Towards the Development of a Rating System for Sustainable Infrastructure: A Checklist or a Decision-Making Tool?

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ABSTRACT

Sustainability rating systems such as LEED, BREEAM, and others, had a significant impact in the design and delivery of buildings and in the increased adoption and understanding of sustainability metrics, solutions and value proposition within governments, developers, and end-users. Sustainability rating systems facilitated the broad adoption of the term by providing point-based certification that is easy to understand, communicate, market, and include in project scope. Notwithstanding the criticism on the scientific base and comprehensiveness of some of the systems available, the adoption, use, and benefits of rating systems for building sustainability is clear and undisputable. However, missing from much of this discussion and action has been infrastructure, the base network for cities and buildings. Although there are examples of infrastructure projects that 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. In this paper we will present our efforts to develop a rating system for sustainability assessment in infrastructure projects. Our research led us to develop a framework or system that can act as a decision-making tool for the major agents involved in infrastructure provisions. Our goal is to provide the infrastructure industry with a sustainability rating system that will be widely adopted and that would improve the adoption of sustainable solutions and make the cities of the future a better place to live and thrive.

KEYWORDS

Sustainability, infrastructure, environmental assessment, rating system, decision-making tool

INTRODUCTION

In recent years, the term sustainability has become widely used and environmental design has become much more prevalent and broadly implemented, with several cities and states even requiring a higher baseline for sustainable new construction. However, missing from much of this discussion and action has been infrastructure, the base network for cities and buildings. While citizens are just starting to wrap their heads around sustainable living, it is clear that sustainable infrastructure has been overlooked and forgotten for the most part, by both the public and private sectors. This neglect is especially apparent as the American system of infrastructure is, in many areas, showing age and is in need of modernization. This need for modernization is immediate lest social and economic growth within the states be constricted. The private sector appears to be positioned to invest in such growth, but faces a lack of political and other guidance. An article posted by MSNBC in March of 2009 states that "Crowded schools, traffic-choked roads and transit cutbacks are eroding the quality of American life, according to an analysis by civil engineers that gave the nation's infrastructure an overall grade of D." This shows how unsustainable infrastructure in American truly has become. The lack of attention that has been paid to it in all respects has affected the sustainability of the nation.

With a great awareness of the deficits in research on sustainable infrastructure, Paul and Joan Zofnass made a generous donation to Harvard University's Graduate School of Design. With this funding, a group of chosen faculty and students have started creating a sustainability framework for infrastructure. The end product of this research will be a sustainability rating system for infrastructure. As a preliminary step in the research efforts, students read academic literature to develop an understanding of existing opinions about both sustainability and infrastructure. Faculty input and expertise supplemented the initial review. The goal of this early research was to develop an understanding of the relationship between sustainability and infrastructure, and more importantly, to begin to understand how to make a system for sustainable infrastructure.

LITERATURE REVIEW

Several papers address general models/frameworks for defining sustainability. Vanegas (Vanegas , 2003) finds that sustainability is comprised of five, interrelated subsectors: people, industrial base, resource base, natural environment, and built environment. These elements are part of a larger system that includes spatial scale, temporal scale, economic and financial systems, environmental systems, and ecological systems. The BEQUEST (Building Environmental Quality Evaluation for Sustainability through Time) system finds four underlying sustainable development principles - environment, equity, participation, and futurity (Bentivegna et al., 2002). Similarly, the Bossel report (Bossel, 1999**)** discusses the many dimensions of sustainability: environmental, material, ecological, social, economic, legal, cultural, political, and psychological. All these papers seem to share similar ideas with Soon Kam Lin and Jay Yang who posit that sustainability characteristics can be grouped into three key categories:

economic, social, and environmental. Their definition of sustainable development also expresses the interconnected nature of these three areas; to them a sustainable ideas lead to an "economically feasible, socially viable, and environmentally responsible project outcome."

The relationship between sustainability and infrastructure is clarified by Vanegas (Vanegas, 2003), who says sustainability ideas must be examined in regard to three aspects of infrastructure – what it does (products, goods, and services), how it does it (operations, procedures, and practices), and with what (natural resources required). These general models are useful for two main reasons. Ugwu (Ugwu et al, 2005) refers to the potential of models to act as alternates to conventional practices (which tend to encourage unsustainable means). A model additionally allows the translation of sustainable objectives into action. On the other hand, Dasgupta and Tam (Dasgupta and Tam, 2004) find that a model can present a hierarchical system, which is a useful means of deciding between alternatives. In their method, mandatory screening indicators (regulatory and project specific) and judgment indicators (environmental and technical) are used in succession to decide between alternatives.

Models also allow the development of key performance indicators. These indicators are crucial to translate sustainable concepts into concrete objectives at the project scale. Soon Kam Lin and Jay Yang find that a large gap currently exists between theory and practice, and Ugwu and Haupt (Ugwu and Haupt, 2005) expand upon this idea, positing that the gap exists because of stakeholders' education (not focused on sustainable concepts), a short term focus rather than long term focus when making decisions, and a lack of flexible user-friendly tools to facilitate quantitative analysis and decision support. Subsequently, Ugwu and Haupt present a method for translating categories of sustainability into a weighted system of indicators. After dividing sustainability into six main categories and approximately thirty subcategories, they mailed this list to different groups (including architects, engineers, "the public," etc.) and asked respondents to rank the importance of each item to "sustainability" on a scale of 1-5. Ugwu and Haupt found that nearly all of the items were significant aspects of sustainability, as each regularly scored greater than a four on their scale. Societal aspects of sustainability, however, tended to receive slightly lower rankings by all groups (with the exception of "public" respondents). The survey allowed the creation of a weighted system of indicators. A second method for creating indicators is described by Sahely (Sahely et al, 2005) who uses a quantitative time series approach. In this process, indicators are chosen and satisfactory ranges for each item are defined. Next, data is collected for each indicator over time and expressed as a time series, which is analyzed using statistical measures. The model then allows users to calculate the relative sustainability of a system using weighted criteria.

Another group of papers dealt with the issue of infrastructure provision, mainly focusing on developing countries. Panayotou (Panayotou, 1998) believes that the private sector is an important provider of infrastructure developing countries. He points out inherent structural differences between buildings and infrastructure and finds that these differences tend to create problems. These problems are exacerbated when infrastructure is provided by the public sector because it tends to be inefficient and costly. Vives (Vives, 1997) picks up on this same idea and argues for private provision of infrastructure. His paper examines specifically the recent surge of private provision of infrastructure in developing countries, investigating whether this increase signals a fundamental shift in the way infrastructure is provided or if it is simply a passing fad. The paper goes on to examine ten ways to "sustain" this private sector involvement.

Although many papers seemed to include "social" aspects in definitions of sustainability, only one significantly addressed this topic. The "Report of the World Summit" in 2002 resulted from an international conference and provides insight about political interpretations of sustainability. Sustainability is described in broad, vague terms and focuses on non-contentious issues in order to gain international support for the agreement. The report focuses on three basic goals (each with measurable, more-detailed sub-goals): eradicate poverty (human health), change unsustainable patterns of consumption and production, protect and manage natural resource base of economic and social development.

SUSTAINABILITY AND INFRASTRUCTURE

"Sustainability" and "Green" have become everyday words as the 21st century has progressed. However, while the concept of sustainability seems to have endless applications, it has proven difficult to define. The key to achieving sustainable infrastructure is by creating systems that not only address material demands now, but can continue to meet the demands of use for future generations. In this way, sustainability has proven to be more of a mindset, and is, therefore, exceedingly difficult to define in a concrete manner. It necessarily must be dynamic in its ability to encompass many fields with the objective of reaching an ideal state of being.

For sustainable initiatives to be successful, they must address issues of infrastructure. To date, most environmental design initiatives have focused on building design. The success of LEED® has brought attention to the emissions and design of the built environment. However, even if all buildings were able to achieve a LEED rating, additional sustainable initiatives would need to be achieved to counter-act ozone-depletion and global warming coming from non-building related emissions and energy consumption. It is predicted that "global energy consumption will increase by 2.7% annually from 1997 to 2020." (Bradley, 2002) Infrastructure plays a massive role in the sustainability of the built environment. Unlike buildings, infrastructure works at a larger scale and requires careful planning to work well and efficiently. It requires a lot of resources, and faces a high amount of wear and tear, while facing the expectation of a longer life cycle than other new construction. Furthermore, construction of infrastructure often has a great impact on local residents and must therefore be completed in as quickly a time as possible with many efforts taken to limit disturbances. Because of these unique issues, infrastructure is not easily guided by systems like LEED, which have been successful at the scale of a building.

When infrastructure is completed well and sustainably, it can limit loss of energy in power delivery, more effectively clean and transmit water, and allow for more seamless travel by motor vehicle, air, train, bike and foot. The design of infrastructure has large implications on local residents and businesses. Infrastructure is not limited to roadways and transportation, but also indicates power sources, pipelines and public commodities such as school systems and hospitals. These broad-reaching construction types that can fall within the conventions of "infrastructure" show how the term remains broad and generic. Because of the inherent differences between the diverse categories of infrastructure, a rating-system for sustainable infrastructure must be tailored specifically/separately for each individual type.

As we strive to provide a framework for sustainable infrastructure, it is important, as with any "sustainable" endeavors, to view and analyze infrastructure as it relates to the three broadly-accepted sub-categories of sustainability: environmental sustainability, social sustainability, and economic sustainability. Within the three classifications fall people, industrial base, resource base, natural environment and built environment. These five factors relate to the scales of space, time, economy, finance, environment and ecology. (Vanegas, 2003) This categorization raises the necessity to approach infrastructure by understanding the various factors, or lenses of influence. The largest of these being the impact that time has on a project. Time seems to be something that has not played a significant role in existing models for sustainable construction. It necessitates attention across design, operations, construction and eventual decommissioning. Time is especially relevant given the typically longer phases and life of infrastructure as compared to buildings.

LENSES OF INFLUENCE

Consideration of time can have a great impact on how sustainability in a project is approached and implemented. If one is to look, for example, at the way that emissions are calculated over the duration of a project, she will notice the following: during the design phase the effort is placed on providing the best solution to limit or completely prevent emissions when the project is complete, during operations. Not much effort is placed on limiting the actual emissions that might occur during the design phase, such as consultant travel. During construction, the goal is to limit emissions that are specific to the construction works, such as truck utilization and material transportation. During operations, emissions are (or should be) monitored and adjusted so that performance goals are met and the project operates efficiently. Finally, the need to monitor emissions during decommissioning is based on the fact that while dismantling or demolishing the project, an additional amount of emissions is released that should not be ignored. From this brief and simple description, one can see how one element can necessitate very different treatment and consideration over the life of the project. Failing to acknowledge these differences will take away from the sustainable nature of the project.

Similarly to viewing time as an axis of analysis, we found that the lenses of economical, political, ecological and social aspects should be included to our axes of analysis so as to provide a well-rounded sustainability assessment and address the needs of multiple generations. While sustainability is most commonly associated with environmental impacts such as reducing emissions, responsibly using resources, and protecting the environment, looking at the political, economical and social impacts can increase the overall breadth of the sustainability analysis. If, as some of the sources above indicate, sustainability is primarily focusing on the future, it is important to lay out infrastructure that can address the health of the local economy and society for immediate improvement that will seamlessly evolve with the needs of the society over time. Infrastructure becomes the foundation of social activity and productivity. After all, being environmentally responsible is pointless if the infrastructure fails to sustain the society for which it is built.

SOCIAL SUSTAINABILITY AND QUALITY OF LIFE

Many current rating systems neglect the importance of social sustainability as it relates to the economy and built environment. Environmental inequalities also often reflect deficits in social issues. Failure to maintain urban infrastructure can lead to poor health and disease due to poor waste and water treatment. Ralph Chapman of New Zealand's Ministry of Economic Development raises the important questions "how might better infrastructure contribute to health, say; how might reducing congestion contribute to both better social and economic outcomes through access to community services; and how might a different energy policy emphasis contribute to both reducing infrastructure costs and improving security of supply, with social, environmental and economic benefits." These are important questions, which have the possibility of leading to synergistic benefits if addressed well. For sustainable initiatives to succeed and effectively save future generations, there must be a movement to improve existing global living qualities while still preserve the earth for future generations in an effort to create a global standard of sustainable living. Solving such environmental issues as pollution will also improve the life quality and comfort of the citizens. Additionally, for social sustainability to be achievable ecosystems must be protected and biodiversity must be preserved. Sustainable design needs to focus on improving quality of life and limiting negative impacts on the environment, two concepts closely linked to social sustainability. This indicates how integrated different fields of sustainability must be in order to succeed.

Focusing on sustainability on a social level, as well as monitoring the influence of construction requires regional and local focus. While understanding environmental impacts at a global scale is important, implementation of sustainable initiatives is much more comprehendible and achievable when done on a local level and monitored by local authorities that are well attuned to area-specific issues and environments. Furthermore, to successfully make a positive global impact, regions must be treated differently in both policy and action. A developing country requires far different initiatives to achieve sustainability than westernized states that are facing issues with over consumption. However, examining community on a local level can create the basis for healthy community leading to a healthy regional economy and to community longevity. Ultimately, by focusing on tasks that communities can accomplish, global sustainability will be achieved.

REGIONAL IMPLICATIONS VERSUS GLOBAL IMPLICATIONS

Understanding the physical area impacted by a project also became a factor that we examined as we compiled research and began to create a system for understanding sustainable infrastructure. Infrastructural projects can have a seemingly limitless zone of disturbance as one can argue that between emissions, impacts on habitat, and carbon footprints, looking at the impacts of a small project can quickly result in examining it on a global scale. Between this concept, and the incredible range in scale throughout infrastructure projects, we feel it is important to set boundaries on which to examine project impacts. These boundaries should relate to the type of project. This means that the zone of influence for a coal plant and a pipeline are to be different in scale, shape and area outside the constructed zone. While it is important to consider the impacts of construction, limiting the zone of impact studied helps to keep projects manageable.

While the scope of the project may act primarily on a local level, creating healthy economy, content citizens, and reducing negative impacts on the local environment, these steps act in a small way to improve, and can help to minimize disaster, which the larger economy must respond to. Furthermore, focusing on the physical environment, such as infrastructure, provides an ‘anchor’ idea for “sustainable urban development” and “sustainable cities” (Bossel, 1999). Additionally, “urban sustainability as comprised of physical (natural, built), social and economic elements and factors that effectively support three main objectives: environmental equity (intra- and inter-generational), long-term allocative efficiency and distributive efficiency.” (Bathis and Christofakis, 2006)

While the theory of sustainable infrastructure has been studied, current research seems to be focusing on theory and current policy has made broad statements that have shown difficult to implement. A set of indicators would help to translate these goals into actuality by showing concrete ways to implement them. New York City has completed a study, including real cases, of High-Performance Infrastructure, which is successfully translating concepts into “best-practices.” Examining indicators of sustainable infrastructure would help to formulate a system of implementation applicable to multiple regions and types of infrastructure. We anticipate that this research close the gap between sustainable infrastructure goals and their realization at the project level. Our intent is not that all infrastructure types would be addressed in one system since, as indicated above; infrastructure is a still a broad reaching subject in itself. Rather, the hope is that a set of guidelines can be established with eventual specificity to one or several infrastructure types.

THE ZOFNASS SUSTAINABLE INFRASTRUCTURE RATING SYSTEM

After studying sustainability, infrastructure and their relation to each other, the research group established five overarching categories which impact sustainable infrastructure: Climate, Natural World, Resource Allocation, Quality of life and Health. With these five categories established, research associates were split into two teams from students chosen from the Harvard Graduate School of Design. The first teams conducted a study of existing literature with the hope of establishing a body of existing information from which to create a system from the top down. A second team examined existing systems relating to infrastructure from around the world and established a list of indicators, a bottom up approach. The focus of this investigation was on LEED ND, CASBEE, Cascadia, CEEQUAL and Green Globes.

From the research of these systems, we found that each places weight differently on the five categories of our research. (Resource Allocation, Climate, Natural World, Health, and Quality of life) Cascadia, for example, placed abut one third of it weight on issues relating to quality of life while Green Globes places almost no emphasis on this area, instead dividing it focus equally among the other three categories. Furthermore, models do not sufficiently respond to contextual factors of individual projects. We also found that across these five systems, there was a large variation of difficulty required to achieve certification. We felt that the existing systems were too focused on achieving a point without placing weight on innovation; they succumbed to a checklist mentality. Also, systems failed to weight requirements by the impact their achievement could have on the sustainability of the project. The systems tended to favor factors that were easily quantifiable, and, therefore, could have an easily defined baseline. Our examination also highlighted the need to include consultants in a system as valuable members of the team. To help analyze the systems from more of a practical standpoint, we combed through the point systems and compiled a table of the most relevant points from each rating system and which of our four categories the point would relate to, and for which infrastructural types.

Using primarily academic literature coupled with knowledge of these systems, the five chosen categories were analyzed and populated with subcategories. After populating categories, it became clear that some of the subcategories could fall into multiple headings. To remove overlaps and streamline the categories, the decision, with the help of faculty members, was made to remove the Health category as all underling subcategories could be defined within either the Natural World or Quality of Life categories. Climate and Resource Allocation remained the same.

With the help of a team of Harvard faculty members, we were able to shine light on several other important issues that we can focus on as we moved forward with our matrix. The discussion highlighted a need to study and consider performance of the built environment. They also pointed out the impact that infrastructure can have on the quality of life of local residents, something which became one of the main focuses of our research. Most importantly, however, was their discussion of infrastructure typology. The faculty strongly encouraged that as infrastructure was researched, that the scale and scope of, for example, a pipeline and a coal plant be understood distinctly with different implications. As the research was considered in terms of a rating system, the faculty members also advised that rather than defining absolute goals throughout the rating system, that benchmarks instead be considered. On this same note, they suggested that we continue to research existing systems as a way to not only educate ourselves on issues, but also as a way to begin to model our own system. Additionally, more overarching questions were raised, such as who would be using the rating system and how can the Zofnass system suit their particular needs.

After taking their comments under careful consideration and working to improve our research, we invited several industry leaders to come listen to the presentation of our findings and to present some of their projects and explain the sustainable goals of their respective companies. They agreed that there was a clear need and place for our research as applied to real world projects. Their discussion highlighted the issues with implementation on the global scale and the need to focus on regional impacts. They believed that by inspiring grassroots efforts through the focus on the individual citizen, the greatest impacts could be made towards sustainability. By educating at the local level, people can begin to spread information to their neighbors and acquaintances and assist them in also taking steps to live in a more sustainable manner. Because of their strong backing of this sort of education, the industry professionals also suggested making the Zofnass system one, which could be user-friendly and understood by a wide variety of individuals. People understand that they need to live more sustainably, but they do not understand how to, or have not been given the tools needed to do so. The industry professionals also suggested the importance of inter-generational understanding, claiming that it was harder for older individuals to adjust to more sustainable lifestyles while young people tended more easily adapt to new trends. They said that their clients used to want LEED certification, but now that LEED has become more common, many are pushing for Net-Zero emissions construction for marketing purposes. At the same time, all felt that the new system must structure its goals at a reasonable cost to achieve so as to be successful.

The information resulting from both academic and industry input informed the four preliminary categories. Within these categorizations, Quality of Life includes education, human comfort, social factors, political implications and economic well-being. Resource Allocation covers resources, materials, technology, energy, water and labor. It is closely tied to Climate, which refers to greenhouse gasses and ozone depletion. Finally, habitats, waste, plant life and vegetation, animals and environmental health characterize the Natural World. Within the main categories, the concept of time, as discussed above, was applied through Design, Construction, Operations and Decommissioning. This allowed for a priority to be placed on indication of when subcategories had impact, and for how long. It also allowed for a differentiation to be made on how the impact might change over time. Together, these time-related categories also serve to indicate the synergies and interconnectivity of the four categories. It not only indicates the synergistic effects, but also helps illustrate the implications of decision-making throughout a project.

Using these diagrams, the decision was made that the best approach to creating guidelines for sustainable infrastructure was to create a decision-making model. This works as an alternative approach to many existing systems, such as GreenGlobes, which prioritize check-lists and rely on users to simply fill a requirement rather than figure out the most practical, case-specific way to solve a problem. Furthermore, we felt that the system should be dynamic, allowing for instant feedback, to aid and influence decisions throughout the delivery process. It, again, also allows the element of time to play an important role throughout the project. This is important, as a factor such as CO_2 will have different implications during design when steps are being taken to prevent such emissions through design choices, and during operations when emissions are being monitored and adjusted to fall in line with the earlier design guidelines.

The Zofnass guidelines are not meant to stop after design, construction, and operations. They also highlight the need for continued monitoring to ensure that projects achieve their designed goals and remain efficient machines. However, eventual decommissioning is also an important factor in design. While longevity of operation should be a clear goal, consideration of alternative uses or deconstructing of the infrastructure it is of great importance for maximizing sustainability. This concept treats a project, in McDonough's words, as Cradle-to-Cradle rather than the conventional Cradle-to-grave. So, design should look beyond the completion of the construction, assuring that materials and space used for the project are thought of on a longer-term cycle. For example, the Bird's Nest Olympic Stadium in Beijing was designed to be adapted for use after the 2008 Olympics as a shopping mall and hotel. Similarly, the recent renovation of old train tracks for the High-line renovation project in New York is reusing the abandoned tracks as an elevated urban park. This adaptive-use concept encourages more accountability for design outcomes and helps results to be accurately achieved.

Finally, we felt that the most sustainable decision that our system could encourage a project team to make was to understand the need that drives the project and why people would want to build it. This is referred to as a go/no-go decision. The decision means that regardless of the sustainability of a particular design, if the infrastructure project is not really needed, or alternative solutions could be applied to satisfy the need, then not proceeding with construction is the most sustainable decision. For example, a new water cleaning plant, which will purify seawater, is proposed to a community. However, if after analysis and discussion with the community members, it is determined that the community is willing to reduce their individual water use, eliminating the need for the new plant. So, while a sustainable construction is proposed, reevaluating the community need shows that there is in fact no need at all as the community is willing to make passive action towards reducing water use. In this case, the go/no go evaluation can save the community millions of tax dollars, and provide a sustainably wiser decision.

CONCLUSIONS AND NEXT STEPS

After compiling all of our research and prototypical decisions, we are now faced with decisions of how a Zofnass project can be certified. We hope to be able to create a user-friendly system which allows for continued monitoring and representation of the project's sustainability performance over time, like, for example, a car's dashboard. We hope that by allowing all project users to see and understand the environmental output of a project on a real-time basis that they will be inspired to take even more actions to improve the metric they can actually influence, even at the smallest scale. So, while the underlying system may be complex and based on rigorous analytics, the ultimate interface will need to be simple enough for many types of users to easily understand and react to. As we move forward, we will continue to work closely with industry members to use their knowledge to conduct case studies of existing projects of built and proposed sustainable infrastructure. We hope that this course of study will help us to further evolve our framework and will allow us to develop a framework for infrastructure that is adaptable and flexible.

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