Pragmatic Passive Sustainable Construction Practices

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A typical building construction process runs through three main consecutive phases: design, construction and operation. Currently, many architects and engineers provide enhanced evidence-based designs that reflect improved energy performance. Similarly, building tenants have demonstrated a dramatic increase in awareness, concerning building operation and energy usage. Although building construction is chronologically located between both the design and the operational phases, the construction phase has not yet been addressed in terms of developing innovative sustainable construction practices that reduces its energy consumption and meet the triple bottom line of economic, social and environmental sustainability. The study applied three passive sustainable practices on an actual construction case study project to understand and compare their financial impacts pre- and post their implementation. To showcase some potential cost savings, these examples applied an adaptive management approach to analyze the overhead costs, productivity of the concrete activities and efficient storage of materials. The results demonstrate that when contractors implement sustainable passive practices during construction the overall project would yield various financial savings. Some of these financial saving are: (1) increasing the productivity of the tiling activity resulting in a 25 % decrease in its duration, which reflected a total saving of $35k, (2) increasing the productivity of the concrete activity, which shortens the duration of the construction by 45 days and thus reflecting a saving of $1.5 Million, and (3) reducing the overheads of the labor camps by efficiently orienting the temporary shelters, which would reduce the need for cooling and heating thus reflect a saving of $10K. Through evaluating the effectiveness of possible sustainable construction practices based on financial savings, this paper contributes to the construction practice body of knowledge by providing proof of concept that encourages contractors to adopt sustainable practices during construction.
Key Words: Sustainable Construction Practices, Overhead costs, Construction Productivity, Storage of Materials, Adaptive Management.

Introduction

The vulnerability of our resources and the human adverse impacts on the environment has urged the scientists, architects and engineers to rigorously consider sustainability and the built environment. There is very little awareness about the complex intricacies that go into the various phases of construction practice. In fact, the building industry is regarded the infrastructure on which the economy is built (Crosthwaite, 2000). The construction industry invests little consideration to implement sustainable construction practices (Halliday, 2008). United States Green Building Council has demonstrated that the building industry consumes nearly half of all energy produced in the United States (Janda, 2011) and buildings are liable for over 41% of total operational energy use (Frey et al., 2012). In addition, the building industry is accountable for more than 73% of electricity consumption (EIA, 2012). These statistics are staggering. It is also important to point out that building industry is regarded as the largest emitter of greenhouse gases on the planet, the greatest contributor to CO_2 emissions and waste outputs (EIA, 2008). However, the research will draw the attention to another critical aspect of the building process. A blind eye is often given to the criticality of the construction's impact on the entire building process, despite construction being the main composer of the economy. In the United States, more than 7.5 million jobs are sustained within the construction sector, proving just how vital this lifeline is to our economy (USCB, 2015).

A growing number of academics and professionals in multi-disciplines are conducting research related to sustainability issues (Chester et al., 2017, ElZomor et al., 2016). Buildings research focus on the post occupancy due to the inception that the user's impact on the energy is the highest compared to the design and construction phases (Arababadi et al., 2017), while minimal efforts have been directed towards contractor behavior and sustainable construction practices specifically during the construction phase. Demaid and Quintas (2006) indicates that contractors have been implementing time-worn construction methods, which do not reflect sustainability or consider the environment. On the other hand, Fowler and Rauch (2006) show that designers and architects, have various building rating systems to enhance the building's design. Similarly the building occupants have been provided with manuals and practices to become more sustainable and reduce energy consumption (Kibert, 2016). Kiernan (2008) stated that investors and building officials are determined that sustainability is the philosophy that should dominate all paradigms. Ashley and Carney (1999) mentions that one of the reasons that this problem exists is that contractors lack awareness that implementing a sustainable technique is critical to both the project and environment. Shi et al. (2013) believe that another barrier to implementing sustainability during construction is that new recruits to the construction industry have never been guided or educated to adopt sustainable energy efficient practices and/or practices. Furthermore it is worth noting that in the field of sustainable construction, research generally has been focused on special case studies that only relate to specific region of the world. For instance, those studies focused on environmental awareness (Majdalani et al., 2006) or Lean construction (Song and Liang, 2011) or construction companies attitude in relation to sustainability (Myers, 2005). However this study will focus on the construction phase and highlight three pilot examples that contractors can implement to embrace sustainability and ensure sustainable construction practices. Correlating them to financial savings during the construction process will reinforce these examples.

Methodology

The case study project used is a mixed-use office park project consisting of nine, 7-stories commercial buildings. The project's duration was 4.5 years with a budget of $120 Million and the first phase was delivered on time and within the allocated budget. The research team chose this two identical phased project, as it is a mixed-use project with commercial and retail spaces. The research team was able to use this project as experimental to monitor and implementing some potential sustainable practices in the second phase. Also, this project is located in a hot arid region and the research provisioned testing the implementation of sustainable practices tailored to hot regions.

Initially, the research team observed several practices in the construction practice that would save energy, manpower, cost, time and quality. This research's methodology integrates between conceptualized sustainable practices and its implementation on an existing case study. Applying and correlating sustainable construction activities to a case study yields to: (1) identify some cost saving practices that could have been implemented or avoided during the construction practice, and (2) evaluate the impacts of implementing these practices on the overall performance. It is worth noting that the potential cost savings will be provided through a comparison table that demonstrates the differences between the actual vs. proposed sustainable costs (which was implemented in phase two of the project). The adopted sustainable concepts were adopted by the contractor and then analyzed to identify its cost implications on the overall project performance. The three provided validation examples, establish a trend, showing that when contractors embrace a sustainable construction practice the overall project would congregate various economical savings. The research refers to an adaptive management system to show how being flexible, ready to adapt/adjust and learn while continuously monitoring are the principle techniques to embrace a new philosophy "sustainability" within the construction practice.

This research uses the adaptive management principles (Allenby, 2014), to encourage and guide contractors to adopt some sustainable passive practices during the construction processes. Endorsing the adaptive management principles through a construction practice aids contractors sense, anticipate, adapt and learn from previous implementations and so realize the potential of implementing sustainable construction practices. As a validation process, the study reverts to an evidence-based case study to reveal and criticize three examples of sustainable strategy practices. Also an energy-modeling tool was used to validate the impact of different layout scenarios on the electrical bills. Through an adaptive management this research was able to introduce and monitor the impact of three sustainable no-cost practices during phase two of the project, which is a continuation of phase one. The research introduced three sample sustainable practices, which are: 1) shortening the construction schedule through effective phasing and planning of the construction activity. 2) efficiently allocating labor camps to support energy reduction, and 3) increasing the labor productivity for the tiling activity through easy access to storage materials. Although the construction practice suffers low quality and inefficiency (Ortiz et al., 2009), this research provides proof of concept to three sustainable construction practices. These pilot examples demonstrate that construction activities could be altered with zero-cost and easy alternations to yield financial savings in addition to sustainable outcomes.

Adaptive Management

An adaptive management process is not an easy practice due to that it implies being flexible and most contractors don't want to endure flexibility and would rather stick with their old traditional practices also it requires learning by practice, which again may seem unfeasible to contractors as contractors may not afford to conduct mistakes to learn from. Furthermore it remains challenging to align all the stakeholders to accept, embrace and manage sustainable construction practices during the construction process. If a contractor opts to manage a complex issue, it requires a real time management. Therefore, equipping the contractor in addition to the stakeholders with an agile and responsive response pave for solving any unforeseen issues that may arise during the implementation process. Adaptive management is a robust progression to implement during construction to achieve sustainable goals. The adaptive management steps face resistance from the construction stakeholders, however this study provides sample examples that demonstrate how these sustainable practices yields financial savings, which could encourage contractors to re-evaluate their construction method statements.

Figure 1, links between the construction phases, drivers and the passive sustainable practices, which are building performance impact areas and Energy Efficiency Measures (Arababadi et al., 2017). The building performance impact areas refer to the extensive data and knowledge exerted by scientists in the field of Architecture specifically focusing on passive sustainable environmental practices (Chester et al., 2017). Several of the practices that will be allied are: orientation and geometry, building envelope, natural daylight and ventilation, shading, material and resources, energy/atmosphere and human comforts. The main goal is providing verified practices that yield to convincing the stakeholders to adopt such passive practices during construction.

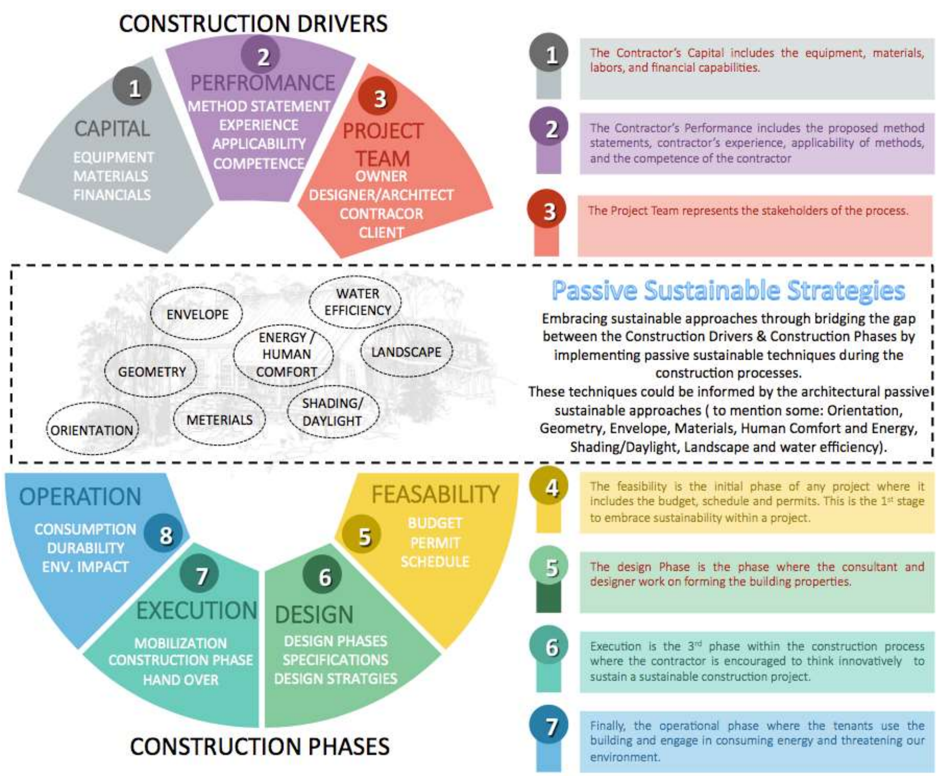

Figure 1: System Diagram – Bridging the Gap between Construction driver and phases by introducing passive sustainable construction practices.

The system diagram identifies the interconnectivity of the construction anatomy, in the sense that all the drivers and phases do maintain correlation links. For example, the stakeholders could not operate without owners also the design/feasibility phase don't get applied unless there is project with stakeholders. Therefore, all the interrelationships between the construction drivers and phases entails thinking towards a complex material flows. Not only material flows are current in this system, but also information, collaboration, decision making and capital flows are all crucial to the construction system diagram. The research identified the financial savings to be the measurement tool for this study to ensure the effectiveness of the system diagram.

Findings of the Sustainable Construction Paradigms

Initially there is a current construction environment that would be referred to as the status quo. This research proposes several passive sustainable practices to make the construction practices measurably "better". These sustainable practices are framed within the current sustainability discourse so they are leading to a more sustainable construction practice or activity's method statements that will transition from the status quo to the definition of "better" construction practices. These practices consist of enormous amount of activities that could be amended to become more sustainable. This research will provide three examples to demonstrate a pragmatic adaptive management towards a sustainable construction method statement. These three examples, exemplifying the correlation between the construction activities and the sustainable environmental practices adopted from architectural pedagogies (Elzomor and Youssef, 2015). This research used a case study to validate its sustainable practices. The first strategy is to efficiently phase and plan the construction sequence. Amending the concrete activity method statement, which increased the productivity of this activity, thus shortened the duration of the construction. In this case study saved 45 days and reflected a saving of $1.5 Million. The second strategy discusses the labor camps, temporary shelters, and their orientation in terms of energy efficiency. General contractors typically are in charge of the labor camps and so their cost are part of the overhead costs. That said and by efficiently orienting the labor camps they reduces the need for cooling and heating especially in hot arid regions. In this case study, the strategy reflected an overall saving of $10K. The third strategy represents storage of material on site to reduce the time of material handling and installation. In this case study, this resulted in a 25% decrease in manpower for tiling while maintaining the same productivity thus reflecting a saving of $3.5k.

Phasing and Planning

The construction method statement should focus on increasing the productivity by effectively embracing a methodology that considers the climate zone, labors comfort, material storage and availability. The phasing and planning example, will demonstrate a real life construction practice that was based on mitigating heat in a hot arid region. The commercial buildings were designed to be relatively close to each other. In other words, due to the tightness of the project's land each building's façade was 19 feet from its adjacent building. In phase one, the contractor's method statement was to build concurrently all the floors, so the 1st floor of entire mixed-use project would be built simultaneously. In phase two, this research proposed to the project team a different construction method, which considered the hot climate and the potential of using the spacing between buildings as shading structures. Figure two provides an illustration to the conventional method (Phase one – a in figure 2) and the phased construction approach (Phase Two – b in figure 2). The phased method, alternating construction, provided self-shaded planes and so productivity rates were increased yielding cost savings of approximately $1.5 Million. Since the this mix-use project consists of 9 building each with 7 floors and based on that the contractor only poured three floors per month in phase one thus the total number of months for concrete works was 21 months. In phase one and two the contractor did not use steal formwork or any other advanced method, yet opted for the traditional wood formwork. Each building has its dedicated material, formwork and the contractor hired 3 crews of manpower to be able to complete 3 floors/month. Based on this research phase two clustered buildings together and suggested a phased/alternating construction method. Egypt is a hot arid region, where the productivity rates drop when labors suffer from heat. Moreover, the project team were aware of the heat waves that threatens the lives of their labors, thus opted to apply the proposed no cost sustainable practice that provided shading for labors during construction. Once the contractor agreed to such strategy an analysis was conducted which showed that the duration of the concrete activity for phase two 9 buildings dropped to 19.5 months. Since the initial plan for phase two was 21 months for concrete activities, the difference of 6 weeks reflected massive savings to both the project and the contractor reflecting $1.5 million. This $1.5 Million represented a 6 weeks of the contractor's overhead costs equivalent to $500k and the remaining costs savings, $1 Million, were associated with reduction of material and manpower. The contractor was able to finish earlier and relocate the project team/crews and materials to other projects.

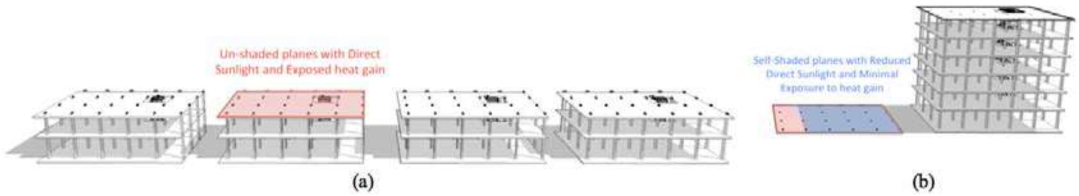

Figure 2: The conventional/default construction Method, Building the Structure Concurrently, and (b) Phased Construction Methods

Labor Camps

Labor camps and warehouse areas can be strategically allocated during the mobilization phase, since the locations can be efficiently oriented to reduce the need for cooling and heating. Therefore, providing a pleasant environment to increase the productivity of labors, since the labors will require less amount of rest and will be able to increase the man-hour index (Jarkas and Bitar, 2011). Labor camps serve as a hostel to construction workers thus reduces the labors' traveling time and transportation expenses. To that end, contractors utilize labor camps to ensure control over the schedule of the project since the labors' focus and productivity shall be merely dedicated to the construction practice (Ailabouni et al., 2007). From the owner's perspective labor camps are an additional preliminary cost that is paid monthly to rent and maintain the caravans and since the owner agrees to pay this monthly cost, both the contractor and owner may try to minimize this overhead cost. Minimizing the overhead costs will reflect higher profits for contractors and less capital for owners.

Architects are conscious that the south façade is the best façade in hot arid climates, shown in figure three, since in its facade orientation is the best option as it transmits the maximum solar radiation in the winter while minimum in summer (Lechner, 2014). However unfortunately contractors generally neglect this fact. The research explores the effect of three alternative labor camp layouts. Figure four (a) and (b) show options with a layout that include minimal south façade percentages while (c) show the optimum and recommended orientation since it maximizes the south façade. The research analyzed these three layout studies in figure four by utilizing e-Quest software, Energy Simulation Program, to qualitatively evaluate the impact of the different layout orientations on energy requirements for these labor camps. There were eight labor camps/caravans, however for the sake of illustration the example demonstrates four caravans only. Figure four (a) illustrates the 1st layout scenario including elongated camps to the North/West and South/East Orientation will provide a 5% south façade thus the actual electrical bill cost $810/month. Figure four (b) the 2nd layout scenario provides various orientations to maximize the usage of land, thus providing 20% of South Façade and so reflects a reduced electrical consumption of $740/month. Figure four (c) the third layout scenario, which displays a staggered and elongated caravans to the East & West orientations that drastically minimize the heat gain and maximize the natural daylight while providing courtyards that introduces micro climate. This effective orientation provided 45% of South façade and an electrical consumption of $620/month. From these three scenarios, it is obvious that in hot arid regions the contactor has to consider the excessive heat during the project's life cycle. If we do compare the 1st layout scenario to the 3rd suggested scenario the contractor could be saving $190/month. A $190/month in a project's duration of four years, translates to an average expected saving of $10.2K.

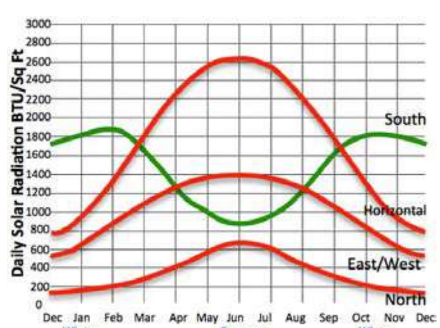

Figure 3: The south facade transmits maximum solar radiation in winter and minimum in summer

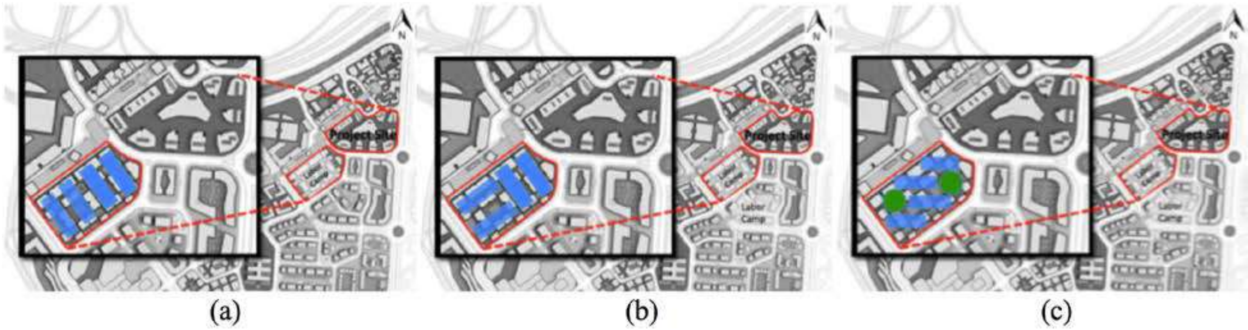

Figure 4: Different Labor camp orientations that were analyzed through Energy analysis program to decide which of the three layouts (a, b or c) requires less heating and cooling energy

Labor Productivity

Manpower is one of the key indicators to the success of projects. Contractors always depend on competent and professional labors to ensure meeting the schedule and budget demands. However, what should the contractor provide to ensure these labors carry on their responsibilities as planned? Therefore, this example will explain how a contractor could facilitate a faster and more convenient activity to the tiling crews. Tiling represents one of the main trades within the case study project, in terms of cost and time. The planned schedule to finish one building's tiling, 75,000 square foot, was 3 months. This example will only be referring to the handling and transportation portion within the tiling CBS (Cost Break Down Structure) and not the installation. The traditional scenario of handling tiles on construction sites in Egypt is by the use of manpower carrying the tiles from its storage area on the ground floor to all the floors. In phase one of this case study the contractor used a manual hoist, where the tiling truck arrives on site, unloads the tiles on the adjacent to the building's perimeter using 4 labors (to facilitate its handling to the upper floors). Afterwards, when the tiling activity is scheduled to commence the contractor allocated 6 labors to pull the tiles by manual hoist, allocated on the roof of each building, to its allocated floor. These labors only transport materials on site and aren't installers. These 6 labors are divided as follows: 2 on the ground floor, 2 on the dedicated floor beside the manual hoist and 2 moving the tiles to its exact location within the floor plans. Each of these labors pocket a minimum wage of $10/day and need an average of 14 days/building to complete all the transportation of materials to the various floors.

Phase two implemented another practice that increased the productivity and decreased the duration of the tiling activity. Utilizing an existing mobile crane that was allocated on site the materials would be transported from the truck directly to the roof. This process eliminated storage space on the ground floor for other activities to take place. Afterwards, with the same manual hoist that is already allocated on the roof, the materials would be transported from the roof to its dedicated floors. Initially, the concept provisioned a saving in the total number of labors from 4 (moving materials from truck to the ground floor) to 2 helping the crane operator to transport the material to the roof, which took half the time and also decreased the labors to 2 labors and shortened the duration from 1 day to 4 hours. Moreover, the 6 labors used during phase one initially handling materials to the dedicated floors were reduced to 4 since the materials were already on the roof thus by the use of gravity releasing the manual hoist, which requires less effort and thus yielded a reduction in time from 14/days/building to 10/days/building. The productivity of the tiling activity was increased and thus yielded a 25 percent decrease in its handling duration, which reflected a total saving of $35k.

Limitation and Future Research

This research evaluated the effectiveness of the proposed sustainable construction practices based on financial savings; other measurement of success could be tested. Other measurement tools include 1) The people who represent the stakeholders are key to measure their cooperation and engagements, 2) Governance and its urgency to apply such practices within codes, regulations or even incentivize tax payers when adopting such practices, 3) Community's impact and response to sustainable practices not only post construction but during the construction's practice, and finally. Another limitation is that this case study focused on hot arid regions, other climate could have different Energy Efficiency Measures. To this end, projects in different climate could be studied to identify other sustainable practices. Although the three examples demonstrate savings that may be negligible sum to a contractor that is building a multi-Million project, the contractor may yield additional collective savings when embracing sustainable practices that focuses on water, heat, waste, artificial lights, generating temporary energy, etc. In other words, these limited savings could be compiled to reflect a greater saving during construction.

Conclusion

The research introduces sustainable strategies during construction by providing simple and no cost construction practices that are sustainable that yield financial savings to contractors during the construction phase. The construction phase is one of the construction processes that need additional awareness to implementing sustainable practices during construction. To be able to convince contractors to apply sustainable practices during construction, the research correlates some financial savings as justifications. This research draws relations between sustainability and construction phase, to ensure that stakeholders of the building process are aware of the importance of sustainable construction practices. There are no doubts that various environmental practices could be utilized to significantly reduce construction costs by addressing orientation, energy, water usage, heat, natural ventilation, shading and day light which are the means by which they impact various construction periods that aim for short and long-term sustainability. The research points out multiple significant contractors' behavior that yields financial savings to the construction practice. This may be a template, which could be attached to tender documents urging contractors to embrace sustainable practices during the construction phase.

References

AILABOUNI, N., GIDADO, K. & PAINTING, N. Factors affecting employee productivity in the UAE construction industry. Proceeding Conference for Postgraduate Researchers of the Built and Natural Environment (PRoBE), 2007. 33-46.

ALLENBY, B. R. 2014. *The Theory and Practice of Sustainable Engineering: International Edition*, Pearson Higher Ed.

ARABABADI, R., ELZOMOR, M. & PARRISH, K. 2017. Selection of energy efficiency measures to enhance the effectiveness of pre-cooling in residential buildings in hot arid climate. *Science and Technology for the Built Environment,* 23**,** 858-867.

ASHLEY, C. & CARNEY, D. 1999. *Sustainable livelihoods: Lessons from early experience*, Department for International Development London.

CHESTER, M., PARRISH, K., COSGROVE, J. & ELZOMOR, M. 2017. *Urban Sustainablility Lab* [Online]. http://urbansustainability.lab.asu.edu/index.php: asu.edu. [Accessed 2017].

CROSTHWAITE, D. 2000. The global construction market: a cross-sectional analysis. *Construction Management & Economics,* 18**,** 619-627.

DEMAID, A. & QUINTAS, P. 2006. Knowledge across cultures in the construction industry: sustainability, innovation and design. *Technovation,* 26**,** 603-610.

EIA, E. I. A. 2008. Assumptions to the Annual Energy Outlook.

EIA, E. I. A. 2012. State Energy Consumption Database, June 2011 for 1980-2009; and EIA, Annual Energy Outlook 2012 Early Release, . Table A2 for 2010- 2035 consumption, and Table A3 for expenditures.

ELZOMOR, M., PARRISH, K., MANN, C. & CHESTER, M. Positioning students to understand urban sustainability strategies through vertical integration: Years 1 through 3. 2016 ASEE Annual Conference and Exposition, 2016 New Orleans. American Society for Engineering Education.

ELZOMOR, M. & YOUSSEF, O. Living and learning in practice: University of Arizona Engineering Innovation Building (EIB). Research for a Better Built Environment: 49th International Conference of the Architectural Science Association, 2015. 33-44.

FOWLER, K. M. & RAUCH, E. M. 2006. Sustainable building rating systems summary. Pacific Northwest National Laboratory (PNNL), Richland, WA (US).

FREY, P., DUNN, L., COCHRAN, R., SPATARO, K., MCLENNAN, J., DINOLA, R., TALLERING, N., MCDANIEL, E., HAAS, D. & HEIDER, B. 2012. The Greenest building: Quantifying theenvironmental Value of building reuse-a report by the US National Trust for historic preservation.

HALLIDAY, S. 2008. *Sustainable construction*, Routledge.

JANDA, K. B. 2011. Buildings don't use energy: people do. *Architectural science review,* 54**,** 15-22.

JARKAS, A. M. & BITAR, C. G. 2011. Factors affecting construction labor productivity in Kuwait. *Journal of Construction Engineering and Management,* 138**,** 811-820.

KIBERT, C. J. 2016. *Sustainable construction: green building design and delivery*, John Wiley & Sons.

KIERNAN, M. J. 2008. *Investing in a sustainable world: Why green is the new color of money on Wall Street*, AMACOM Div American Mgmt Assn.

LECHNER, N. 2014. *Heating, cooling, lighting: Sustainable design methods for architects*, John wiley & sons.

MAJDALANI, Z., AJAM, M. & MEZHER, T. 2006. Sustainability in the construction industry: a Lebanese case study. *Construction innovation,* 6**,** 33-46.

MYERS, D. 2005. A review of construction companies' attitudes to sustainability. *Construction Management and Economics,* 23**,** 781-785.

ORTIZ, O., CASTELLS, F. & SONNEMANN, G. 2009. Sustainability in the construction industry: A review of recent developments based on LCA. *Construction and Building Materials,* 23**,** 28-39.

SHI, Q., ZUO, J., HUANG, R., HUANG, J. & PULLEN, S. 2013. Identifying the critical factors for green construction–an empirical study in China. *Habitat international,* 40**,** 1-8.

SONG, L. & LIANG, D. 2011. Lean construction implementation and its implication on sustainability: a contractor's case study. *Canadian Journal of Civil Engineering,* 38**,** 350-359.

USCB, US. Census Bureau. 2015. Construction Industry Statistics. Available: http://www.statisticbrain.com/construction-industry-statistics/ [Accessed 24th of Jan 2016)].