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Measuring infrastructure sustainability with the use of eco efficient performance criteria

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***Abstract**: Civil engineering projects can have significant site-specific and cumulative impacts on our ecological and social systems if not correctly planned, designed and implemented. As we face significant planetary issues such as global warming, it is clear that the engineering profession has a significant part to play in affecting the future of our planet.*
This paper aims to demonstrate the importance of eco efficient criteria on infrastructure projects. The use of the proposed criteria would ensure a sustainable design for township infrastructure services through the consideration of scare resources, ecological sensitivity in the design and planning of infrastructure projects. This paper also gives an overview of the proposed Green Township Infrastructure Design toolkit and promotes the use of green practices on infrastructure services design, that are environmentally sound, placing fewer burdens on the environment. This paper also compares two case studies that utilises green infrastructure criteria to rate its eco efficiency.

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

I. Introduction

In order to stay competitive and to meet upcoming stricter environmental regulations and customer requirements, designers have a key role in designing civil infrastructure so that it is environmentally sustainable.
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 [5].
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. This paper describes a case study that uses this green infrastructure approach, as opposed to traditional methods of design as well as the benefits of using an eco-approach to infrastructure design.

II. Climate Change and Sustainability

The need to make development sustainable is based on the sound evidence showing that we are using up critical resources and ecological carrying capacity faster than they are being renewed, replaced or replenished [2]. It has been established that municipalities are not delivering infrastructure service in a sustainable manner. Most of the challenges are due to planning, implementation and monitoring systems failure. Further assessments revealed that municipalities do not comply with basic principles for sustainable service delivery [1].
Climate change is introducing many uncertainties into the management and planning of township infrastructure projects. 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
Engineers will have to be at the forefront of developments finding ways to maximise water capture, ensuring conservation of the resource from supply through to distribution, and the issues of innovation, technology and design. Sustainability and adaptive and mitigative approaches to climate change, in the design of infrastructure are therefore important steering elements [2].
Making the wrong choices now will cause the future generations to live in a changed climate, depleted resources and without the green space and biodiversity.

III. The need to implement green technology on civil engineering infrastructure projects

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 [2].
Environmentally sustainable design on township infrastructure services entails the use of ecologically sensitive innovative design solutions, integrating a consideration of resources, the environment, maintenance and recyclable materials, from the early design stages of a project.
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. Due to the ecologically sensitive nature of civil engineering infrastructure, there is a need for a green rating tool to evaluate the performance of infrastructure. The proposed research assesses the environmental impacts of infrastructure design decisions on development.
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.

IV. Infrastructure eco efficiency criteria

The role of criteria for sustainable green infrastructure are tools 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 eco efficient infrastructure solutions. 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 eco efficient criteria that characterize sustainable criteria of Green township infrastructure are listed in Table 1. The criteria, namely Economy, Functional Efficiency, Safety and Environmental Quality were derived from goals that were set out for layout planning and related services for residential township developments [3]. The proposed Eco Efficient Infrastructure 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. Safety minimises the environmental impact of infrastructure by incorporating safety into the design. 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 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 eco efficient 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;

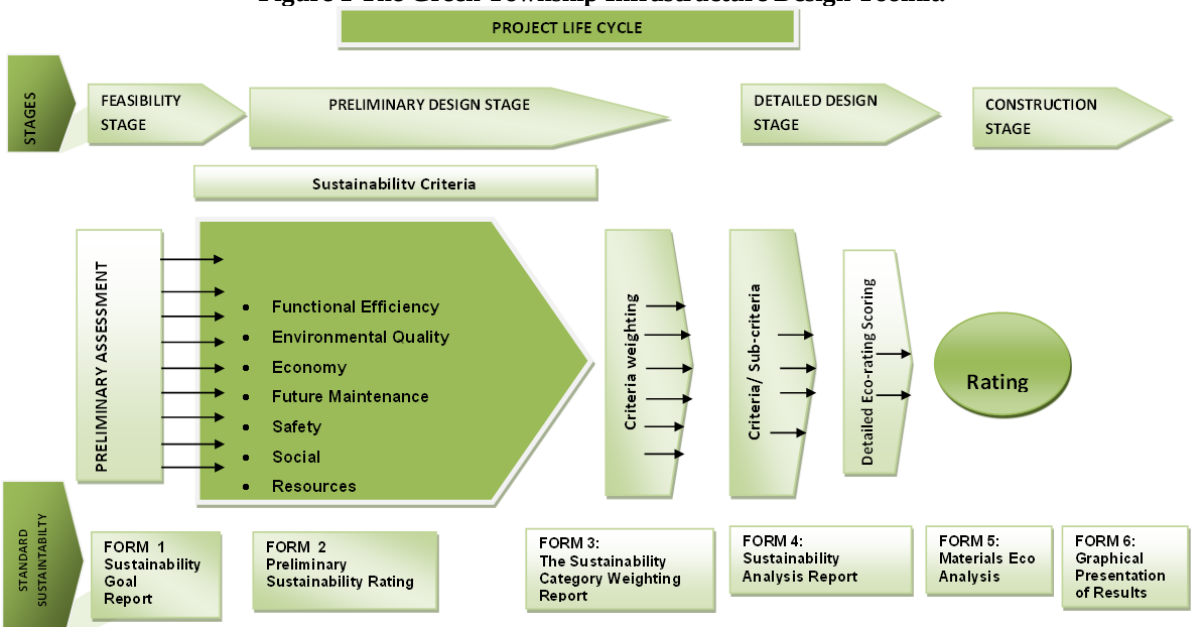
V. Weighting of Eco Efficient Criteria

Weighting of the Infrastructure eco efficient criteria allows the design team to target or prioritise certain infrastructure environmental sustainable performance categories over the various elements of the project. 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. Weighting the infrastructure eco efficient criteria enables 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 benefit by focusing on specific categories applicable to each design situation.

VI. The Green Township Infrastructure Rating System for infrastructure projects

This paper proposes a 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 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 .
During the briefing and preliminary design stage, (1 and 2), the client and engineer have a joint responsibility of deciding just how green the project should be, or alternatively of deciding what environmental quality of services can be provided. During the detailed stages (3), the engineer has the responsibility of designing, while maximising the green value of the project. Stage 4 gives the designers an opportunity to add environmental value at the construction stage, by analysing eco-friendly construction material.

Figure 1 The Green Township Infrastructure Design Toolkit.



VII. A case study to compare the usefulness of the eco efficient criteria

The two residential development case studies were compared to each in order to test the usefulness of the rating in searching for green solutions. Each element is categorised, prioritised and rated into the various eco efficient criteria. Case study 1used conventional infrastructure and was chosen to assess how the model rates conventional infrastructure.

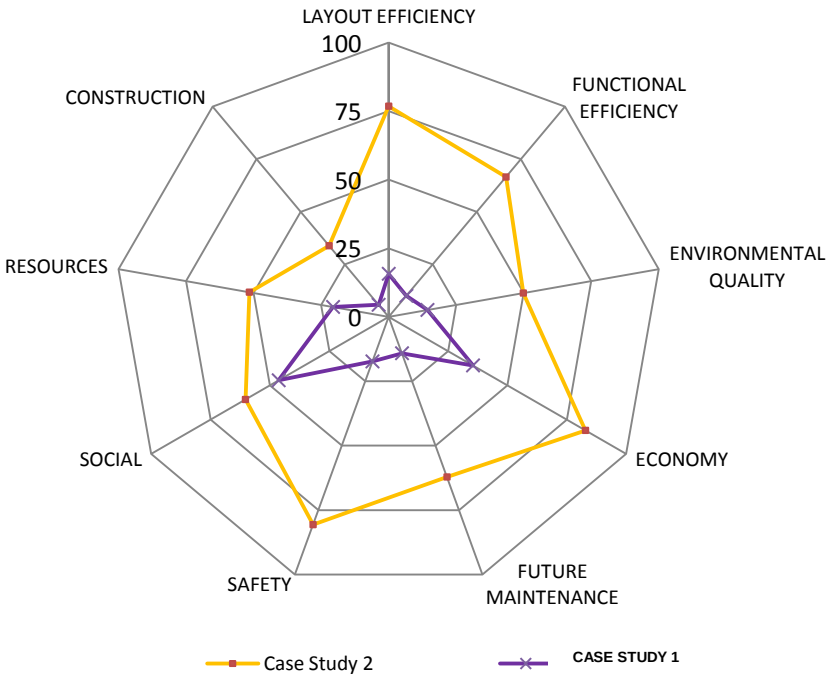
The second case study was a low income development that aimed to have a restricted damage to the environment, by using a combination of green solutions and conventional infrastructure
The results indicated that Case Study 2 achieved a green rating of 66 and performed satisfactory to moderate scores across all dimensions of sustainability, being able to maintain a balance between the needs of society and the preservation of the environment.

Case Study 1 on the other hand demonstrated a significantly different performance, achieving a green rating of 18 and receiving low scores for almost all components, due to the lack of environmental interventions. This therefore offers a useful contrast to the situation in that Case study 1 indicates the results when only conventional designs are used, compared to simple, inexpensive green interventions that can be used, as shown in Table 2 and illustrated in Figure 2.

Table 2: Comparative assessment between Case Study 1 and Case Study 2

	Case Study 1					Case Study 2				
PERFORMANCE CATEGORIES	**OVERALL PROJECT**	ROADS	STORM WATER	SEWER	WATER	**OVERALL PROJECT**	ROADS	STORM WATER	SEWER	WATER
LAYOUT EFFICIENCY	**16**	13	10	3	10	**77**	88	60	89	60
FUNCTIONAL EFFICIENCY	**10**	15	7	6	7	**67**	75	63	53	67
ENVIRONMENTAL QUALITY	**14**	21	8	10	11	**50**	57	62	40	33
ECONOMY	**35**	55	11	27	30	**83**	82	89	82	80
FUTURE MAINTENANCE	**14**	10	13	13	25	**62**	50	73	63	75
SAFETY	**17**	13	10	17	33	**81**	80	60	83	100
SOCIAL	**46**	50	17	75	40	**60**	75	17	75	60
RESOURCES	**21**	22	22	36	0	**52**	44	56	64	50
CONSTRUCTION	**6**	14	0	0	0	**34**	43	33	50	0
SCORING	**18**	24	10	8	16	**66**	69	66	62	66

Figure 2: Comparative assessment between Case Study 1 and Case Study 2



VIII.Advantages of using the eco approach to infrastructure design

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

Health and community benefits:

- Improved air, thermal, and acoustic environments
- Community safety
- Convenience of users
- Enhanced occupant comfort and health
- Minimized strain on local infrastructure
- Contributed to overall quality of life.

VI. 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 [4]. 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.

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