4th Construction Specialty Conference
4e Conférence spécialisée sur la construction

Montréal, Québec
May 29 to June 1, 2013 / *29 mai au 1 juin 2013*

Dynamic Sustainability Assessment of the Built Environment

Mehmet Boz[1] and Islam El-adaway[2]
[1]Ph.D. Candidate, Department of Civil and Environmental Engineering, Mississippi State University, Mississippi, United States and Chief Executive Officer, Xicon Infrastructure, Statesboro, Georgia.
[2]Assistant Professor, Department of Civil and Environmental Engineering, Mississippi State University, Mississippi, United States.

Abstract: In order to attain sustainable assessment of the built environment, it is of the utmost necessity to develop standardized methods, metrics, and tools to effectively and efficiently study, measure, and analyze the wide range of impacts of the construction processes from planning to completion and beyond. The narrow focus of the currently available assessment methods does not adequately address the technical, environmental, economic, social/cultural, and individual sustainability indicators as well as the temporal, spatial and behavioral aspects of sustainability. This paper develops a dynamic sustainability assessment framework for the built environment that is based on the three novel infrastructure forms, namely nature, work, and flow that were previously proposed by the second author. The "work form" defines the socio-behavioral relationships amongst the construction products and the actors of the built environment. It also attempts to delineate how the end-product is affected by how well the producers are connected to the product. The "nature form" focuses on the effects of the built process on the environment through studying the interaction between the construction actors, their associated processes, and the end-products within their host systems. The "flow form" identifies the changes within the community host systems and the effects of these changes on the natural environment and the socio-economic setting that encompasses the project. The authors applied this innovative framework to a transportation infrastructure project. This research improves our understanding of environmental, social, and economic effects of the built environment resulting in a sustainable infrastructure.

1 Introduction

The construction industry is very active in both developed and developing countries. According to Simonson, the Chief Economist for Associated General Contractors of America (AGC of America), the construction industry employed 5.5 million workers in the United States (US) and reported a 2010 spending total of $816 billion (AGC of America, 2011). In related industries, US manufacturers produced $486 billion in construction materials and supplies and $31 billion in new construction equipment (AGC of America, 2011). In Europe, the construction industry is Europe's largest industrial employer, directly employing 11.8 million workers, which accounts for 7% of total employment in the EU, and reporting 910 billion euros in construction spending in 2003 (Ortiz et al., 2009).

The goal of efficiency in construction is creating financial value, which does not always parallel what is environmentally or socially desirable. For the sake of efficiency and under the premise of urban growth, a large number of communities now accommodate and even subsidize businesses even when those businesses operate under practices that disregard the environment and proper land use (LeRoy and McIlvaine, 2010). Construction industry is responsible for high-energy consumption, solid waste generation, global greenhouse gas emissions, external and internal pollution, resource depletion, and as a result, environmental damage and, at times, an economic burden that localities have to find or invent ways to mitigate. In most cases, sustainable development has been the answer.

Over the years, the desire and the need for sustainable development pushed communities, as well as organizations of the construction industry, to come up with or adopt ways, means, and methods to study and analyze the building process and its effects. Especially since the early 1990s, the building sector has been active in developing assessment tools, which have gained considerable success and amassed new knowledge databases through the contributions of actors and experiences from across the construction spectrum (Haapio and Viitaniemi, 2008). While this awareness brought forth a series of positive consequences, most of the sustainable built process evaluation means and methods are narrowly focused and fail to place the object of the analysis within a broad holistic context that reaches beyond the study of that particular object of study. A great number of the existing methods are not designed for evaluating construction activities and fail to provide a standard to assess work performance and establish a performance benchmark. This shortcoming makes it difficult for building professionals to keep records of their goals and achievements (Tam et al., 2004).

Sustainable built process evaluation methods available to the industry and its customers today place their focus mainly on construction materials, construction techniques, and environmental impact. The disconnections amongst the actors within the building industry, disagreements within the construction industry on what method to implement, lack of communication between the construction industry and its customers, and the disconnection amongst communities and governments highlight the need for an integrated, holistic assessment approach that is based on the interdependencies of the construction industry and the people whom it serves.

2 Goal and Objectives

This paper develops an innovative three-step systems methodology that brings the construction industry and its customers together to recognize the broad sustainability indicators (i.e. technical, environmental, economic, social/cultural, and individual) of the construction processes. This novel approach creates a holistic and multi-disciplinary framework that can be utilized to evaluate the actors, products, and the dynamics within the industry and their evolution through time and interactions in the context of sustainable development.

3 Background Information

3.1 Construction Ecosystem

Construction ecology studies and evaluates the built environment in a manner similar to traditional methods employed in the natural and social sciences where the associations and relationships amongst the actors, stakeholders and resources within a system are studied as a whole. In order to understand the construction process from an environmental perspective, the effects of the built environment on the natural environment must be studied in great detail. When describing the systems theory, Haapio and Viitaniemi (2008) explain that the effectiveness and efficiency of a system, which can be a product, process, or human activity, must be assessed using a variety of factors including the perspectives of engineering, social science, and humanities.

3.2 Construction Products

Dulaimi (2005) asserts that in the construction industry, the products are immobile and custom-made following consultation with the buyer before the product is made. This process places the buyer, or the owner, in a position where, unlike most other industries, he is involved in the production process, not as a producer, but as a participant who provides direction and funding. Yitmen (2007) points out that a strong argument can be made that the disconnection between the construction professionals and the customers is due to the lack of communication and the lack of common understanding of the process by the actors, which often leave the parties involved with a certain level of disappointment, even if the end-product performs per design standards.

3.3 Sustainable Development

The term "sustainable development" was first introduced in the Our Common Future report of the World Commission on Environment and Development in 1987, and the concept has since been adopted as a policy principle by the UN, the EU, numerous countries, companies, business councils, political parties, NGOs, etc., often sub-divided into three dimensions: (1) Economic; (2) Environmental; (3) Social (Heijungs et al., 2010). After the 1992 Rio Earth Summit, sustainable development became an important factor in planning of construction projects and developments in general. According to Haughton and Counsell (2004), early applications of the concept focused almost solely on protecting environmental resources.

Chiu (2004) points out that the concept of sustainability was initially understood as what we now call "environmental sustainability" or "ecological sustainability", referring to the long term goal of minimizing the effects of human needs and wants on the natural ecology. As sustainable development gained more attention, other branches of sustainability such as "social sustainability", "cultural sustainability" and "economic sustainability" also gained traction as important elements of sustainable development. These four branches of sustainability are codependent, and each are subject to varying degrees of interpretations by those whom apply these concepts to the overall concept of sustainable development.

According to Ndubisi (2008), the most noticeable effect of urban development is the fragmentation of land into smaller parcels. The negative consequences of urbanization are also seen in land use conversions, and changes in land use type and intensity. For many policy makers, growth is good, no matter the cost, as population growth is often preceded by economic growth.
Sustainability and the Construction Industry

Bilec et al. (2010) explain that the built environment has significant regional, national, and global environmental impacts, in addition to its socio-economic effects: From design to material extraction and processing, manufacturing of materials, construction, use and maintenance of built facilities, and deconstruction of decommissioned buildings, the processes that compose the construction or built environment use energy, produce waste, and disturb established environmental setting. Nonetheless, existing research concludes contradicting findings on whether the environmental effects of the construction process are negligible or underestimated (Bilec et al., 2010).

3.4 Fragmentation and Regionalism

Gonzalez et al. (1998) argue that variations in regulations, institutional restrictions, and labor and tax regulations imposed on the construction industry are the main culprits of the fragmentation of the construction industry. Fragmentation is an increase in the number of entities and a decrease of the average size of these entities. According to Gonzales et al. (1998), the fragmentation process is a qualitative change that de-emphasizes employment relationships and emphasizes market relationships. If firms are defined as teams, entrepreneurship transfers from the team to the team members through the process of fragmentation.

According to Haughton and Counsell (2004), since then, planning at the regional level has been considered essential in providing a discussion platform and a path for deciding the nature of future settlement patterns. Many regional government bodies are now either tasked with or desire to pursue sustainable development as a part of their regional development policies. While regionalism provides a framework and guideline for development, the number of players involved in the decision making process of regional policies and strategies may cause sustainable development to be interpreted differently by the different stakeholders. This can then lead to differences between the policy areas of economic development and planning, due to the assumptions about the importance of employment and wealth creation (Haughton and Counsell, 2004).

3.5 Sustainable Development Assessment Methods

Heijungs et al. (2010) point to a Hacking & Guthrie report that claimed “At an international workshop on ‘SEA and Sustainability Appraisal’ it was apparent that there is little consensus regarding the meaning of Sustainability Assessment.” Forsberg and von Malmborg (2004) explain that the necessity to determine ways and means to achieve a sustainable society and quantify “how green” the building process is born out of the rising interest by communities, and demands from policy makers. According to Bilec et al. (2010), though much of the assessment attention lies in the immediate environmental effects of construction, some methods also focus on energy use in buildings, the sick building syndrome, indoor climate, hazardous materials etc. (Bilec et al., 2010).

Forsberg and Malmborg (2004) discuss two classes of assessment tools, as previously defined by Reijnders and van Roekel. These two classes are: (1) qualitative tools based on scores and criteria; (2) quantitative tools using a physical life cycle approach with quantitative input and output data on flows of matter and energy. These two divisions display a wide variety of assessment tools available and utilized all over the world. Some of these tools are CASBEE, BREEAM, Envest, UrbanSim, LEED, and ENVISION.

3.5.1 Life-Cycle Assessment

An objective study of the environmental impacts associated with built environment is a core tenet of sustainable development. Life-cycle assessment (LCA), which promotes consideration for global, national, and regional impacts on social and environmental problems, provides a method to select materials, study processes associated with construction, evaluate the systems utilized in the process, and creating a methodology with which processes are implemented. LCA is described by the International Organization for Standardization’s ISO 14040 series as an iterative four-step process: (1) Goal and scope definition, (2) Life-cycle inventory (LCI), (3) Lifecycle impact assessment (LCIA), (4) Interpretation. This method provides a framework to study the social and environmental inputs of products and processes from conception to completion, as well as their effects on human health, resource depletion, and ecosystem quality (Bilec et al., 2010; Fthenakis and Kim, 2011).

Though a helpful tool for discussing the environmental effects of processes and products, due to the issues outlined above, LCA remains an underdeveloped tool that requires a series of improvements in order to be considered a reliable method with objective conclusions (Krozer and Vis, 1998). For this reason, a method that highlights the sustainability of built environment within a greater socio-economic setting and one that is not limited to the traditional ecology driven approaches has yet to be established (El-adaway and Knapp, 2012).

3.6 Knowledge Gap

When assessing the sustainability of the built environment, it is necessary to conduct analysis from the perspectives of individual, local, and regional/global perspectives. The individual perspective focuses on the overall quality of life and the health of the product user. At the local level, the emphasis is surrounding communities, neighborhoods and the socio-economic and natural environments. The regional/global perspective is concerned with the extraction, manufacturing and transport of materials and its associated energy use, the energy use of the final product, and the impact of this final product to the socio-economic and natural environments at a larger scale (Tessema et al., 2009).

While the need for assessing the sustainability of built environment is widely recognized, there is little agreement on what methods and tools are the most effective. Daniell et al. (2005) points to previous research and literature that concludes that governments and planners require more holistic sustainability assessment methods; however, the narrow focus of the assessment methods available today do not adequately address the sustainability goals of future developments and temporal, spatial and behavioral aspects of sustainability. In addition, there is lack of common methodology to collectively address resource usage together with various sustainability indicators (i.e. technical, environmental, economic, social/cultural, and individual). These shortcomings make it necessary to develop a new assessment method to measure the sustainability of built environment (Daniell et al., 2005).

4 Methodology

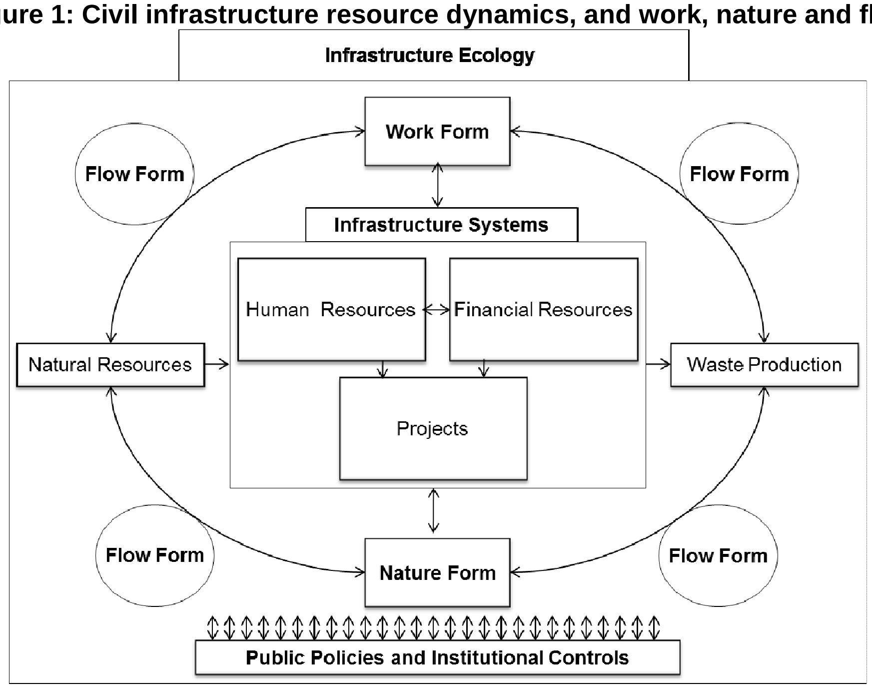
4.1 Overview

The methodology utilized in this study encompassed four interdependent steps where the author: (1) developed a scientific basis for the concepts of work, nature, and flow; (2) developed and distributed an expert survey to validate these concepts; (3) collected project data for five civil infrastructure projects; (4) applied the concepts of work, nature, and flow to the project data.

4.2 Basis of Work, Nature, and Flow

In any given construction process, the interconnected and interdependent variables of the construction ecosystem are affected by rules and regulations, and are shaped by the ever-changing and developing nature of the actors, settings, and resources. In order to understand the dynamic nature and the effects of the construction products and the construction ecosystem, a number of meaningful benchmarks must be defined to identify the points at which the relationship between the two concepts affect one another. The framework must include the process, producers, products, the natural and socio-economic environments and the relationships of each one of these concepts with one another, and utilize the five key terms previously described: technical sustainability, environmental sustainability, economic sustainability, social and cultural responsibility, and individual sustainability. The innovative and transformative benchmarks used to develop this framework can be grouped in three categories: (1) Work, (2) Nature, and (3) Flow. The relationship between these three benchmarks and the resource dynamics within a system are depicted in Figure 1.

Figure 1: Civil infrastructure resource dynamics, and work, nature and flow



4.3 Work

"Work" benchmark defines the socio-behavioral relationships amongst the construction products, and the actors and stakeholders of the built environment. It brings clarity to the interactions between what is made, by whom it is made and why it is made. In any given project, the involvement of the actors is not due to the desirability of the construction process or the relationships with other actors, but the usefulness and the need for the end-product. Thus, while the interactions amongst the actors are important, the relationship between the product and the actors is more important.

4.4 Nature

"Nature" benchmark focuses on the effects of the built process on the environment by studying the interactions of the actors, the process and the end-products with the environment. Ndubisi (2008) points out the negative effects of rapid urbanization on the environment, and Bilec et al. (2010) describe in detail the significant regional, national, and global environmental impacts of the built process, in addition to its socio-economic effects. The timeline that makes up any given construction project, from design to completion, includes many sub-processes that may have significant impacts on the environment.

4.5 Flow

The focus of the "flow" benchmark recognizes the dynamic nature of the industry. It focuses on the means and methods used to analyze the changes that the actors, stakeholders, and the products experience over time. Understanding the ever-changing nature of those who are involved in the process can explain the changes seen in the construction products over time. Identifying the positive changes, and finding associations with these improvements and the changes in the attitudes of and the methods used by the construction professionals indicates that there is a clear pathway between positive changes in the process and the positive changes in the products, which in turn identifies the level of lessened impact to nature.

4.6 Approach

An expert survey was utilized to assess a number of industry experts' attitudes towards various project attributes and their effects on sustainable built environment. In light of the concepts of work and nature, and expert opinions, as well as other data available from existing literature, a series of sustainability indicators were developed. The researcher then analyzed the project data to measure these sustainability indicators for the project studied.

Data was studied based on a number of scalable factors that are representative of the producer-product relationship, and the effects on natural and socio-economic environments. In order to develop a set of sustainability indicators for the purposes of this study, the researcher included topics that were developed in parallel with the questions posed in the expert survey and the responses received, and the information from existing literature on the sustainability indicators for the assessment of civil infrastructure projects.

5 Results and Analysis

5.1 Expert Survey

In order to understand the attitudes of construction professionals towards various elements of sustainable built environment, the researcher distributed surveys to twenty-four experts that are licensed engineers, architects, landscape architects, and planners. The experts are either known to the researcher through work-related connections and activities, or are identified and recommended by the researcher's peers as persons of desired level of expertise. The survey communicated to the participants that their identities are confidential and their answers will be kept anonymous. Of the twenty-four surveys distributed, fifteen were returned to the researcher, which corresponds to a response rate of 62.5%.

5.2 Data Collection

In order to develop these concepts and to avoid being unrepresentative of the industry, the author chose projects with different scopes representing a wide spectrum of construction projects. This approach of breadth, instead of one of depth that would focus on a single type of project, allowed the researcher to develop the concepts described within this study and to avoid focusing on a single type of project that would not be representative of the entire industry. This process provided an improved understanding of the environmental, social, and economic effects of these projects from a systems perspective.

5.3 Sustainability Indicators

As previously discussed, it is necessary to organize the data related to the interactions and collective effects of the sustainability related project data in a manner that adequately explains and helps appraise the sustainability of construction projects. Consequently, the first step in analyzing the sustainability of construction projects is to develop sustainability indicators that are easy to understand by the stakeholders and apply to the type of project data that is usually readily available. With this in mind, the expert survey, existing literature and the key terms of sustainability are used as a guidance to develop sustainability indicators that correspond directly to the two benchmarks of sustainable built environment that this study follows, work and nature.

5.4 Project

5.4.1 A Highway Project

This project is located in the greater metro area of Dallas – Fort Worth, TX. The project scope includes construction of new roadway lanes for approximately one and a quarter (1.25) miles. The construction budget for this project exceeds $30MM.

In highway projects, the owner usually has a specific vision, and a source of funding approved to implement that vision. Since the funding of projects is dependent upon public perception and approval, it can be concluded that that highway projects, in general terms, involve a level of communication between the owner, the industry and the end-users. For this reason alone, the designer's approach must match or closely follow that of the owner's. The owner's vision, in this case, intends to improve traffic flow and reduce congestion, which in turn is expected to improve social and economic conditions for those that utilize this stretch of highway. Impact to the natural environment is considered, though the effort is focused on meeting the minimum requirements to meet environmental regulations. As mentioned previously, transportation infrastructure projects usually serve a population that is greater than people located immediately adjacent to the project site. Thus, it is important to identify a population that benefits from the project. In this case, the researcher used the population of the entire County, instead of the City where the project is located.

In this particular project, the degree of connection between the actors and stakeholders involved is high, which in turn leads to a greater awareness by the end-users of the effects of the construction process on their livelihood. It also increases the awareness and accountability of the decision makers, designers and the builder on the same topic. The end-result is a project that satisfies the needs of today without compromising the needs of tomorrow, and one takes into account the obvious negative effects of built environment.

As this project and the researcher's discussion demonstrate, the approach must extend beyond an environmentally conscious framework and include a broader understanding of variables. This project does not address the greater socio-economic effects of the project, and it also does not take into account the responsibility of the industry professionals beyond project completion. Table 1 lists the project scores for work and nature, based on the scoring system developed by the author:

Table 1: Highway Project, Sustainability Indicators, and Scoring

Sustainability Indicator	*Key Term of Sustainability*	*Relevant Topic*	*Highway*
WORK			
Vision	Technical	Owner's vision and design consultant's approaches match	5
Vision	Technical	Design consultant proposes multiple approaches	1
Experience	Technical	Design consultant firm's experience working on similar	5

		projects	
Experience	Technical	Design professionals' similar project experience	5
Experience	Technical	Construction contractor's experience working on similar projects	5
Cost	Economic	Project cost is comparable to other projects of similar scope	4
Cost	Economic	Life cycle cost of the project considered	3
Vicinity	Social and Cultural	Project approach addresses effects on employment of labor	1
Vicinity	Social and Cultural	Project approach addresses effects on nearby businesses and residences	4
		Average =	3.7
NATURE			
Environment	Environmental	Project approach considers impact on natural environment	2
Environment	Environmental	Project approach considers impact on socio-economic environment	1
Environment	Environmental	The project considers effects on trees within project limits	4
Environment	Environmental	The project considers effects on natural habitat	2
Environment	Environmental	The project does not contribute to noise pollution (during and post construction)	4
Environment	Environmental	The construction effort does not produce hazardous waste	5
Environment	Environmental	The project considers effects on cultural heritage	2
Land Use	Environmental	The need for land acquisition is minimal	3
Land Use	Environmental	The need for re-zoning is minimal	5
Re-use and Re-cycle	Environmental, Individual	The project utilizes re-use and re-cycling of water within project limits	1
Aesthetics	Environmental, Individual	The project aesthetically "fits in" with the adjacent existing improvements	4
Proximity	Social and Cultural, Individual	Designer's nearest permanent office to the proj site (desirable proximity is considered 50 miles or less)	5
Proximity	Social and Cultural, Individual	Contractor's nearest permanent office to the proj site (desirable proximity is considered 50 miles or less)	5
		Average =	3.3

Note: A score of 5 shows the most amount of agreement with the relevant topic, and a score of 1 shows the least amount of agreement.

5.4.2 Work Analysis

Table 1 above summarizes the scores for each criterion for the highway project. The work benchmark includes sustainability indicators that are vision, experience, cost, and vicinity, and key terms of sustainability that are technical sustainability, economic sustainability, and social and cultural responsibility. This project received a low score of 1 in "vision" sustainability indicator that is linked to technical sustainability, and another low score of 1 in "vicinity" sustainability indicator that matches a key term of sustainability of social and cultural responsibility. The remaining scores were between 3 and 5, which indicate average to high sustainability ratings.

5.4.3 Nature Analysis

Nature benchmark includes sustainability indicators that are environment, land use, re-use and re-cycle, aesthetics, and proximity, and key terms of sustainability that are environmental sustainability, individual sustainability, and social and cultural responsibility. This project received low scores of 1 and 2 in four "environment" sustainability indicators that are linked to environmental sustainability, and another low score of 1 in "re-use and re-cycle" sustainability indicator that corresponds to a key term of sustainability of environmental sustainability and individual sustainability. The remaining scores were between 3 and 5, which indicate average to high sustainability ratings in remaining categories.

6 Conclusions and Future Related Work

A thorough review of the dynamics within the construction industry and the sustainable built environment assessment tools reveals the need for a more comprehensive method that brings the construction industry and its customers together to recognize the socio-economic impact of the construction process by developing a holistic and multi-disciplinary framework that can be utilized to evaluate the actors, products, and the dynamics within the industry and their evolution through time and interactions in the context of sustainable development. In order to address the issue, this research developed three innovative system-based concepts to assess sustainability of civil infrastructure projects namely: (1) work, (2) nature, and (3) flow. The "work benchmark" defined the socio-behavioral relationships amongst the construction products and the actors of the built environment. It also attempts to delineate how the end-product is affected by how well the producers are connected to the product. The "nature benchmark" focused on the effects of the built process on the environment through studying the interaction between the construction actors, their associated processes, and the end-products within their host systems. The "flow benchmark" identified the overall system changes within the community host systems and the effects of these changes on the natural environment and the socio-economic setting that encompasses the project. It can be concluded that this research succeeded in: (1) defining a sustainability systems approach to study of the built environment; (2) assessing the degree of communication between the construction industry and its community host systems; and (3) evaluating the relationship between the construction industry and its customers.

The future work of this study will further explain the three benchmarks, and focus on the development of the "flow" benchmark, and the variables that make up the ongoing and ever-changing relationships that define the producer-product-user triad. The interdependent causal interactions and relationships of the five key sustainability terms can be computationally defined and a multi-faceted performance and reliability model can be developed. This model and respective simulation efforts can lead to a new scientific approach to assessing the sustainable built environment. Through modeling and simulation, more accurate real-time decisions will be made efficiently, and databases containing project based data as well as experience based information can be collected. Based on the results of the current research, the modeling process should follow three levels of aggregation:

1) Macro-level to model the actors' and stakeholders' use of local resources over time.
2) Micro-level to model the network of decision makers and resource managers using agent-based simulation.
3) Multi-objective optimization to allow agents to determine the Pareto optimal balance among alternative resources and strategies, as well as utilize ranked prioritization.

Eventually, this study and the future work that will follow will entirely re-consider the mechanics of the construction process, and find contemporary answers to the questions of how we build, for whom we build, and by whose hands we build.

References

AGC of America. (2011, March 4). The Economic Impact of Construction in the United States. US.

Bilec, M. M., Ries, R. J., & Matthews, H. S. (2010). Life-Cycle Assessment Modeling of Construction Processes for Buildings. *Journal of Infrastructure Systems*, 199-205.

Chiu, R. L. (2004). Socio-Cultural Sustainability of Housing: a Conceptual. *Housing, Theory & Society*, 65-76.

Creswell, J. W. (2012). *Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research.* Boston, MA: Pearson Education, Inc.

Daniell, K. A., Kingsborough, A. B., Malovka, D. J., Somerville, H. C., Foley, B. A., & Maier, H. R. (2005). Sustainability Assessment of Housing Developments: A New Methodology. *Colloque CABM-HEMA-SMAGET 2005, Joint Conference on Multi-Agent Modeling for Environmental Management, Bourg-Saint-Maurice : France*, (pp. 1-31).

Dulaimi, M. F. (2005). The challenge of customer orientation in the construction industryC. *Construction Innovation*, 3-12.

El-adaway, I., & Knapp, J. (2012). Towards a More Sustainable Rating for the Built Environment. *Construction Research Congress*, 1981-1990.

Forsberg, A., & Malmborg, F. v. (2004). Tools for environmental assessment of the built environment. *Building and Environment*, 223-228.

Fthenakis, V., & Kim, H. (2011). Photovoltaics: Life-cycle analyses. *Solar Energy*, 1609-1628.

Gonzalez, M., Arrunada, B., & Fernandez, A. (1998). Regulation as a Cause of Firm Fragmentation: The Case of the Spanish Construction Industry. *International Review of Law and Economics*, 433-450.

Haapio, A., & Viitaniemi, P. (2008). A critical review of building environmental assessment tools. *Environmental Impact Assessment Review*, 469-482.

Heijungs, R., Huppes, G., & Guinee, J. B. (2010). Life cycle assessment and sustainability analysis of products, materials and technologies. Toward a scientific framework for sustainability life cycle analysis. *Polymer Degradation and Stability*, 422-428.

Krozer, J., & Vis, J. (1998). How to get LCA in the right direction? *Journal of Cleaner Production*, 53-61.

LeRoy, G., & McIlvaine, L. (2010). *Paid to Sprawl: Subsidized Job Flight from Cleveland and Cincinnati.* Washington, DC: Good Jobs First.

Ndubisi, F. (2008). Sustainable Regionalism: Evolutionary Framework and Prospects for Managing Metropolitan Landscapes. *Landscape Journal*, 51-68.

Ortiz, O., Castells, F., & Sonnemann, G. (2009). Sustainability in the construction industry: A review of recent developments based on LCA. *Construction and Building Materials*, 28-39.

Tam, C., Tam, V. W., & Tsui, W. (2004). Green construction assessment for environmental management in the construction industry of Hong Kong. *International Journal of Project Management* , 563-571.

Tessema, F., Taipale, K., & Bethge, J. (2009). *Sustainable Buildings and Construction in Africa.* Federal Ministry for the Environment, Natura Conservation, and Nuclear Safety (BMU).

Yitmen, I. (2007). The challenge of change for innovation in construction: A North Cyprus perspective. *Building and Environment*, 1319-1328.