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A Case Study Approach to Compare the usefulness of Sustainability Criteria in the Design of Infrastructure Projects

Shian Hemraj Saroop[1*], Dhiren Allopi[2]

[1] *Royal HaskoningDHV, South Africa*
[2]*Durban University of technology, South Africa*

Abstract

The provision of civil infrastructure has a major impact on the natural environment and on the quality of life. However, there are no systems in place at the design stage to assess the environmental impact of design decisions on township infrastructure projects. In order to stay competitive and to meet upcoming stricter environmental regulations and customer requirements, designers have a key role in designing sustainable civil infrastructure. There is an urgent need to apply technologies and methods that deliver better and more sustainable performance of civil infrastructure as well as a need to establish a standard of measurement for greener infrastructure. The objectives of the research study were to establish a standard of measurement for greener infrastructure that can be used in township infrastructure, at the various stages of the project. This would require the development of a green reporting system, aimed at ensuring high-performance, eco-efficient, economical and environmentally friendly design decisions on stormwater, roads, water and sanitation related to township infrastructure projects. Various case studies were undertaken on a range of infrastructure projects to ensure consistency and reliability of the toolkit. Through a series of green reports, developed for each stage of a project, the toolkit measured the environmental efficiency of the design solutions taken.

Keywords— Department of Civil Engineering and Surveying, Durban University of Technology

Introduction

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 an urgent need to developsustainable infrastructure technologiesmore cost effectively[7].

Civil engineering projects have significant impacts on our ecological systems if incorrectly planned, designed and built.

Engineers need to find innovative solutions to maximise water conservation, from supply through to distribution so that environmental impacts can bemitigated[10].

There is a need for tools to assess the environmental impacts of infrastructure design decisions, at the design stage, where they will be most influential in the final outcome.

Objective

The objectives of this paper are as follows:

- To introduce environmentally conscious design decisions at inception stage, where they are influenced the most.
- To define sustainability criteria for township infrastructure design.
- Develop an interactive decision making toolkit that assists consultants and clients by showing the greener options on infrastructure projects.
- Present the results of case studies when using the proposed toolkit.
- To highlight the benefits using environmental friendly design decision.

The Effect of Climate Change on Infrastructure Sustainability

*All correspondence related to this article should be directed to Shian Hemraj Saroop from Royal HaskoningDHV, South Africa
Email: shiansaroop@gmail.com

Civil engineers are central to the success of the infrastructure networks that support society and the global economy. To address climate change impacts and develop resilience in infrastructure, the design, construction and operation of infrastructure must be changed (American Society of Civil Engineers, 2009). Effective actions and design technologies to date are only scratching the surface of true sustainability. In the developing world where the gap between energy supply and demand is increasing rapidly, lessons and new technologies relating to sustainability and energy efficiency are not being applied owing to the lack of regulation, investment and technology transfer [7].

Adapting infrastructure to reduce climate change is an explicit driver aimed at addressing the issue of flooding, social impacts and sustainability. Making the wrong design choices now will cause future generations to live with a changed climate, depleted resources and without green space and biodiversity. The focus areas for reducing the effects of climate by implementing sustainable infrastructure include reducing water consumption through using efficient fixtures, water meters and fittings, and developing water efficient layouts to decrease pressure and velocities as well as the minimisation of pumpstations and protection of sewer outfalls. Road infrastructure presents many opportunities for reducing air pollution, cooler pavements, and reduced environmental impacts

The Influence of Early Design Decisions on The Environmental Impact and Sustainability on Infrastructure Projects

During the design stage a large number of environmental interventions can be achieved, as the design is flexible enough to incorporate relatively significant changes. A sustainable project is managed by totally involving clients in the decision making process.

Figure 1 shows the typical life cycle of a project from conception through to operation and occupation. It illustrates that the ideal time to agree on green interventions on a project is at the concept design stage and that the ideal time for developing an integrated design response is at the master planning or concept design stage.

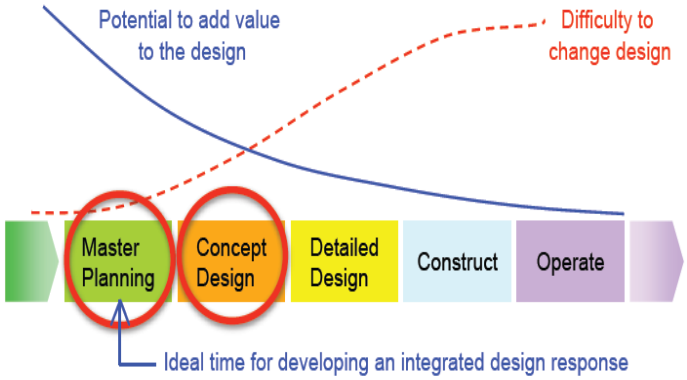

Figure 1: Ideal time for developing an integrated design response [10]

It also shows the declining influence of environmental interventions on a project. 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.

Early planning for green solutions is particularly crucial as decisions made during the early stages of the development process have a far greater sustainable affect than the relatively limited green design interventions which are made later in the process.

Currently design stakeholders are more interested in the project's performance in the later stages of construction, operation, and maintenance. However current reporting strategies for sustainability must lean towards to periodically presenting the project's social, economic and environmental performance [13].

Methodology

The methodology for this research study consisted of undertaking a literature review of sustainability concepts, the need for green infrastructure and green technologies that can be applied to township services and green rating

systems that are already established. Sustainability infrastructure criteria were identified in order to be able to identify certain focus areas for the client such as environmental quality, resource efficiency, economic or social issues.

A framework for the proposed toolkit was developed together with the proposed outputs. The green technologies identified in the literature review were used to create the actual green township infrastructure rating system. Each infrastructure element underwent a detailed analysis of the potential green interventions that could be implemented from feasibility, to the design and construction stage.

Once the green township infrastructure rating system was complete, it was evaluated through various case studies in order to determine its suitability and applicability to township infrastructure projects. A variety of projects were chosen such as high income developments, low income developments, industrial parks, mixed use developments and a project with no green interventions to determine its scorings. The rating system scoring method was evaluated and fine tuned in order to determine its applicability and suitability for all types of projects.

Literature Review

The lack of appropriate tools and skills for sustainable design has often been quoted as a barrier to sustainable design [14].

There is a lack of adequate tools and skills to undertake sustainable design on infrastructure projects. Matar et al [11] highlight the fact that more than 600 sustainability assessment tools currently exist, most of these are primarily oriented toward buildings, and do not direct sufficient attention for infrastructure projects.

Infrastructure plays an important role in the sustainability of the built environment. Infrastructure operates at a larger scale than buildings and requires careful planning to ensure efficiency.Although there are examples of infrastructure projects that have adopted sustainable solutions throughout the country, there is no system available to compare and assess the differential in sustainability results and performance within the infrastructure project domain [2].

The green rating of buildings briefly examines the infrastructure components of a building, but do not adequately assess the environmental impacts of infrastructure on developments. The construction of a sustainable building must include more than just the building itself – those involved must recognise it as being a component in a system which must itself be assessed for sustainability [4].

There needs to be an improvement in the awareness of eco-efficiency concepts among designers, planners and decision-makers. However the criteria and measures for developing eco-efficient and sustainable infrastructure have not been fully identified.

The Proposed Green Township Infrastructure Rating System

This paper proposes Green Township Infrastructure Design Toolkit developed to assess the environmental impact of design decisions at each stage of the infrastructure project. Green infrastructure entails using technologies that use natural systems, or engineered systems that mimic natural processes and includes low impact development and Urban Green Best Management Practices [12].

The Green Township Infrastructure Design Toolkit, illustrated in Figure 2,allows the designer to evaluate greener design options. It encourages developers to consider green practices on all stages of the project.

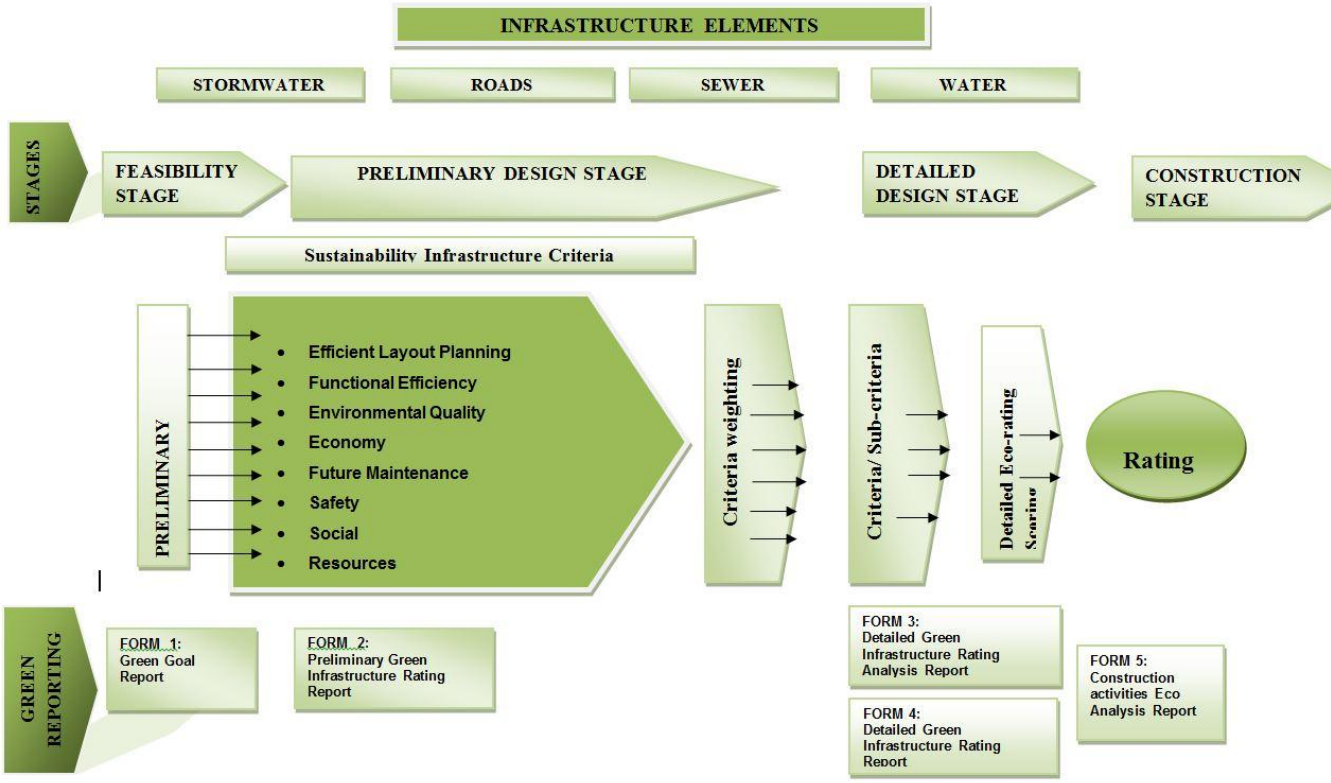

Figure 2: The Green Township Infrastructure Design Toolkit

The Use of Sustainability Criteria on Township Infrastructure Design

Infrastructure Sustainability criteria can be used to monitor and measure the impact that the infrastructure has on the environment and reflect the performance of the element [5].

The project sustainability categories provide the means to measure a project by comparing the performance achieved on a project with the intended performance.

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 barriers to implementing green technology include the lack of indicators for evaluating the sustainability and a procedure for a green infrastructure [8].

The Infrastructure Sustainability criteria proposed in the Green Township Infrastructure Design Toolkitwere developed to:

- Provide a means for the consultants and clients to work together on evaluating sustainable infrastructure solutions;
- Establish a means for infrastructure sustainability to be assessed, quantified and verified at any stage of the project;
- Achieve the required balance of sustainability, value for money and quality, between the various project elements.

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

Four of the nine criteria proposed, namely Economy, Functional Efficiency, Safety and Environmental Quality were adopted from goals that were set out for layout planning and related services for residential township developments [6].

Table 1:
The Sustainability Performance Criteria

Sustainable infrastructure criteria	Measure
1. Efficient Layout planning	Placement of infrastructure in an environmentally responsible, efficient way.
2. Resources	Encourage the efficient utilisation of materials/ resources and the selection of environmentally friendly materials.
3. Environment Quality	Design elements that mitigate environmental impacts of infrastructure, and aim to reduce the effects of pollutants
4. Functional Efficiency	Design of infrastructure that maximizes functional efficiency of infrastructure.
5. Future maintenance	Integrate operational issues of infrastructure, thereby ensuring a reliable of level of service
6. Economy	Identify cost effective green solutions.
7. Safety	Minimizes the environmental impact of infrastructure through incorporating public safety into the design elements.
8. Social	Promoting convenience, public participation, ensuring social sustainability of infrastructure

A Comparativeassessment of Case Studies to Review the Usefulness of the Proposed Green Infrastructure Toolkit

Two residential development case studies were compared to each in order to test the usefulness of the rating in searching for green solutions.

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 3.

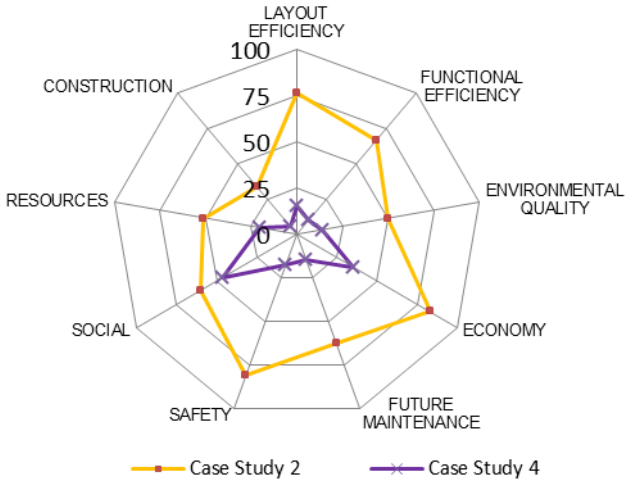

Figure 3: Comparative assessment between Case Study 1 and Case Study 2

Table 2:
Comparative assessment of 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
1	LAYOUT EFFICIENCY	**16**	13	10	33	10	**77**	88	60	89	60
2	FUNCTIONAL EFFICIENCY	**10**	15	7	6	7	**67**	75	63	53	67
3	ENVIRONMENTAL QUALITY	**14**	21	8	10	11	**50**	57	62	40	33
4	ECONOMY	**35**	55	11	27	30	**83**	82	89	82	80
5	FUTURE MAINTENANCE	**14**	10	13	13	25	**62**	50	73	63	75
6	SAFETY	**17**	13	10	17	33	**81**	80	60	83	100
7	SOCIAL	**46**	50	17	75	40	**60**	75	17	75	60
8	RESOURCES	**21**	22	22	36	0	**52**	44	56	64	50
9	CONSTRUCTION	**6**	14	0	0	0	**34**	43	33	50	0
	SCORING	**18**	24	10	18	16	**66**	69	66	62	66

Using an Eco Approach to Infrastructure Design

An Eco-approach to infrastructure design takes a “softer” design approach, in order to reduce the potential impacts of a development. The benefits of this approach are as follows:

- Reduces the ecological footprint of roads, sewer, stormwater and water, allowing ecosystems to function naturally;
- Reduces, reuses, and recycles resources and uses local materials;
- Conserves, recycle and reuses stormwater runoff on-site;
- Recharges ground water flow.

Balancing the potential benefits against the costs, including installation and downstream costs, is crucial when deciding the green design elements to implement [3].

Green infrastructure may save capital costs associated with paving, creating curbs and gutters, building large stormwater conveyance systems, other hard infrastructure and energy costs.

Conclusions

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, greener engineering improves urban aesthetics and community livability, by providing recreational and wildlife areas. As can be seen in this paper, there are numerous opportunities for improving eco-efficiency in infrastructure design. The sustainability criteria focus on green technologies, limiting the use of scarce resources and prioritizing focus areas for the client; improving accountability and linking project level work to the achievement of strategic objectives. Attention to greener infrastructure solutions from the early phases of a project will ensure that quality design environmental solutions are "built in" from the beginning of a project, thus long term sustainability of infrastructure can be achieved.

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