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

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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

Eco-efficient infrastructure Sustainable criteria	**Measure**
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).

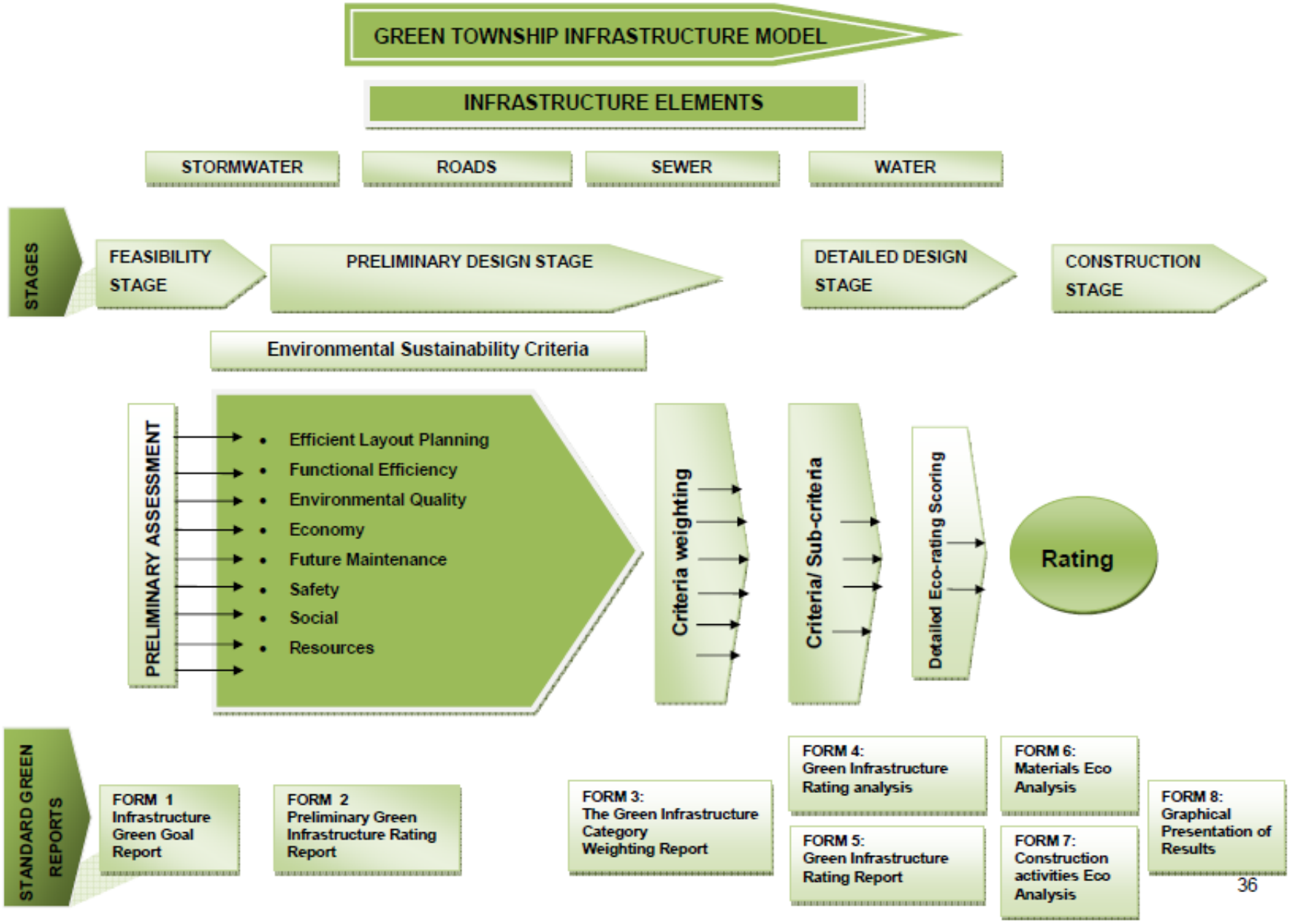

Figure 1: The Green Township Infrastructure Design Toolkit (Saroop, 2013)

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	- Relaxed Setbacks and narrow frontages	-Layout promote midblock sewer	- Green corridors-Natural drainage paths	-Location & Spacing of Fire hydrants
	- Promote concept of greenstreets	.- Minimise sewer pipeline in floodline	.- Multipurpose stormwater facilities	.- Optimised pipe route alignment
	.-Ecological Connectivity-Open spaces	.-Avoidence of pumpstations	.- Open spaces for retarding/ponding sw	.- Reticulation pipes are looped -effeciency
	.- Shared driveways (Permeable)	- Optimised route alignment	.- Buffer systems (width)	.- Piping arranged to allow ready shut off valves
	.-Landscape: Water efficient plantings	.- Contour layout planning	.- Attenuation/ retention facilities planned	.- Low demand land uses on high ground
	- Align roads with natural topography	.- Catchment planning		.- land uses with high demand close to bulk mains
2. RESOURCES	.-Alter Surfacing-Permeable pav/asphalt/conc.	.- Backfill - non commercial source	.- Pipe material - pvc/concrete/hdpe	.- Water demand management measures
	Reinforced Turf, Grass block, Paved strips	- Reed bed systems	.- Source/type of Bedding	- Smart Zone and bulk metering
	.- Pavement Layerworks-Recycled	.-Manhole types- brick/precast	- Use of Eco. Fr Manhole types- brick/precast	.- Raw water quantity requirements & availability
	.- Alternative Transportation Options	.-Pipe material - pvc/concrete/hdpe	- Rain water harvesting and Reuse	.- Use of Present & future water consumption figures
	.- Earthworks- balanced-Cut / Fill	.-Avoid the Use of pumpstations	- Recycling of stormwater	.-Promote use Water Efficient fixtures/Appliances
	.- Tree conservation	.- Nutrient resource recovery & reuse	.- Promote aquifer storage and recovery	
3. ENVIRONMENT QUALITY	- Reduce no. of valley crossings	- Reed bed systems	.- Post Development < Predev Flow	.- Use of boreholes & reliability of water source
	- Erosion control measures	-non water-based sewage conveyanc	.- Recharge rates maintained	.- Spring protection measures
	- Mitigate impacts on environment	- Prob of groundwater contamination	.- Protection measures of wetlands	.-Water quality & proximity to sources of potential
	.-Reduce clearing and grading (Site Vegetation	- Flood protection of pumpstation	- Runoff quality-Constructed Wetlands/filters	water supply contamination
	.-Habitat Restoration	- Waste effluent quality	.- Minimize stormwater concentration	.-Valve/Meter/Standpipe located convenient positions
4. FUNCTIONAL EFFICIENCY	.- Use of Permeable pavements	- Separate grey water/ black water	.- Quality of runoff from residential rooftop:	.- Water-Efficient Irrigation & landscaping measures
	- Use drainage and storage functions of roads	.- Oil/grease/grit separators	Downpipe disconnect, Rain Barrels,soakaways	- Use of Roof tank/intermediate storage
	.- Use of cool/warm mix asphalt	.- Use of On-site Treatment	.-Runoff Flow Control-Sand Filters	.- Pressure Management as part of design
	.- Use of Streetscaping	- Primary/Secondary greywater reuse	.-Bioretention swales/ponds/infiltration berms	.- Dry Fire Hydrants. suction pipe systems from pond
	.- Low impact road design	.-Sewer attenuation	-Erosion control(Geotextile/cells,gabions)	- Efficient water systems design
	.-Enhanced pedestrian facilities/bicycle paths	.- Reticulated recycled water supply	-Sediment control- Silt fences/Stilling basin	,-Watertight joints/Seals quality - pressures
	- Parking ratios/codes/parking lots	.-Innovative wastewater technology	- Rooftop runoff direct to pervious surfaces	.- Ensure water balance in system
	- Quiet Pavement		.- Stormwater Management Plan	.- Optimised velocity in pipe
	.-Varying detail to create diversity and interest			- Water efficient fittings
5. FUTURE MAINTENANCE	.- Maintainance of grass/natural environment	.-Self-cleaning velocity in sewers	.-Design consider maintenance needs	.- Life span of the pipes and materials
	-Bank slopes must be designed to be gentle	.-Life span of the pipes and materials	.-Flood plain accessible	.- Services watertight
	- Pavement lifecycle design	.-Access for maintenance(Mh & pipe)	.-Life span of the pipes and materials	. -Positioning of trees - proximity of services
	Type of tree planting- prevent leaves falling	-Erf have a rodding eye	- Reduce large open spaces	-Leak Detection devices in retic.
		-Services watertight	.-Inlet/outlet design to reduce blockages	.- Provisions for future expansion of the system
6. ECONOMY	.- Optimised level of service	- Optimised level of service	.- Optimised level of service	.- Optimised level of service
	.- Minimize the number of road intersections	-Increased % mid-block sewer	- Rain water harvesting techniques	- Use of shared trenches
	.- Use of narrower shorter streets	-Maximum manhole spacing	-Use of shared trenches	.- Max. hydrants, airvalve spacing
	.-Curvelinear roads increases no of manholes	-Use of shared trenches	.- Maximum manhole spacing	.- Apropriate water demands
	.- Pavement Life-Cycle Cost Analyses	.-Long lengths of opens space		.- Use of eco Pipe material - pvc/concrete/hdpe
7. SAFETY	.-Use of traffic calming measures	-Trench depths <3m	-Safe discharge routes	- Increased Fire risk category
	.- Signage and sense of place	.- Position in relation to water pipe	.- Reduced velocity /depth of stormwater flow	.-Velocity of water flowing
	.-Safe street and unique public space	.- Reduced depth of manholes	.- Reduced depth of manholes	.- Reduced depth of manholes
	.-Safe intersection-pedestrian friendliness		.-Inconvenience of overland flow	.- Reduce pressure on pipeline
8. SOCIAL	- Public facilities			
	.-Convenient pedestrian paths / crossings			
	- Accessibilty during the repair of services			
	Planning for social and physical infrastructure			
	Improving the quality of life for the area			
	Ensuring developments contribute to economic growth			
	Informing and involving internal and external stakeholders			

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.

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