CORNELL UNIVERSITY CEE CRANDALL WRITING COMPETITION 2013

The Case for Green Infrastructure

Rethinking the Current Infrastructure Paradigm

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4/29/2013

Civil Infrastructure Category

Introduction

The American Society of Civil Engineers recently released the 2013 American Infrastructure Report Card. The Report Card grades the performance and current state of the infrastructure located in the United States. Infrastructure includes both traditional systems of infrastructure (e.g. airports, bridges, damns, transit systems, energy) and systems provided to the public (e.g. parks and schools). While the overall grade of the nation's infrastructure rose from four years ago, a grade of D+ is still a poor grade by any standards. The ASCE estimates that the nation will need $3.6 trillion in investments in order to *maintain* a state of "good" repair (Engineers, 2013).

Once hailed as the global example of a nation that offers high-quality services to its citizens, the United States has quickly been falling behind in improving its infrastructure services for its people, instead preferring to support crumbling and outdated systems. Providing energy, safe travel, trade and clean and reliable water, infrastructure is the backbone of our society. Without reliable and state-of-the-art systems, the United States will struggle to compete in a global market and attract highly educated immigrants. In light of recent events such as Hurricane Sandy, the public is starting to realize how vulnerable their old infrastructure is to the unpredictable forces of Climate Change.

It is clear that we must act quickly to improve the state of our infrastructure if we wish to remain not only a resilient nation, but also a modern nation with modern services for its people and businesses. It is equally clear that our government will not be able to approve the necessary amount of money deemed necessary by the ASCE to upgrade our infrastructure in any reasonable amount of time. Therefore, the responsibility lays heavily upon civil engineers and other built environment professionals to come up with creative solutions that provide updated infrastructure at lower costs. In order to do this, we must re-evaluate the current design process, as it is evident that current methods of thinking will not generate radically innovative solutions. We must challenge the current paradigms. We must rethink what is infrastructure, and how to design, construct, and maintain infrastructure.

Also known as Soft Infrastructure, Green Infrastructure is a relatively old method that is quickly gaining popularity. As opposed to the current "Hard" or "Grey" Infrastructure, Green Infrastructure utilizes natural processes at mainly the ecosystem level to provide services that Grey Infrastructure has traditionally provided. Current Infrastructure is static, expensive, massive and inflexible; Green Infrastructure challenges those characteristics and seeks to redefine Infrastructure for a rapidly changing world. While there are a variety of definitions for Green Infrastructure, I will define the method as “techniques and technology that utilizes natural services and processes for the benefit of human society.” I am well aware that this definition is quite broad and includes many methods, such as Engineered Ecologies and even renewable energy. I have even heard a practicing Civil Engineer respond, “By that definition, anything can be Infrastructure.” Indeed, it can. It simply means that as engineers of infrastructure, Civil Engineers have far more responsibility than originally thought. I assert that in our society, Civil Engineers must learn to loosen their definitions of infrastructure if they hope to reach creative insights. The goal of an engineer is not to create a bridge; the goal is to create a way to get people over the gap as efficiently and cost-effectively as possible. Infrastructure will be viewed at its absolute fundamental characteristics.

This paper will provide alternative views of infrastructure in order to inspire creative solutions to improve our country’s infrastructure with an emphasis on Green Infrastructure strategies. A brief introduction to Green Infrastructure will be provided, followed by its advantages and disadvantages. Examples of Green Infrastructure thinking as practiced in the United States and abroad will be presented. Currently, Green Infrastructure is utilized to address issues of water quality, wastewater and flood protection, but this paper will also suggest how to apply the same design thinking to other forms of infrastructure. Most importantly, however, this paper serves as a call for Civil and Environmental Engineers to be innovative in infrastructure design – to think outside the box. The common definitions of infrastructure will be challenged in an effort to promote alternative approaches to infrastructure problems. Suggestions will be provided on how this thinking can be applied to all forms of infrastructure and consequences of this new paradigm will be discussed. The goal of this paper is to inspire new ways of thinking and to encourage Civil and Environmental Engineers to take the lead in creating a sustainable society.

What is Green Infrastructure?

While the United States has made great strides in Environmental Protection and Quality in the past few decades (i.e. the creation of the EPA, the Clean Water Act, the Highway system ect.), the task requires continual management and revisions. Water Infrastructure has steadily been on the decline since the 1970s due to lack of federal investment, forcing municipalities and states to come up with innovative solutions constrained by tight budgets (Alliance, 2011). One of these solutions is Green Infrastructure – an old method that is gaining popularity, especially among Architects and Landscape Architects.

The EPA defines Green Infrastructure as "an approach that communities can choose to maintain healthy waters, provide multiple environmental benefits and support sustainable communities…By weaving natural processes into the built environment, green infrastructure provides not only stormwater management, but also flood mitigation, air quality management, and much more" (Environmental Protection Agency, U.S., 2013). Examples of such methods include bioswales, green roofs, rain gardens, permeable concrete or even simply planting trees (e.g. the MillionTreesNYC initiative). Traditionally, Green Infrastructure has been a method to address stormwater runoff. As stated earlier, the definition used in this paper includes not just water-issues, but renewable energy, and even transit and building infrastructure.

The Green Infrastructure I refer to involves integrating natural processes and systems with our mechanical processes and systems. Environmental Engineers have been implementing this sort of thinking for a while, such as utilizing the degradation process of microorganisms to clean up polluted sites. Green Infrastructure calls for utilizing processes at greater scales than just microbiology, it applies ecosystem services and knowledge to our engineered solutions. If natural areas can provide services that infrastructure provides, is it not reasonable to regard these natural areas as infrastructure, and thus fully within the realm of the Civil Engineer? Implementing the Green Infrastructure method includes utilizing natural processes to assist in the construction and design of the system – in other words, change as little as you can and create the most impact by allowing nature to take charge. Examples include engineered ecologies, artificial coral reefs and wetlands, and using processes such as hydrological flows to assist in construction.

Advantages and Disadvantages

As the ultimate goal of the Civil Engineer is to create a sustainable society, the advantages and disadvantages of Green Infrastructure will be evaluated based on the three commonly accepted pillars of Sustainability: Environmental sustainability, Economic sustainability and Social sustainability.

Green Infrastructure highlights the importance of ecosystems and the services they provide. Therefore, Green Infrastructure gives more credibility to the conservation movement, while stressing the benefits the environment brings to society. The environment has always provided for humans, Green Infrastructure simply makes it more evident. Additionally, services that Green Infrastructure provides to humans – such as clean air, improved water quality, flood mitigation – also benefits the species surrounding the area (Alliance, 2011). As Green Infrastructure utilizes natural processes, the potential for pollution and degradation greatly declines as the processes dictating the infrastructure are the same processes that naturally occur. Green Infrastructure works with nature, not against it, ensuring that Green Infrastructure will be resilient and adaptable.

Economically speaking, the reputation of sustainable development may discourage municipalities from adopting Green Infrastructure practices. The main deterrent to sustainable development is the capital costs. However, both the capital and maintenance costs for Green Infrastructure are far lower than that of current costs for maintaining traditional infrastructure (Talberth & Hanson, 2012). It is this reason that has driven many municipalities to adopt Green Infrastructure methods. Often passive in design, Green Infrastructure requires less input of energy, greatly decreasing maintenance costs. As 'natural' areas, Green Infrastructure also attracts tourists, thereby increasing revenue for municipalities.

The natural charm of Green Infrastructure attracts not only tourists, but also locals, who can utilize the space as places of gathering. Green Infrastructure blends built and natural environments, which many find quite appealing. Green Infrastructure can serve as places of community building and foster appreciation of nature. Such areas can easily be symbols of forward thinking and be the pride of a community.

Unfortunately, the fact that Green Infrastructure often works on the ecosystem scale means that these systems require more land to operate, which can result in pushing people off their own property and present problems when siting near urban areas. Green Infrastructure's intimate connection with nature can also be viewed as its downfall, as these systems can be subject to environmental disturbances. The main barrier for implementing Green Infrastructure is its social acceptability, as many people are still uneasy with the idea. The public does not consider Green Infrastructure as true infrastructure, and therefore are less able to trust in it. This unease towards these methods not only belongs to the public, but practicing engineers as well. In a manner of speaking, the engineer is relinquishing some of his or her control and allowing nature to take over, but in ways deemed beneficial for providing services.

Examples of Green Infrastructure

The following are examples of Green Infrastructure methods that are practiced by cities in the United States and abroad, as well as proposed solutions that may or may not be implemented in the future. While these examples focus on water-issues, it is important to note that the same method of design thinking can be utilized for other infrastructures.

Recognizing the very real threat of climate change in their low-lying lands, the Dutch government sought out new methods of flood protection. Rather than fight the rising tides, the Dutch are choosing to let the tide come in on their own terms. An initiative called “Room for the River” dedicates $3 billion to infrastructure investment. The money is not going towards building higher walls on dikes and dams, but instead towards lowering the dikes. The Dutch recognize that blocking the rising sea levels will be a very expensive and near-hopeless battle, so they are instead lowering the dikes to allow for ‘controlled flooding.’ Water will only flood certain areas of the engineer’s choosing in order to protect more highly populated areas. Other methods include constructing mangrove forests as buffer zones, using new materials such as geotextiles, flexible cement and bacteria to mimic rocky coasts and fortify dikes, and installing state-of-the-art sensors in dikes to warn nearby cities of rising water levels (Kimmelman, 2013). While much farmland has been sacrificed for the repurposing of land as controlled floodplains, newly constructed dikes feature retail, office and public space and some farmers have developed ways to continue farming on nearby artificial mounds. Green Infrastructure does not require a complete lack of modern technologies, it simply requires one to go with the flow and work with nature. The best example of such design thinking by the Dutch is the Sand Motor.

The Sand Motor is a project that uses the process of *Zandsuppletie* (Dutch for *Beach Nourishment*) as a way to revitalize the eroding Dutch coasts. In short, the Sand Motor is a large pile of sand deposited on the coast to form an artificial beach and island. As years pass, the natural processes of coastal winds and waves will push the sand along the coast, effectively smoothing out the artificial beach and act as protection for the coast (Katz, 2013). The project required an immense amount of planning and design by engineers, as they needed to understand the natural processes that governed winds and waves to create a desired form. This is an exemplary example of allowing nature to take over to shape the process of a system.

Within the United States, New York City has been a leader in adopting Green Infrastructure. Sewer overflows have been negatively affecting the water quality of the city, prompting the city to use vegetation, soils and porous pavement to hold storm water to prevent overflow of the sewer systems. New York City plans to invest $186 million over the next three years to install green roofs and bioswales (Navarro, 2012). These are traditional Green Infrastructure practices that are gaining popularity in cities all over the country for their cost-effectiveness and small land-use requirement.

Hurricane Sandy proved that New York City had more water-related issues than just sewer overflows. As Climate Change worsens, natural disasters are predicted to increase, and sea levels are forecasted to rise. Many solutions have been concocted to prevent another great disaster which rely on natural processes and services (Feuer, 2012). One approach is the construction of mossy wetlands bordering Lower Manhattan's coastline. These wetlands would act as sponge-like barriers during floods and reduce the force of surges. Wetlands and marshes would be woven together and combined with additional landfill to create park spaces. Another solution includes the creation of an artificial reef near the neighborhood of Red Hook made up of rocks, shells, rope and ingredients that would promote the growth of oysters. Oysters are known to act as barriers that break up incoming waves, as well acting as natural water filters. These solutions are examples of Engineered Ecologies – ecosystems designed by humans to provide services. They highlight the ecosystem services environments and species provide and utilize them for the benefit of society.

The cities of Baltimore, Maryland and Madison, Wisconsin are utilizing a technology called 'floating wetlands.' These wetlands consist of an array of floating vegetation which trap silt and nutrients within its soil to improve the quality of bodies of water and prevent erosion. Not only do these floating wetlands improve water quality, they also promote aquatic life (Wheeler, 2012). These artificial wetlands essentially mimic the wetland ecology to provide services to the environment and by extension, the people. These solutions have shown benefits in as quickly as twenty-one days (Tarr, 2012).

The city of Arcata, California is the site of the Arcata Marsh, a unique ecosystem that serves as a wastewater treatment facility (Marsh, 2013). The Arcata Marsh and Wildlife Sanctuary was constructed on a landfill and has now become a home for plants and animals as well as a site for pedestrians and birdwatchers – all while treating human wastewater in a safe an innovative way. After primary treatment, the water flows into oxidation ponds and then into treatment marshes to break down any food waste and remaining algae. These treatment marshes utilize plants, sunlight, machinery and chemicals to achieve their goals. Once chlorinated and de-chlorinated, the water enters the public part of the marsh where a series of enhancement marshes remove organic matter, algal nutrients and heavy metals. The Arcata Marsh serves as a great example of an engineered ecology that provides numerous social, ecological and environmental benefits.

While some of these examples may fall within the realm of Environmental Engineering, it is important to realize that infrastructure comes in many forms, and as designers of infrastructure, Civil Engineers must be aware of the variety of non-traditional solutions that exist to tackle growing problems. Civil Engineering has historically been a wide field that covers many sub-disciplines; it makes sense for the modern Civil Engineer to be knowledgeable in many areas.

Applying the New Paradigm

The above examples encourage engineers, designers and planners to rethink the current definition of infrastructure. The examples prompt the question, "how does nature solve these common infrastructure problems and how can the engineer apply these processes and principles?" This style of thinking is very common within the realm of biomimicry and in many cases, Green Infrastructure can be thought of as a form of biomimicry. The intention is to emulate the natural world while incorporating these systems into the urban framework. This style of thinking addresses the source of the problem, not just the symptoms. It is important to note that this paper does not claim that Green Infrastructure is the only way to address infrastructure challenges, it simply wishes to encourage a different framework to use when designing solutions. Green Infrastructure is just one tool in the engineer's toolbox and should be used in conjunction with traditional practices. In some cases, a traditional bridge or building may be the best solution, but asking ourselves why the solution is the best one based on fundamental principles is extremely important.

From the Green Infrastructure examples, one can see a clear shift in characteristics that define infrastructure. Where traditional infrastructure is made of ‘hard’ materials, Green Infrastructure is made of ‘soft’ materials. Traditional infrastructure is centralized and large scale; Green Infrastructure is generally decentralized and works on a variety of scales. Traditional is immobile, Green is responsive, adapting to its environment and even strengthened by the environment. Traditional Infrastructure is built to last as long as possible, while Green Infrastructure allows for updates, adaptations and even if necessary – the ability to fail safely. Paul Kirshen of the University of New Hampshire suggests that the infrastructure of the future must be designed to fail, but fail safely (Weeks, 2013). The idea is to plan infrastructure while considering the future use of the infrastructure (e.g. changing demand based on population growth or decline). Like many engineering designs, this thinking will develop safety measures in the event that when infrastructure fails, the public will be in an advantageous position to mitigate the damage. Kirshen proposes modular seawalls and prefabricated highway bridges with adjustable heights as examples of adaptable and updateable infrastructure. While demand flexibility has always been accounted for in infrastructure design, Kirshen calls for climate flexibility and a creative class of civil engineers.

How can these ideas be applied to other non-water infrastructures? One approach is Biomimicry – gathering inspiration from nature to inform transportation and structural design. Another way is to think about utilizing smart materials such as self-healing concrete. Instead of relying on classic heating and cooling systems we could utilize lichen on walls to regulate temperature (Matus, 2012). We could even feed a system of microbes that generate heat (Armstrong, 2013). There are many options available to Civil Engineers when considering biological approaches.

This new paradigm for infrastructure opens up numerous possibilities for integrative, naturally informed designs. Infrastructure will be enforced by nature, not damaged by nature. Civil Engineers will plant a well-designed ‘seed’ and allow it to grow and strengthen into a fully functional and adaptable public service. We will provide not just ecosystem services, but urban ecosystem services. Applying the new paradigm will bring about creative solutions to pressing problems.

Discussion

As Civil, Structural, Geotechnical, Transportation and Environmental Engineers, our roles are not simply to provide the mathematical calculations and designs for traditional infrastructure, our role is to be leaders in the infrastructure field and challenge the status quo. We must ask why we do the things we do, and consider changing the way we think about infrastructure in order to create new approaches. We cannot be boxed in by traditional roles in a heavily specialized culture. Infrastructure is the foundation of this country and needs to be reevaluated in order to improve it. As integral actors in the infrastructure design process, Civil Engineers cannot sit back and allow Landscape Architects and Architects to design and challenge paradigms, they must change them as well. The problem is an interdisciplinary one, and requires interdisciplinary engineers with basic knowledge in not just structures, mechanics and materials, but also chemistry, earth science and ecology. Civil Engineering is not just about math and structures, it's about tackling pressing problems. By widening the definition of infrastructure, I am not diminishing the importance of Civil Engineers, I am claiming that Civil Engineers have far more responsibility in this age to shape our society.

This new paradigm encourages one not to focus on simply the concrete calculations and designs, but also on the design process – what are the fundamental principles that influence our designs? We simply cannot stay with the same old methods. Our environment, economy and society will not allow us to remain complacent. We must continually push to innovate, and Civil Engineers must lead the way.

Green Infrastructure challenges the current method of viewing engineered services, which is crucial for tackling global issues and improving quality of life in a resource-constrained world. As designers, maintainers and constructors of Infrastructure, Civil Engineers must take the lead in changing the way the public regards the crucial systems that make up our society.

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