IJST EXPLORE International Journal of Science and Technology
CENTRE OF PROFESSIONAL RESEARCH PUBLICATIONS
ISSN 2049-7318

International Journal of Science and Technology Volume 3 No. 2, February, 2014

Developing ECO Sensitive Infrastructure Solutions with the use of Sustainability Criteria

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ABSTRACT

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.

Demands for energy, drinking water, clean air, safe waste disposal, and transportation will drive environmental protection [alongside] infrastructure development.

Globally, the construction industry is one of the main contributors to the depletion of natural resources and a major cause of unwanted side affects such as air and water pollution, solid waste, deforestation, health hazards, global warming, and other negative consequences. The awareness of environmental impacts is growing and many movements seeking to address sustainability concerns are gaining momentum (Harvey B. and Wayne B, 2008).

The lack of appropriate tools and skills for sustainable design was often quoted as a barrier to sustainable design. (Richardson J, Irwin T. & Sherwin C. 2005)

A systematic and iterative analysis of the environmental impact of various design solutions is commonly suggested for infrastructure projects, but rarely happens.

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. These and other factors have compelled the engineer to design with greater care and in more detail. The changing roles of engineers will be highlighted, in order to react to changes in climate. Government legislation pertaining to sustainable infrastructure is briefly examined. 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 demonstrate the importance of criteria and sub-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 focuses on the concept of eco-efficiency in Infrastructure Design that promotes the use of the greener engineering options, enabling him/her to choose the one likely to yield the best performance with the least environmental impact. It looks at a number of recommended green practices on infrastructure services design, that are environmentally sound placing, fewer burdens on the environment.

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

I. OBJECTIVES

In view of the inadequacy of tools to assess the environmental impacts of infrastructure design decisions, the aims of this paper are as follows:

- To emphasis the influence of climate on sustainability;
- To highlight the changing role of engineers;
- To highlight the need for environmentally friendly, ecologically sensitive innovative design, at the design stage of township infrastructure projects;
- To demonstrate the importance of criteria and sub-criteria on infrastructure projects;
- To establish a means of identifying environmental leadership on civil engineering projects;
- To define green infrastructure solutions amongst engineers by establishing a common language and standard of measurement;

- To raise awareness of green engineering benefits and the environmental impact of consultants' design decision, in order to reduce the environmental impact of development;
- To introduce environmentally conscious design decisions at inception stage, where they are influenced the most.

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. (FIDIC, 2009: p6)

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 (DPLG, 2007).

Climate change is introducing many uncertainties into the management and planning of township infrastructure projects. However, in the case of sustainable development, there are highly compelling reasons for the consulting engineering industry to take more of a leadership role, not necessarily in determining client needs, but in drafting the technology roadmap for achieving conditions of sustainability.

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, design.

Sustainability and adaptive and mitigative approaches to climate change, in the design of infrastructure are therefore important steering elements (FIDIC, 2009: p44).

However, effective actions to date are really only scratching the surface of true sustainability. In the developing world, where the gap between energy supply and demand is increasing rapidly, the lessons and new technologies relating to sustainability and energy efficiency are not being applied owing to the lack of regulation, investment and technology transfer (FIDIC, 2009: p38).

Climate change can have direct and indirect impacts on infrastructure. The direct impacts are due to the effects of the environment, primarily moisture, which weakens flexible pavements, increased flood heights and frequencies and high water tables.

The indirect impacts of climate change on infrastructure are due to the effects on the location of population and human activity altering the demand for roads (Austroads, 2004)

Making the wrong choices now and will cause the future generations to live with a changed climate, depleted resources and without the green space and biodiversity.

III. THE CHANGING ROLE OF ENGINEERS

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.

Demands for energy, drinking water, clean air, safe waste disposal, and transportation will drive environmental protection alongside infrastructure development.

Engineers have a critical role to play to achieve sustainable development. It is clearly no longer possible to be a professional engineer and ignore the challenges and opportunities that arise from needing to achieve sustainable development (Desha et al, 2007).
Engineers must be prepared not only to react to changes in climate and resource availability but also to help manage that change through sustainable engineering.

With the potential for disasters increasing dramatically, engineers are expected to highlight the potential events, assist in the development of mitigation initiatives, and ensure appropriate design and construction. Measures adopted will have to explore shifts in paradigms to find innovative solutions that allow man to work with nature rather than against it. Engineers urgently need to find innovative solutions that meet the required social and planning objectives whilst being energy efficient, sustainable, of high value in terms of quality and efficiency, and remain cost effective. (FIDIC, 2009: p43)

The engineering community also has a major opportunity to contribute to structuring of infrastructure projects. The lack of sustainability systems or tools has led to poor design solutions and continues to degrade the environment.

Engineers will have to be at the forefront of developments. Whether finding ways to maximise water capture, ensuring conservation of the resource from supply through to distribution, or increasing usage before final disposal, the issues of innovation, technology, design, and management will be crucial for the engineer in meeting the challenges.
Civil engineering projects can have significant site-specific and cumulative impacts on our ecological and social systems if not correctly planned, designed and implemented. Engineers are at the forefront of civil works and play an important role in ensuring environmental impacts are avoided or mitigated. Understanding the context of the environment in which they work is thus essential (Kilian D and Gibson D, 2007).

The need to implement green technology on civil engineering infrastructure projects

As the custodians of existing infrastructure and the developers of future infrastructure, consulting engineers recognise a responsibility to innovate and improve the products of their efforts and to understand the importance of instituting a dialogue with the rest of society on these subjects (FIDIC, 2009: p12).

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 and adaptive and mitigative approaches to climate change, in the design of infrastructure are therefore important steering elements (FIDIC, 2009: p44).

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

By utilising improved environmentally friendly-seeking design methods, 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.

The influence of early design decisions on the environmental impact and sustainability on infrastructure projects

It is essential that the environmental issues be integrated into achieving the most appropriate solutions. A sustainable project is managed by taking control of the client's decision making processes as early as possible, to provide the certainty of decision making. This should be done by totally involving clients in the decision making process. 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. Figure 1 shows the declining influence of environmental interventions on a project.

It is important to implement the environmental management from the early stages of the process, since the "freedom" to make decisions, of importance for the environment, decreases with the progress of the project.

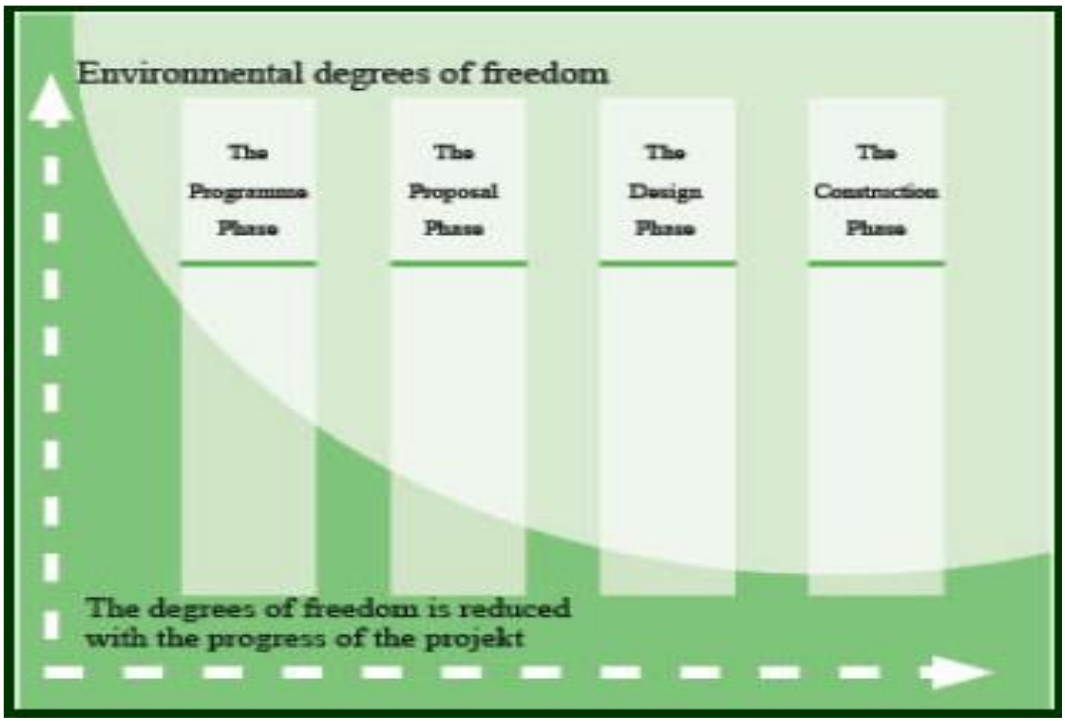

Figure 1. The environmental degrees of freedom (European Green Cities Network, 2004)

IV. INFRASTRUCTURE ENVIRONMENTAL SUSTAINABILITY 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 by which sustainability may be assessed. Collectively, the criteria provide an implicit, generally agreed-upon global definition for the concept of sustainability. Each criterion relates to a key element of sustainability. Through the measurement and monitoring of these indicators, the environmental effects of infrastructure solutions, can be assessed and evaluated, to meet stated aims and clients 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. They enable 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 sustainability of Green township infrastructure projects 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. 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 Sustainability criteria 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 can be carried out in order to allow the design team and client to target or prioritise certain infrastructure environmental sustainable performance categories over the various elements of the project. The weighting of the various categories are carried out at this early stage, before the design is developed, to avoid redesign later in the process.

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

The weighting and setting of Targets for the Sustainability Categories helps the designer understand the many design choices which need to be made in relation to Layout Planning, Functional Efficiency, Environmental Quality, Economy, Future Maintenance, Safety, Convenience 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.

Green design elements that will improve the environmental performance on township infrastructure projects

Innovative approaches to planning and design can greatly mitigate the negative impacts of infrastructure services on the environment. Various green technologies 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 pavements 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, bioretention, and swales. Greener Water infrastructure opportunities include a reticulated recycled water supply, water efficient fittings, intermediate storage, etc.

This various eco-efficient design sustainable infrastructure solutions were broken down into various sustainability criteria and are briefly tabled, under various elements in the Figure 2 below:

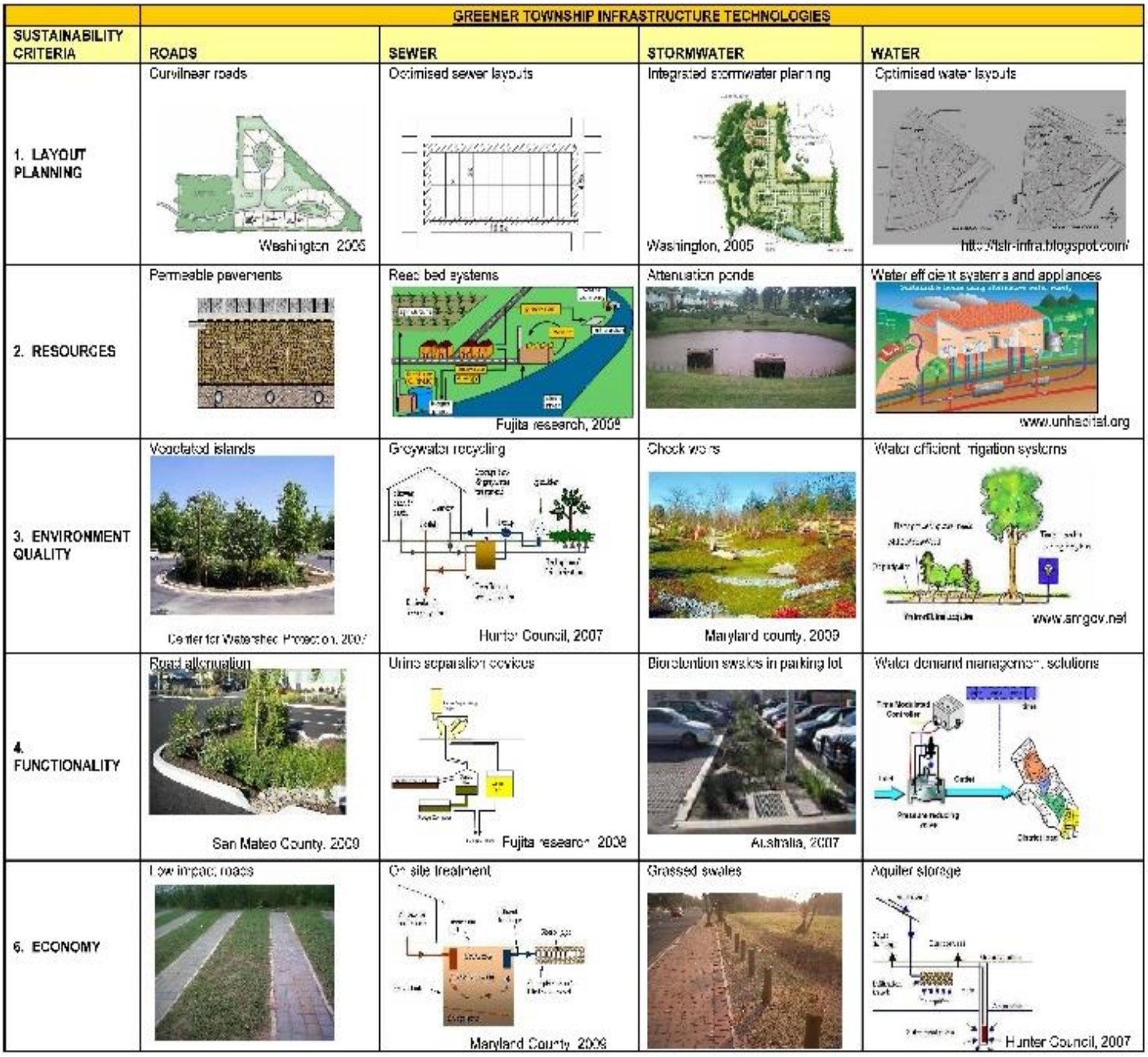

Figure 2. Green infrastructure technologies that can be used on infrastructure projects

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:

- Conservation of natural resources;

- Reduces the ecological footprints of roads, sewer, stormwater and water, allowing ecosystems to function more naturally;
- Uses energy-efficiency systems and materials;
- Minimized impervious surfaces reducing soil erosion;
- Enhance and protect ecosystems and biodiversity;
- Conserves and reuses water and treats stormwater runoff on-site;
- Recharged ground water flow for streams, conserving water supplies.

V. CONCLUSIONS

By using this green approach, sustainable design of township infrastructure services can be achieved by enforcing the consideration of resources, environmental impacts of design decisions, ecologically sensitivity, innovation, maintenance and materials, at the design stage of a project. As can be seen in this paper, there are numerous opportunities for improving eco-efficiency in infrastructure design. A new paradigm for infrastructure design is required in order to maintain environmental sustainability and mitigate flooding or drought.

Engineers need to look at greener technologies rather than just using traditional engineering solutions.

The Environmental Sustainability criteria characterize sustainability of township infrastructure projects and can be used in the conceptualization, implementation, and monitoring of progress of sustainability in township infrastructure projects.

The Green technologies proposed 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.

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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