

# CONCEPTUAL FRAMEWORK OF ENVIRONMENTAL SUSTAINABLE INTERVENTIONS WITH THE USE OF GREEN INFRASTRUCTURE DESIGN CRITERIA ON PROJECTS

**S SAROOP and D ALLOPI** <sup>2</sup>

<sup>1</sup>Royal Haskoning DHV, P O Box 55, Pinetown, 3600, Tel: +27 (0)31 7195500  
Fax: +27 (0)31 7195505, E-mail: shian.saroop@rhdhv.com

<sup>2</sup>Department of Civil Engineering and Surveying  
Durban University of Technology, P O Box 1334, Durban, SA  
Tel (031) 3732310 Fax (031) 3732020  
E-mail: allop@dut.ac.za

## ABSTRACT

This paper presents a conceptual framework that incorporates eco-efficiency on Infrastructure projects with the use of the environmentally sustainable criteria on infrastructure projects.

Mainstreaming environmental aspects and incorporating the eco-efficiency concept into various stages of infrastructure development have not been considered as much as they should have been. Engineers need to look at greener technologies rather than just using traditional engineering solutions.

This paper aims to develop a framework that enables a project to be designed in accordance with environmentally sustainable criteria. The key aim of the framework was to create a more socially, economically, and environmentally sustainable neighbourhood, which focused on combating flooding, waste management, water recycling and enhancing biodiversity.

**Keywords:** Green Technology, Infrastructure design, Eco-efficiency, Sustainable development, Green infrastructure

## INTRODUCTION

As we face significant planetary issues such as global warming, it is clear that the civil engineering projects have a significant part to play in affecting the future of our planet. Globally, the construction industry is one of the main contributors to the depletion of natural resources and a major cause of unwanted side effects such as air and water pollution, solid waste, deforestation, health hazards, global warming, and other negative consequences.

There is lack of adequate tools and skills to undertake sustainable design on infrastructure projects

Civil engineering projects can have significant site-specific and cumulative impacts on our ecological and social systems if not correctly planned, designed and implemented.

Relatively few designers have as yet explored the transformative potential of ecological design and have preferred to remain apolitical and unconcerned with the distributional impacts of design as they affect the health of humans and ecosystems (Van Wyk, 2009).

Infrastructure development has been focused mainly on financing issues and engineering aspects in the region. Mainstreaming environmental aspects and incorporating the eco-efficiency concept into various stages of infrastructure development have not been considered as much as they should have been.

By utilising improved environmentally friendly-seeking design solutions, this study aims to introduce environmentally friendly design decisions prior to the infrastructure design approval process. This increases overall competitiveness by bringing a whole new class of productive solutions to problems while at the same time adding a fresh perspective to the traditional infrastructure design process.

## **OBJECTIVES**

The objectives of this paper are as follows:

To emphasis the influence of climate on sustainability;

- To incorporate environmentally friendly, ecologically sensitive innovative design, at the design stage of township infrastructure projects;
- To define green infrastructure solutions amongst engineers by establishing a common language and standard of measurement;
- To demonstrate the importance of criteria and sub-criteria on infrastructure projects;
- To raise awareness of green engineering benefits and the environmental impact of consultants' design decision, in order to reduce the environmental impact of development;

## **THE NEED TO IMPLEMENT SUSTAINABILITY ON CIVIL ENGINEERING INFRASTRUCTURE PROJECTS**

Infrastructure development has been focused mainly on financing issues and engineering aspects in the region. Mainstreaming environmental aspects and incorporating the eco-efficiency concept into various stages of infrastructure development have not been considered as much as they should have been (United Nations Economic and Social Commission for Asia and the Pacific, 2006).

The literature review undertaken of the various existing green rating tools, revealed that there are no tools in place, to rate the environmental impact of design solutions on infrastructure projects. There are a various rating tools presently available to Architects, builders and developers, such as the LEED Green Building rating system, the Green Star Rating Tool, etc., that rate the environmental performance of buildings.

The existing rating tools evaluates the environmental impacts of buildings but with little emphases on the environmental performance of civil engineering infrastructure. These tools do not adequately assess design criteria of civil infrastructure.

Green buildings embedded within unsustainable urban infrastructures will not deliver sustainability. There is a need for the whole site design as opposed to only the building. (Swilling, 2008).

In the area of sustainability, there is an urgent need to apply technologies and methods that deliver better and more sustainable performance in a way that is cost effective. Sustainability, adaptive and mitigative approaches to climate change, in the design of infrastructure are therefore important steering elements (FIDIC, 2009).

In light of the above, there is a need for more effective methods of assessing and rating infrastructure design options and components on infrastructure projects. Given the broad global range of issues and challenges, in the quest for creating a sustainable built environment, stakeholders desperately need a consistent framework of indicators to measure sustainable civil infrastructure.

Civil infrastructure has various opportunities to undertake an innovative, efficient and sustainable design instead of a conventional design but this rarely happens in practice.

Incorporating this perspective into the civil engineering infrastructure designing, planning, and building stages can have significant effects on the outcome.

Infrastructure elements such as roads, water, sewage and stormwater can result in loss of critical ecosystems and biodiversity. There is a need to create an eco-sensitive infrastructure design rating system that encourages and promotes the use of “softer” design solutions.

The proposed research proposes a toolkit that uses the concept of green building tools and develops a green infrastructure design rating system that assesses the environmental impacts of infrastructure design options on developments.

Diligent attention to greener infrastructure solutions from the very earliest phases of a project will help guarantee that quality design environmental solutions are "built in" from the beginning.

## **THE USE OF SUSTAINABILITY CRITERIA ON INFRASTRUCTURE DESIGN**

The role of criteria for sustainable green infrastructure are tools or indicators, which can be used in the conceptualization, implementation, and monitoring of progress in township infrastructure projects. The criteria define the essential components of the proposed Green infrastructure toolkit against which sustainability may be assessed. Thus, collectively, the criteria provide an implicit, generally agreed-upon global definition, for the concept of sustainability on infrastructure projects.

Each criterion relates to a key element of sustainability. Through the measurement and monitoring of these indicators, the overall effects of the proposed Green infrastructure toolkit, can be assessed and evaluated, and action can be adjusted to meet stated aims and objectives more effectively

The client’s vision, goals and objectives for Environmental sustainability on a project can be translated into a core set of project criteria. While project goals set the direction, the project sustainability categories provide the means to measure a project. It enables clients, engineers and stakeholders to gauge progress toward sustainable development by comparing the performance achieved on a project with the intended performance.

The Environmental Sustainability criteria that characterize sustainable criteria of Green township infrastructure are listed in Table 1.

The Eco Efficient Infrastructure Sustainability Criteria namely Efficient Layout Planning ensures that infrastructure is placed in environmentally responsible ways. The Resources criteria encourage an efficient utilisation of materials/ resources. Environmental Quality mitigates environmental impacts of infrastructure. Functional Efficiency ensures that infrastructure is designed optimally. Future Maintenance maximizes the opportunities for integrating capital and operation of infrastructure. Economy maximizes the opportunities for integrated cost effective adoption of green infrastructure options. The Safety criteria encourages the designer to assess potential safety hazards of the infrastructure element from both an operational and construction point of view. Social sustainability of infrastructure promotes the use of social resources, encourages public participation and the placement of infrastructure in the most convenient manner.

**Table 1: The eco efficient infrastructure performance criteria**

<b>Eco-efficient infrastructure Sustainable criteria</b>	<b>Measure</b>
1. Efficient Layout planning	Placement of infrastructure in environmentally responsible, efficient ways, conserve land.
2. Resources	Encourages the efficient utilisation of materials/ resources, selection of environmentally friendly materials.
3. Environment Quality	Design features that mitigate environmental impacts of infrastructure, by reducing the effects of pollutants
4. Functional Efficiency	Design of infrastructure that maximizes functional efficiency of infrastructure.
5. Future maintenance	Maximizes the opportunities for integrating capital and operation of infrastructure, ensuring reliability of level of service
6. Economy	Maximizes the opportunities for integrated cost effective adoption of green infrastructure options.
7. Safety	Minimizes the environmental impact of infrastructure by incorporating safety into the design.
8. Social	Ensuring social sustainability of infrastructure, promoting convenience, social resources and public participation.

The Infrastructure Sustainability criteria used in the proposed Green Township Infrastructure Design Toolkit were developed to:

- Determine the means by which eco- environmental efficiency can be assessed, monitored, quantified and verified at any stage of the project, to ensure a value-added, quality driven, green approach to infrastructure design;
- Provide a basis for the consultants and clients to work together on creating and evaluating sustainable infrastructure solutions, thereby ensuring comprehensive infrastructure planning with maximum stakeholder involvement;
- Achieve the required balance of sustainability, expenditure, value for money and quality, between the various elements of the project;

## **WEIGHTING OF ENVIRONMENTAL SUSTAINABILITY INDICATORS**

Weighting of the Infrastructure Environmental Sustainability Categories allows the project team to target or prioritise certain infrastructure environmental sustainable performance categories over the various elements of the project.

The client may have specific green goals in mind, such as Functional Efficiency, Economy or Social criteria that are more important than the other. The weighting of the various categories is carried out at this early stage, before the design is developed, to avoid redesign later in the process.

The proposed Infrastructure Environmental Sustainability Categories Weighting Report Form enable the project to be tailored to the client's project requirements and specifications, at the earliest stages of the development process.

A lot of flexibility exists in the green township design rating system, so that designers can focus on specific categories applicable to each design situation. The weighting and setting of Targets for the Sustainability Categories helps the designer understand the many design choices which need to be made using sustainability such as Efficient Layout Planning, Functional Efficiency, Environmental Quality, Economy, Future Maintenance, Safety, Social and Resources, and their impact on the overall economics of the project.

Sustainability criteria focus on scarce resources and priority areas; and to improve accountability linking project level work to the achievement of strategic objectives.

This Green Value approach will transform design goals into specific performance objectives and provide a framework to assess the overall design, using the standardised Report thus ensuring Sustainability

## **THE GREEN TOWNSHIP INFRASTRUCTURE RATING SYSTEM FOR INFRASTRUCTURE PROJECTS**

This paper is a follow up on the proposed rating system that enforces environmentally sustainable design on township infrastructure services by integrating a consideration of resources, the environment, ecologically sensitive innovative design, maintenance and recyclable materials, from the early design stages of a project.

The Green Township Infrastructure Design Toolkit, as illustrated in Figure 1, uses the concept of eco-efficiency and would allow the designer to evaluate design options, enabling him/her to choose the one most likely to yield the best performance with the least environmental impact, based on proven technology.

This toolkit is intended to encourage developers to consider green methods and practices in the earliest stages of project planning, by assessing a number of recommended green practices and its environmental impacts on infrastructure services design, placing fewer burdens on the environment.

The various Green Report Forms, enables the client to select a combination of alternatives and evaluate a number of possible design options – with their environmental implications – at each stage of the design process (Saroop and Allopi, 2013).

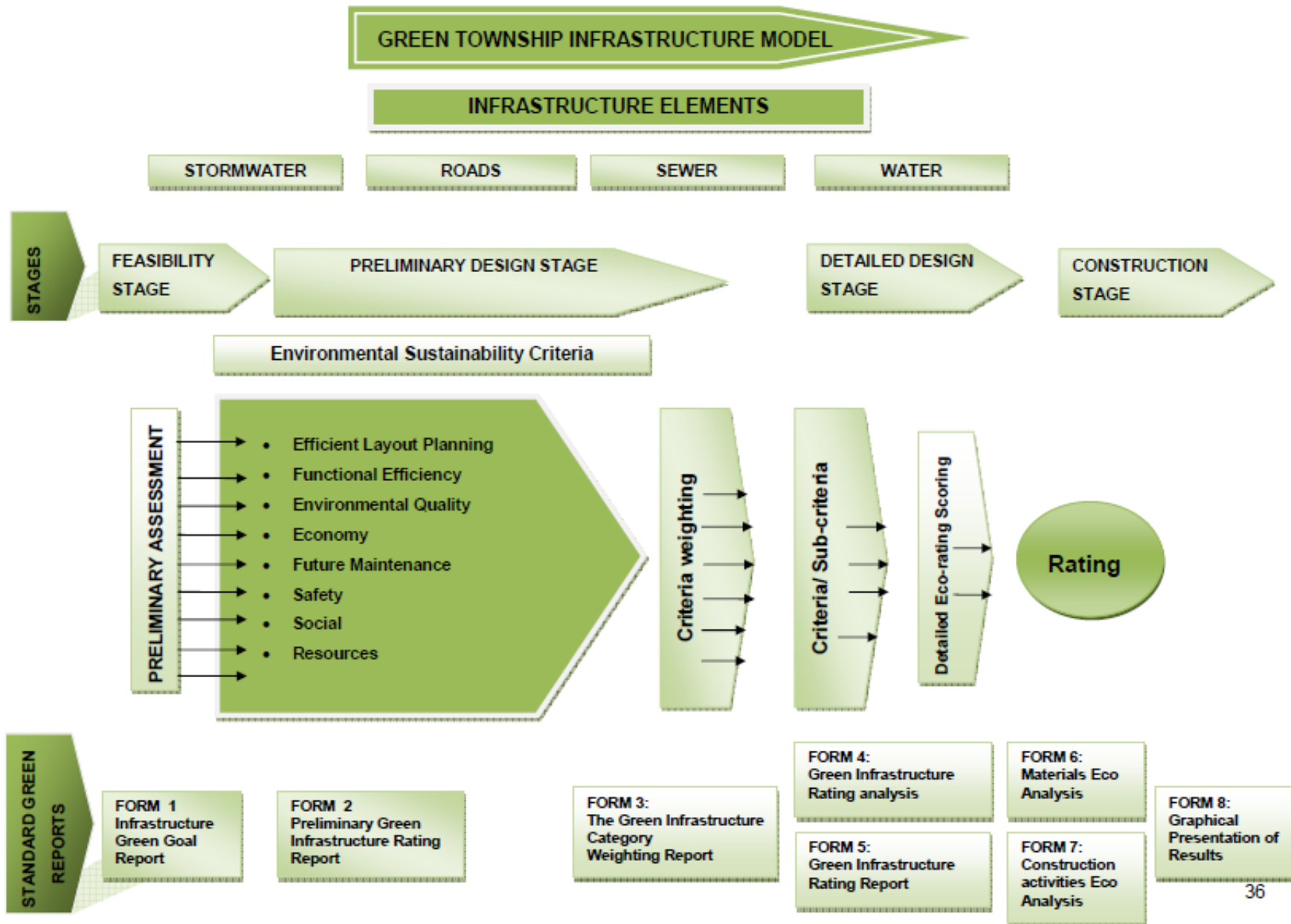


Figure 1: The Green Township Infrastructure Design Toolkit (Sarop, 2013)

## **GREEN INFRASTRUCTURE TECHNOLOGIES THAT CAN BE USED ON TOWNSHIP INFRASTRUCTURE PROJECTS**

Innovative approaches to planning and design can greatly mitigate the negative impacts of infrastructure services on the environment. Various green technology concepts were researched and modified to suit township infrastructure projects, with the aim of reducing the impacts of civil engineering infrastructure on residential developments.

Green Technology that can be used on infrastructure projects may include the utilization of natural or engineered systems that mimic natural landscapes in order to capture, cleanse and reduce stormwater runoff. Greener stormwater infrastructure solutions can include rain gardens, rain barrels, green roofs, wetlands, permeable pavement and other methods intended to significantly reduce the amount of stormwater runoff entering the sewer system and our waterways.

Roads present many opportunities for green infrastructure application that incorporates a wide variety of design elements, including street trees, permeable pavements, bio-retention, and swales. The various design solutions of a township were broken down into various elements in order to identify alternative ways in which greener solutions can be achieved.

This eco-efficient design various sustainable infrastructure solutions which are categorized into various sustainability criteria, under various elements in the Figure 2 below:

### **ADVANTAGES OF USING THE ECO APPROACH TO INFRASTRUCTURE DESIGN**

Green township infrastructure technologies will contribute to greenways and green corridors and provide linkages between habitats, and wetlands. Green technologies have a number of environmental, economic benefits and community benefits. The benefits of this approach are as follows:

#### **Resource benefits:**

- Recycling of used products
- Conservation of natural resources
- Recharged ground water flow for streams, conserving water supplies.

#### **Environmental benefits:**

- Enhance and protect ecosystems and biodiversity
- Increased vegetation, improve air quality by filtering many airborne pollutants
- Minimized impervious surfaces, reducing soil erosion
- Reduced concentrations of pollutants

#### **Economic benefits:**

- Reduced infrastructure costs by water collection, storage, treatment and distribution
- More efficient use of existing infrastructure
- Reduced operating costs
- Enhanced asset value and profits
- Optimized life-cycle economic performance

#### **Social and community benefits:**

- Promoting convenience, social resources and public participation
- Improved environments
- Community safety
- Convenience of users
- Enhanced occupant comfort and health
- Minimized strain on local infrastructure
- Contributed to overall quality of life

Green techniques provide adaptation benefits for a wide array of circumstances, by conserving and reusing water, promoting groundwater recharge, and reducing surface water discharges that could reduce to flooding.

In addition to this, vegetation improves urban aesthetics and community liveability by providing recreational and wildlife areas. Green infrastructure may save capital costs associated with paving, creating curbs and gutters, building large stormwater conveyance systems, other hard infrastructure; energy costs and costs of repairing the damage caused by stormwater, such as streambank restoration.



GREEN TOWNSHIP INFRASTRUCTURE TECHNOLOGIES				
	ROADS	SEWER	STORMWATER	WATER
1. LAYOUT PLANNING	<ul style="list-style-type: none"> <li>- Relaxed Setbacks and narrow frontages</li> <li>- Promote concept of greenstreets</li> <li>- Ecological Connectivity-Open spaces</li> <li>- Shared driveways (Permeable)</li> <li>- Landscape: Water efficient plantings</li> <li>- Align roads with natural topography</li> </ul>	<ul style="list-style-type: none"> <li>- Layout promote midblock sewer</li> <li>- Minimise sewer pipeline in floodline</li> <li>- Avoidance of pumpstations</li> <li>- Optimised route alignment</li> <li>- Contour layout planning</li> <li>- Catchment planning</li> </ul>	<ul style="list-style-type: none"> <li>- Green corridors-Natural drainage paths</li> <li>- Multipurpose stormwater facilities</li> <li>- Open spaces for retarding/ponding sw</li> <li>- Buffer systems (width)</li> <li>- Attenuation/ retention facilities planned</li> </ul>	<ul style="list-style-type: none"> <li>- Location &amp; Spacing of Fire hydrants</li> <li>- Optimised pipe route alignment</li> <li>- Reticulation pipes are looped -efficiency</li> <li>- Piping arranged to allow ready shut off valves</li> <li>- Low demand land uses on high ground</li> <li>- land uses with high demand close to bulk mains</li> </ul>
2. RESOURCES	<ul style="list-style-type: none"> <li>- Alter Surfacing-Permeable pav/asphalt/conc. Reinforced Turf, Grass block, Paved strips</li> <li>- Pavement Layerworks-Recycled</li> <li>- Alternative Transportation Options</li> <li>- Earthworks- balanced-Cut / Fill</li> <li>- Tree conservation</li> </ul>	<ul style="list-style-type: none"> <li>- Backfill - non commercial source</li> <li>- Reed bed systems</li> <li>- Manhole types- brick/precast</li> <li>- Pipe material - pvc/concrete/hdpe</li> <li>- Avoid the Use of pumpstations</li> <li>- Nutrient resource recovery &amp; reuse</li> </ul>	<ul style="list-style-type: none"> <li>- Pipe material - pvc/concrete/hdpe</li> <li>- Source/type of Bedding</li> <li>- Use of Eco. Fr Manhole types- brick/precast</li> <li>- Rain water harvesting and Reuse</li> <li>- Recycling of stormwater</li> <li>- Promote aquifer storage and recovery</li> </ul>	<ul style="list-style-type: none"> <li>- Water demand management measures</li> <li>- Smart Zone and bulk metering</li> <li>- Raw water quantity requirements &amp; availability</li> <li>- Use of Present &amp; future water consumption figures</li> <li>- Promote use Water Efficient fixtures/Appliances</li> </ul>
3. ENVIRONMENT QUALITY	<ul style="list-style-type: none"> <li>- Reduce no. of valley crossings</li> <li>- Erosion control measures</li> <li>- Mitigate impacts on environment</li> <li>- Reduce clearing and grading (Site Vegetation)</li> <li>- Habitat Restoration</li> </ul>	<ul style="list-style-type: none"> <li>- Reed bed systems</li> <li>- non water-based sewage conveyanc</li> <li>- Prob of groundwater contamination</li> <li>- Flood protection of pumpstation</li> <li>- Waste effluent quality</li> </ul>	<ul style="list-style-type: none"> <li>- Post Development &lt; Predev Flow</li> <li>- Recharge rates maintained</li> <li>- Protection measures of wetlands</li> <li>- Runoff quality-Constructed Wetlands/filters</li> <li>- Minimize stormwater concentration</li> </ul>	<ul style="list-style-type: none"> <li>- Use of boreholes &amp; reliability of water source</li> <li>- Spring protection measures</li> <li>- Water quality &amp; proximity to sources of potential water supply contamination</li> <li>- Valve/Meter/Standpipe located convenient positions</li> </ul>
4. FUNCTIONAL EFFICIENCY	<ul style="list-style-type: none"> <li>- Use of Permeable pavements</li> <li>- Use drainage and storage functions of roads</li> <li>- Use of cool/warm mix asphalt</li> <li>- Use of Streetscaping</li> <li>- Low impact road design</li> <li>- Enhanced pedestrian facilities/bicycle paths</li> <li>- Parking ratios/codes/parking lots</li> <li>- Quiet Pavement</li> <li>- Varying detail to create diversity and interest</li> </ul>	<ul style="list-style-type: none"> <li>- Separate grey water/ black water</li> <li>- Oil/grease/grit separators</li> <li>- Use of On-site Treatment</li> <li>- Primary/Secondary greywater reuse</li> <li>- Sewer attenuation</li> <li>- Reticulated recycled water supply</li> <li>- innovative wastewater technology</li> </ul>	<ul style="list-style-type: none"> <li>- Quality of runoff from residential rooftop: Downpipe disconnect, Rain Barrels,soakaways</li> <li>- Runoff Flow Control-Sand Filters</li> <li>- Bioretention swales/ponds/infiltration berms</li> <li>- Erosion control(Geotextile/cells gabions)</li> <li>- Sediment control- Silt fences/Stilling basin</li> <li>- Rooftop runoff direct to pervious surfaces</li> <li>- Stormwater Management Plan</li> </ul>	<ul style="list-style-type: none"> <li>- Water-Efficient Irrigation &amp; landscaping measures</li> <li>- Use of Roof tank/intermediate storage</li> <li>- Pressure Management as part of design</li> <li>- Dry Fire Hydrants, suction pipe systems from pond</li> <li>- Efficient water systems design</li> <li>- Watertight joints/Seals quality - pressures</li> <li>- Ensure water balance in system</li> <li>- Optimised velocity in pipe</li> <li>- Water efficient fittings</li> </ul>
5. FUTURE MAINTENANCE	<ul style="list-style-type: none"> <li>- Maintainance of grass/natural environment</li> <li>- Bank slopes must be designed to be gentle</li> <li>- Pavement lifecycle design</li> <li>- Type of tree planting- prevent leaves falling</li> </ul>	<ul style="list-style-type: none"> <li>- Self-cleaning velocity in sewers</li> <li>- Life span of the pipes and materials</li> <li>- Access for maintenance(Mh &amp; pipe)</li> <li>- Erf have a rodding eye</li> <li>- Services watertight</li> </ul>	<ul style="list-style-type: none"> <li>- Design consider maintenance needs</li> <li>- Flood plain accessible</li> <li>- Life span of the pipes and materials</li> <li>- Reduce large open spaces</li> <li>- Inlet/outlet design to reduce blockages</li> </ul>	<ul style="list-style-type: none"> <li>- Life span of the pipes and materials</li> <li>- Services watertight</li> <li>- Positioning of trees - proximity of services</li> <li>- Leak Detection devices in retic.</li> <li>- Provisions for future expansion of the system</li> </ul>
6. ECONOMY	<ul style="list-style-type: none"> <li>- Optimised level of service</li> <li>- Minimize the number of road intersections</li> <li>- Use of narrower shorter streets</li> <li>- Curvilinear roads increases no of manholes</li> <li>- Pavement Life-Cycle Cost Analyses</li> </ul>	<ul style="list-style-type: none"> <li>- Optimised level of service</li> <li>- Increased % mid-block sewer</li> <li>- Maximum manhole spacing</li> <li>- Use of shared trenches</li> <li>- Long lengths of opens space</li> </ul>	<ul style="list-style-type: none"> <li>- Optimised level of service</li> <li>- Rain water harvesting techniques</li> <li>- Use of shared trenches</li> <li>- Maximum manhole spacing</li> </ul>	<ul style="list-style-type: none"> <li>- Optimised level of service</li> <li>- Use of shared trenches</li> <li>- Max. hydrants, airvalve spacing</li> <li>- Aproprate water demands</li> <li>- Use of eco Pipe material - pvc/concrete/hdpe</li> </ul>
7. SAFETY	<ul style="list-style-type: none"> <li>- Use of traffic calming measures</li> <li>- Signage and sense of place</li> <li>- Safe street and unique public space</li> <li>- Safe intersection-pedestrian friendliness</li> </ul>	<ul style="list-style-type: none"> <li>- Trench depths &lt;3m</li> <li>- Position in relation to water pipe</li> <li>- Reduced depth of manholes</li> </ul>	<ul style="list-style-type: none"> <li>- Safe discharge routes</li> <li>- Reduced velocity /depth of stormwater flow</li> <li>- Reduced depth of manholes</li> <li>- Inconvenience of overland flow</li> </ul>	<ul style="list-style-type: none"> <li>- Increased Fire risk category</li> <li>- Velocity of water flowing</li> <li>- Reduced depth of manholes</li> <li>- Reduce pressure on pipeline</li> </ul>
8. SOCIAL			<ul style="list-style-type: none"> <li>- Public facilities</li> <li>- Convenient pedestrian paths / crossings</li> <li>- Accessibility during the repair of services</li> </ul>	
			<ul style="list-style-type: none"> <li>- Planning for social and physical infrastructure</li> <li>- Improving the quality of life for the area</li> <li>- Ensuring developments contribute to economic growth</li> <li>- Informing and involving internal and external stakeholders</li> </ul>	

Figure 2: Green infrastructure technologies that can be used on infrastructure projects

## CONCLUSIONS

Sustainability criteria focus on scarce resources and prioritize areas; and to improve accountability linking project level work to the achievement of strategic objectives.

Improvement in the awareness of eco-efficiency concepts is urgently needed among policy-makers, planners and decision-makers. However, the criteria applicable to, and measures for developing eco-efficient and sustainable infrastructure are yet to be fully identified (United Nations Economic and Social Commission for Asia and the Pacific, 2006).

Green techniques provide adaptation benefits for a wide array of circumstances, by conserving and reusing water, promoting groundwater recharge, and reducing surface water discharges that could reduce to flooding.

A new paradigm for infrastructure design is required in order to ensure environmental sustainability on infrastructure projects

The weighting and rating of environmental sustainability criteria provide adaptation benefits and also provide the means to measure projects.

Engineers need to look at greener technologies rather than just using traditional engineering solutions. By using this green approach, sustainable design of township infrastructure services can be achieved by enforcing the consideration of resources, environmental impacts of ecologically sensitive design decisions, innovation, maintenance and materials, at the design stage of a project.

Taking a greener approach to infrastructure development not only mitigates the potential environmental impacts of development but makes economic sense as well. By softening the environmental footprint, avoiding waste and finding efficiencies, clients and local governments can increase their long term sustainability.

## REFERENCES

FIDIC, 2009. FIDIC State of the World Infrastructure Report 2009.

Richardson, J., Irwin T. and Sherwin C. 2005. Design & Sustainability: A Scoping Report for the Sustainable Design Forum. [Online]. Available at:

[http://webarchive.nationalarchives.gov.uk/tna+/http://www.dti.gov.uk/sustainability/pdfs/design\\_and\\_sustainability\\_report\\_June\\_2005.pdf](http://webarchive.nationalarchives.gov.uk/tna+/http://www.dti.gov.uk/sustainability/pdfs/design_and_sustainability_report_June_2005.pdf) [Accessed 1 December 2010].

Saroop, S. H. and Allopi, D. 2013. Enhancing Sustainable infrastructure with the aid of the Green Infrastructure Toolkit. Proceedings of the 6th International Conference on Sustainable Development and Planning 2013 (SDP13) Conference, May 27-29, held in Kos, Greece.

Swilling, M. 2008. Beyond buildings to city infrastructures. Proceedings of the Green Building Convention South Africa, November 2-4, South Africa.

Van Wyk, L. 2009. EcoBuilding: Towards an Appropriate Architectonic Expression, In Green Building Handbook for South Africa [online]. Available at: [http://researchspace.csir.co.za/dspace/bitstream/10204/3262/1/vanWyk1\\_2009.pdf](http://researchspace.csir.co.za/dspace/bitstream/10204/3262/1/vanWyk1_2009.pdf) [Accessed 13 April 2011]

United Nations Economic and Social Commission for Asia and the Pacific. 2006. Sustainable Infrastructure in Asia [online].

[http://www.unescap.org/esd/environment/mced/singg/documents/Sustainable Infrastructure in Asia.pdf](http://www.unescap.org/esd/environment/mced/singg/documents/Sustainable_Infrastructure_in_Asia.pdf) [Accessed 1 April 2010].