decimal numbers) were then normalized to add up to unity, hence standardizing them to a common reference scale. The decision matrix was then analyzed in Microsoft Excel by weighted summation using the normalized criteria weights to obtain aggregate indices. The weighted sum of rated strategies along the rows gives an index whose magnitude can be interpreted as the overall effectiveness of the given strategies in addressing all the given sustainability criteria. The sum along the columns $\sum_{i=1}^{10} d_{i,j}$ gives scores for the given criteria by taking contributions from all the strategies in the decision matrix.

The formula $SI_i = \sum_{j=1}^{9} d_{i,j} W_j$ gave the aggregate suitability index

(SI_i) for each of the ten strategies depending on how they scored on all the nine weighted criteria w_j in Table 4.1. The summation $\sum_{i=1}^{10} d_{i,j}$ gave the total score for each criterion depending on how it is effectively addressed by the given array of strategies. The outranking technique in MCDA was used to choose the most consistently highly ranked strategies, with high SI_i. These strategies, therefore, informed the priorities for policy intervention.

5. Results and Discussion

The reviewed literature and concepts confirm that environmental sustainability is a real issue for Kenya's development agenda. Kenya's estimated EF in the year 2003, which was about 15 per cent higher than its biocapacity, means the country has become an ecological debtor and is running an ecological deficit. The most likely reason is that Kenya liquidates its own productive ecosystems by using national resources faster than they can be regenerated, and urban lifestyle seems to be the stronger driver of these changes.

5.1 Findings on Spatial Efficiency

Site occupancy and floor area ratios are used in zoning policy to limit the amount of construction on a given site. Best environmental practices require preserving about 20-30 per cent of built environments as open space. These planning parameters are usually adapted to suit local socio-economic and physical conditions. A site occupancy ratio of about 70 per cent is optimal for most core areas, but local conditions can necessitate upward or downward adjustments.

Analysis of the Local Physical Development Plan for Nairobi (zones 3, 4, 5) revealed policy provisions for site occupancy ratios of 80 per cent in the CBD and core areas, 50-80 per cent for commercial and industrial sites, 50 per cent for mixed-use areas (residential and commercial combined), and 25-50 per cent for residential areas. The zoning policy provisions for Nairobi give a high site occupancy ratio. The vertical rise in urban housing for Nairobi is also relatively high, with Floor-Area Ratios of up to 6 in Nairobi's CBD and core areas. The serious problem at present is a lack of up-to-date master plans to guide spatial development in Kenyan cities, and this should be addressed urgently.

5.2 Rated Impact of the Strategies on the Studied Environmental Criteria

Engaging stakeholders in a consultative and participatory exercise is recommended in decision making processes for effective and socially acceptable results. Information exchange and consensus in opinions are also central to public policy development processes (Birkland, 2001). The tables below (Table 5.1 and 5.2) show the results based on the modeller's rating and the ones based on stakeholder ratings. Figures 5.1 and 5.2

show the aggregate indices from the analysis of the decision matrices in Microsoft Excel (Tables 5.1 and 5.3). The strategies that score higher on the criteria have higher aggregate indices.

Like the modeller, the stakeholders consistently gave the highest ratings to the criteria of air quality and health and safety, meaning there is consensus on the high relative importance of these criteria in Kenya's urban built environment. This result compares with the South African study, where health and safety criteria also scored highest (Ugwu and Haupt, 2007). Waste, land and water management criteria were ranked second in the order of importance. Ecology was rated lower than most of the criteria, but still recognized by the stakeholders to be an important factor (at a normalized mean weight of 0.09) and ranked higher than energy efficiency (Table 5.2).

5.3 Observed Differences in Stakeholder Views

The varying weights assigned in Table 5.2 attest to the dominance of divergent opinions on environmental criteria across the stakeholder groups . For instance, architects assigned critical importance to visual impact; surveyors and physical planners accorded such high importance to land management but least to energy efficiency; and environmentalists ascribed critical importance to the highest number of criteria: six out of the total nine. Common interests could be seen under the criteria of ecology, air quality, and health and safety; this is reflected by the lowest standard deviations (Table 5.2).

Energy efficiency scored the highest standard deviation, reflecting the high variation and potential for conflicts in rating the importance of energy efficiency in building and construction design and operations. Informed consensus building is therefore highly needed to improve the consideration of energy efficiency in urban planning and design strategies, which is indeed a highly important factor of environmental sustainability in the built environment, given the increase in carbon footprint fuelled by energy-intensive activities within urban communities.

5.4 Findings on Effective Environmental Strategies and Criteria Performance

Based on the aggregate indices obtained, both the modeller's results and the results based on balanced stakeholder views yielded the following

Table 5.1: Modeller-assigned weights and strategy scores based on informed judgement

Strategies \ *Criteria*	*Land management*	*Water management*	*Waste management*	*Energy management*	*Visual impact*	*Noise pollution*	*Ecology*	*Air quality*	*Health & safety*
Criteria weights	3	3	3	2	2	2	2	3	3
Waste re-use, recycling, reduction	2	3	3	1	2	0	2	1	2
Water-saving measures	2	3	2	1	1	0	2	0	1
Energy-saving measures	1	1	2	3	0	0	2	2	2
Porous pavements	2	2	1	0	-1	0	2	0	1
Slum upgrading	2	2	3	2	3	0	2	2	3
Harmonizing new development with neighbourhood	2	1	1	1	3	1	2	2	1
Noise pollution reduction measures	0	0	0	0	0	3	1	0	1
Space economy	3	2	1	1	2	0	2	0	1
Regeneration of brownfields	3	2	3	1	2	0	2	2	3
Landscaping	2	1	1	1	3	1	1	1	2
Normalized mean weights	0.13	0.13	0.13	0.09	0.09	0.09	0.09	0.13	0.13

Table 5.2: Weights assigned by stakeholders (based on different stakeholder evaluations)

	Land management	*Water management*	*Waste managemen*	*Energy efficiency*	*Visual impact*	*Noise pollution*	*Ecology*	*Air quality*	*Health & safety*
Civil engineers	2	3	3	2	2	3	2	3	3
Enviromentalists	2	3	3	3	2	3	2	3	3
Architects	2	2	2	2	3	2	2	3	3
Surveyors	3	2	2		3	3	2	2	3
Urban planners/physical planners	3	2	3		2	2	2	3	3
Econo[illegible]ts	3	3	3	1 2	2	2	2	3	3
Public	3	3	3	1 2	2	2	2	3	3
M[illegible]	2.57	2.57	2.71	1.86	2.29	2.43	2	2.86	3
Standard deviation	0.53	0.53	0.49	0.69	0.49	0.53	0	0.38	0
Normalized mean	0.12	0.12	0.12	0.08	0.10	0.11	0.09	0.13	0.13

Table 5.3: Weights and strategy scores based on a balanced viewpoint of stakeholders

Strategies \ Criteria	*Land management*	*Water management*	*Waste management*	*Energy efficiency*	*Visual impact*	*Noise pollution*	*Ecology*	*Air quality*	*Health & safety*
Criteria weights	2.57	2.57	2.71	1.86	2.29	2.43	2	2.86	3
Waste re-use, recycling, reduction	2	3	3	1	2	0	2	1	2
Water-saving measures	2	3	2	1	1	0	2	0	1
Energy-saving measures	1	1	2	3	0	0	2	2	2
Porous pavements	2	2	1	0	-1	0	2	0	1
Slum upgrading	2	2	3	2	3	0	2	2	3
Harmonizing new development with neighbourhood	2	1	1	1	3	1	2	2	1
Noise pollution reduction measures	0	0	0	0	0	3	1	0	1
Space economy	3	2	1	1	2	0	2	0	1
Regeneration of brownfields	3	2	3	1	2	0	2	2	3
Landscaping	2	1	1	1	3	1	1	1	2

Figure 5.1: Modeller's results on aggregate indices for strategies in the decision matrix

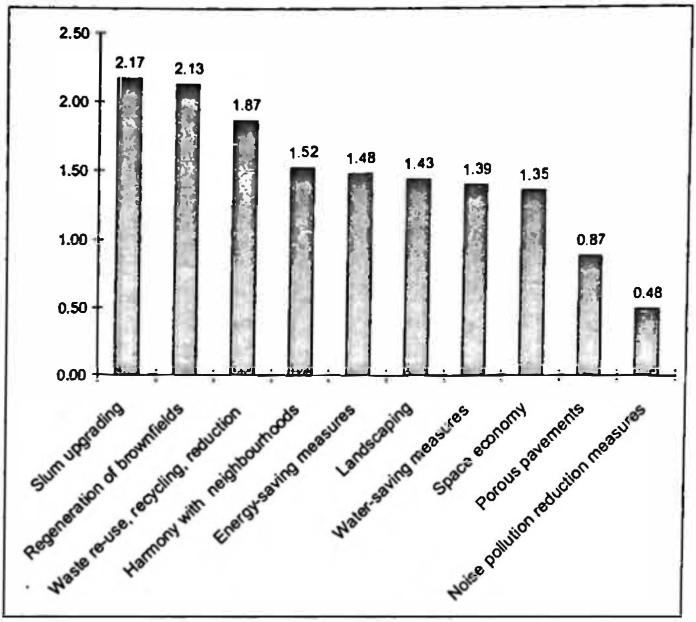
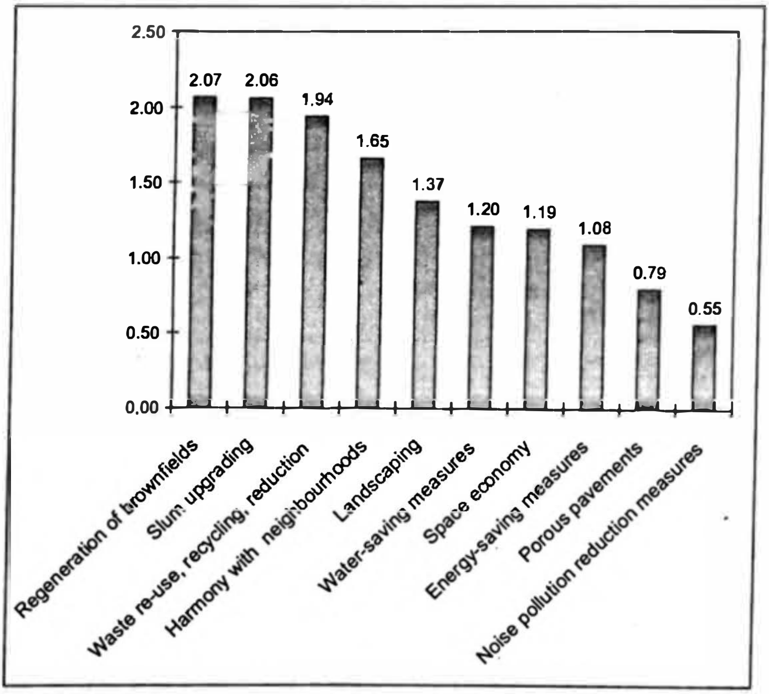


Figure 5.2: Stakeholders' results on aggregate indices for strategies in the decision matrix



four strategies that consistently emerged tops (Figures 5.1 and 5.2): slum upgrading, regeneration of brownfields, waste mitigation measures, and harmonizing new developments with their neighbourhoods. Given the different actors and instances involved, it is not possible to obtain the same aggregate indices for each case study. The consistency of higher ranking for particular strategies in both cases with different actors, however, displays these strategies to be the high-priority or most effective solutions.

On balance, these four strategies are the most effective since the results mean that they score well on most of the criteria considered, especially the critical ones, and can therefore pay back on preferential emphasis by delivering solutions that are more effective in the urban built environment. Noise-reduction strategies and porous pavements ranked lowest in both cases, meaning that they do not deliver quality on many of the (important) criteria. Porous pavements had a negative score on the criterion of visual impact because of the perceived negative impact on aesthetics. The lower score of these two strategies shows that they address only a few specific criteria. Results from both the modeller and stakeholders gave the criteria of noise pollution, energy efficiency, and air quality the lowest total score in their columns, got using $\sum_{i=1}^{10} d_{i,j}$. This suggests that the three criteria receive the weakest overall impact from the given strategies. New innovative strategies are therefore required to improve performance on these criteria.

5.5 Comparison with Other Research Findings

Parallels could be drawn to the methodological approach and findings by other researchers on similar sustainability topics. Morais and Almeida (2006) factored the importance of tourism in identifying priority cities for water supply investment in Brazil using qualitative measures converted to a numeric scale from 0 - 1 (0 = weak; 0.33 = regular; 0.67 = good; 1.00 = very good). Ugwu and Haupt (2007) used a sample of 49 industry stakeholders attending national health and safety workshops and seminars in South Africa. They justified this sample size as a convenient source of reliable expertise and ensured consensus in assignment of weights to performance indicators by engaging stakeholders in focus group discussions.

Gomes *et al.* (2008) used a scale from 1 to 11 to rate the impact of waste recycling on corporate image. They used a sample of only nine experienced specialists, three per category (government, manager, and consumer) and justified this number on the basis that the chosen specialists had enough experience and skills to represent the "ideal" point of view for each category. The used sample of 17 experienced stakeholders representing different professions and institutions of relevance to Kenya's urban building and construction sector, given resource limitations to carrying out a comprehensive primary data collection, is therefore justifiable for this study.

This study identified the four leading strategies that can most effectively ensure the achievement of the policy targets on the Kenya Vision 2030 for sustainable housing and infrastructure development. This small number of key strategies can guide investigations into a small set of sustainability indicators suitable for each environmental action.

6. Conclusions and Recommendations

6.1 Conclusions

The study identified that the building and construction sector is key both globally and locally to environmental sustainability agenda, with existing estimates confirming that it contributes to at least a third of environmental degradation processes. The situation in Kenya is wanting in terms of data and a system of indicators and criteria for sustainable building and construction. Stakeholders are, however, conscious of the need to ensure environmental sustainability in the urban built environment against the backdrop of urban population pressures. Based on both the modeller's results and results got through stakeholders' participation, health and safety and air quality are undisputedly viewed locally as the most critical criteria in urban building and construction. Waste, land and water management follow closely in this perceived hierarchy of importance. Ecology, though unanimously recognized to be important, is still mostly regarded less important than the criteria of noise pollution and visual impact. The top-four priority strategies that stakeholders considered most effective in ensuring an environmentally safe and healthy urban built environment are:

- Slum upgrading
- Brownfield regeneration
- Waste re-use, recycling and reduction (3R philosophy)
- Harmonizing new spatial developments with their neighbourhoods

These results, based on the case of Nairobi, are considered typical of the scenarios characterizing upcoming Kenyan towns. The multiple criteria decision aid proposed in this study can facilitate a participatory identification of crucial policy interventions based on stakeholder judgements. The dilemma between economic growth and environmental sustainability goals is not anything new, and tools for assessing sustainability must be able to handle subjective value judgements in a multiple criteria and a multi-stakeholder setup. Evidently, if population growth and urbanization continue in their most likely upward trends, the environment will remain the most vulnerable pillar of sustainable development. The disconnect between economic and environmental mandates of institutions has been a major setback to sustainable development, and bridging this gap is the principal challenge in terms of methodology and operations.

The Kenya Vision 2030 and national targets on MDG 7 can draw lessons from this study in terms of benchmarking and modelling for decision making amidst multiple criteria and stakeholder interests in this sector that remains critical to national development and environmental sustainability. There is no single-criteria method that can seek best-compromise solutions to the concerns and biases characterizing this sector.

6.2 Environmental Implications and Policy Recommendations

Though debatable, environmental sustainability will remain one of the most central issues claiming growing research interests in developing countries, as studies create more awareness of the vital and complex connections between the state of environment and human survival. The ecological footprint concept raises real questions on Kenya's ecological sustainability in the face of urbanization, the associated rising living standards, and population growth. The fact that Kenya has an ecological debt (deficit) aggravates this concern.

The built environment in Nairobi reveals a weak spatial development strategy and glaring loopholes for environmental degradation and risks to human health and safety. One of the goals of the Vision 2030 is to establish housing technology centres in each constituency to increase access to decent housing by promoting location-specific building materials and low-cost housing (Government of Kenya, 2008a). Ensuring environmental sustainability in the local building and construction must, therefore, meet the following requirements:

- A comprehensive review of the building code and the current state of affairs in the urban building and construction sector. The process should aim at combating the main causes of environmental degradation and addressing policy gaps and environmental awareness creation
- A structured methodology for handling multiple criteria and conflicting or competing stakeholder views in order to facilitate decision making on policy priorities among various options.

Increased interdisciplinary environmental research and environmental education are therefore of essence. Using the standard estimate of 600g/capita/day of urban solid waste generation, it becomes evident that the housing and construction sector impacts immensely on urban environments. Only a quarter of solid waste is collected by municipal authorities and private garbage collectors in Kenya's urban areas (Government of Kenya, 2008b).

The four leading strategies from the MCDA results imply the need for greater emphasis on sustainable waste management, slum upgrading, regeneration of urban wasteland (hence the Nairobi Dandora dump site and abandoned or idle lands in Nairobi), and high professionalism in construction design and spatial planning to harmonize new urban developments with neighbouring land uses. As seen from the results above, the criteria of noise pollution, energy efficiency, and air quality received the lowest overall score from the strategies considered. The implication is that these criteria are addressed least effectively by the totality of the strategies above; therefore, economic incentives specifically targeting these criteria are necessary to promote new innovative strategies for addressing them and improving their environmental performance.

There is also the need for greater awareness creation and interventions to ensure energy efficiency in Kenya's urban housing and construction activities. Long-term strategic plans for urban development will require greater stakeholder participation.

The following policy recommendations were made from this study:

- Policy emphasis on slum upgrading and prevention of new slum formations is needed and a strict regulatory framework for implementing space-economical construction through densification principles.
- Redevelopment of brownfields needs conducive land policy instruments in urban planning so that potential building sites such as old abandoned sites left lying in waste can be taken stock of and regenerated. This policy provision will offer strategic advantages given the projected rise in Kenya's urban population (about 60% by 2015) and the concomitant rising need for new housing and construction. Local governments should therefore consider using land banking as a tool for development control and urban renewal.

- Policy on waste management should target the reduction of building and construction waste by promoting the use of recycled and prefabricated materials and borrowing adaptable "green building" concepts in new design and construction work.
- Physical planning policies and zoning must underscore the spatial harmony between existing land uses and new spatial developments.
- More economic incentives or disincentives need to be devised and implemented to ensure high environmental standards in building and construction and related research, especially targeting the highly rated health and safety and air quality aspects. Incentives for new innovative strategies are needed to address, particularly, the criteria of noise pollution, energy efficiency and air quality in Kenya's urban built environment. There is need for more education towards increased energy efficiency
- Kenya's education policy needs to use both formal and informal methods innovatively to reach diverse groups, increase public environmental awareness, and encourage efficiency in the management of water, waste, and energy within buildings.

The study can be improved by involving a wider cross-section of stakeholders and using additional sustainability indicators drawn from social and economic dimensions. In this respect, the Multi-attribute Utility Trade-off Analysis method will be suitable because factors such as resource consumption and management can be included, which requires an expanded scope of study and extensive collection of primary data on the costs and social implications of implementing the strategies. The high-priority factors identified in this study will offer treasured environmental input into the recommended evolutionary approach to, and adaptive management of, the progress towards sustainability.

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Appendix

Elements of the HQE²R methodological framework

5 SD objectives	21 SD Targets	51 Key Issues	
To preserve and enhance heritage and conserve resources	1 – To reduce energy consumption and improve energy management	1A	To improve energy efficiency for heating and cooling
		1B	To improve energy efficiency for electricity
		1C	To use renewable energy sources
		1D	To fight against the greenhouse effect gas emissions
	2 – To improve water resource management and quality	2A	Drinking water consumption
		2B	Use of rainwater
		2C	Rainwater management
		2D	Sewerage network
	3 – To avoid land consumption and improve land management	3A	Optimization of the land consumption
		3B	Regeneration of brownfields and polluted sites and soils
		3C	Integration of environmental concerns in urban planning
	4 – To reduce the consumption of materials and improve their management	4A	Integration of recycled and reusable materials in construction, retrofitting and demolition process
		4B	ibid for public spaces
	5 – To preserve and enhance the built and natural heritage	5A	Enhancement of the architectural quality
		5B	Preservation / valorisation of the natural heritage
To improve the quality of the local environment	6 – To preserve and enhance the landscape and to improve visual comfort	6A	Visual quality of natural landscape
		6B	Visual quality of urban landscape
	7 – To improve housing quality	7A	Building Quality
		7 B	Housing Quality
		7C	Satisfaction of users and residents

5 SD objectives	21 SD Targets	51 Key issues	
	8 - To improve cleanliness, hygiene and health	**8A**	Improvement of the cleanliness in the neighbourhood and in the common spaces
		8B	Substandard housings
		8C	Right and access to care and health
	9 - To improve safety and risk management	**9A**	Improvement of safety of people and goods
		9 B	Improvement of the road safety
		9 C	Local management of technological risks
		9 D	Local management of natural risks
	10 - To improve air quality	**10A**	Quality of interior air
		10 B	Quality of outside air
	11 - To reduce noise pollution	**11A**	Nuisances linked to the neighbour
		11 B	Noise pollution activity in the neighbourhood due to traffic or to activity
		11 C	Noise pollution due to construction site building
	12 - To minimize waste	**12A**	Household waste management
		12B	Site building waste management
To ensure diversity	13 – To ensure the diversity of the population	**13A**	Social and economic diversity
		13B	Age distribution diversity
	14 - To ensure the diversity of functions	**14A**	Presence of economic activities
		14B	Presence of retail stores
		14C	Presence of local amenities in the neighbourhood

5 SD objectives	21 SD Targets	51 Key issues	
	15 - To ensure the diversity of housing supply	**15A**	Diversity of housing
To improve integration	16 - To increase the levels of education and job qualification	**16A**	Foster academic success
		16B	Reinforcement of the role of the school in the neighbourhood
	17 - To improve access for all residents to all services and facilities of the city by means of an easy and non expensive transportation mode	**17A**	Improvement of the public transportation system
	18 - To improve the integration of the neighbourhood in the city by creating living and meeting places for all the inhabitants of the city	**18A**	Presence of attractive amenities in the neighbourhood
	19 – To avoid unwanted mobility and to improve the environmentally sound mobility infrastructure	**19A**	Safe and convenient footpaths and bicycle ways
		19B	Implementation of non-pollutant, coherent and efficient displacements systems
To reinforce social life	20 – To reinforce local governance	**20A**	Residents and users engagement in the SD process
		20B	Participation of residents to decision and projects related to the neighbourhood
	21 – To improve social networks and social capital	**21A**	Strengthening of community
		21B	Developing social economy
		21C	Cultural links across the globe

Source: Charlot-Valdieu et al. (2003)

Appendix Table 2: My ecological footprint: Quiz results

(Rated "ecologically conscientious lifestyle" that would need only one-third of the Earth to sustain assuming everyone lived such a lifestyle. Assumed 30 km daily travel by bus)

	My Footprint	Kenya Average
Carbon footprint (global acres)	2.75	0.91
Food footprint (global acres)	1.72	1.72
Housing footprint (global acres)	0.15	0.24
Goods and services footprint (global acres)	0.20	0.25
My total footprint (in global acres)	**4.82**	**3.12**
	My Footprint	**Kenya** Average
Cropland footprint (global acres)	0.62	0.42
Pastureland footprint (global acres)	1.88	1.31
Marine fisheries footprint (global acres)	0.91	0.49
Forestland footprint (global acres)	1.42	0.91
My total footprint (in global acres)	**4.82**	**3.12**
Number of Earths Needed	**0.31**	**0.20**

Annex Table 3: Ecological footprint: Quiz results for a chosen KIPPRA employee

(Rated a lifestyle that would need only half of the Earth to sustain assuming everyone lived such a lifestyle. Assumed 30 km daily car driving distance)

	Footprint	Kenya Average
Carbon footprint (in global acres)	6.18	0.91
Food footprint (in global acres)	2.07	1.72
Housing footprint (in global acres)	0.22	0.24
Goods and services footprint (global acres)	0.20	0.25
Employee's total footprint (global acres)	8.67	3.12

	Footprint	Kenya Average
Cropland footprint (in global acres)	1.02	0.42
Pastureland footprint (in global acres)	2.97	1.31
Marine fisheries footprint (in global acres)	1.61	0.49
Forestland footprint (in global acres)	3.08	0.91
Employee's total footprint (global acres)	**8.67**	**3.12**
Number of Earths Needed	**0.55**	**0.20**

Source: Online quiz done at Redefining Progress - The Nature of Economics, www.rprogress.org