Modeling Impact of Sustainability Policies in Qatar using Agent Based Approach and Life Cycle Analysis

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ABSTRACT

Implementation of sustainability practices in construction projects is highly dependent on the policies adopted by governmental authorities. Therefore, it is critical for decision makers in authority entities to understand, in measurable terms, the possible consequence of implementing different policies and hence select the combination of policies that leads to optimum positive results. The objective of this paper is to present a framework for assessing the impact of different sustainability policies using agent based modeling and life cycle analysis. Under the presented framework, while agent based modeling is proposed to simulate the diffusion of sustainability in a construction market, discrete event modeling is used to map the interaction of main stakeholders in order to model selection of sustainability credits on a project level. Life cycle analysis is introduced as an objective quantifiable tool to assess the saved environmental impact associated with application of project sustainability credits as a result of targeting certification levels in light of the adopted sustainability policies. The saved impact on the level of projects is expanded to represent the full market and therefore reach an approximate assessment of the saved impact due to applying different policies. The proposed framework is designed to the case of the state of Qatar and can be utilized for other markets provided necessary customization is considered.

INTRODUCTION

The construction industry has been recognized worldwide to be one of the high contributors to the environmental challenges that our globe currently faces. For example, the United Nations Environmental Program (UNEP) (2002) revealed that the construction industry consumes 40% of Europe's energy, in addition to it being responsible for a large contribution to the greenhouse gases concentration in the

United States. Meanwhile, although various companies are coming to the conclusion that a sustainable development approach brings value to their organizations (Gilding et al. 2002), there is still a need to develop policies that motivate companies to adopt sustainability in a construction markets especially if additional cost related to implementation is taken into consideration. Consequently, the international community witnessed the development of organizations and policies that encourage environmentally friendly construction practices (Bosch and Pearce 2003). These policies provide strong incentives for stakeholders responsible for buildings to aim to minimize their environmental impacts and resource consumption especially energy requirements during construction.

Some of these policies have provided project owners and builders with tangible incentives for taking up such challenging projects such as tax reductions and energy cost reliefs. To explore the impact of these developed policies or regulations, a number of studies have looked at the possible businesses impacts of environmental sustainability on construction business. Beheiry et al. (2006), for example, carried out an evaluation of the impact of corporate commitment to sustainability on capital project planning and capital project performance. Another study, by Gomes and da Silva (2005), evaluated at a higher level the impact and effectiveness of sustainable construction practices in the developing economies of Latin America and the Caribbean. One of the important conclusions of the study is that the buy-in of stakeholders at multiple levels was shown to be a determinant factor to the effectiveness of the application of these policies. Also, some studies have looked at modeling sustainable communities and mapping interaction at different levels between humans and their environment in order to develop a better understanding of the macro effect. One of these studies developed a framework for simulation models that could be used for evaluating the sustainability of building practices (Mani et al. 2005).

However, there is still lack of methodologies that provide decision makers with tools to assess quantitatively the consequences of their decided policies. Accordingly, the objective of this paper is to present a methodology for assessing the impact of implemented sustainability policies in measurable terms to act as a support tool for decision making. The methodology is an endeavor to integrate different simulation models with life cycle analysis (LCA) as an objective quantification method. Work on the different models is ongoing under a research project carried in the state of Qatar to assist in enhancing sustainability as a national target especially in the construction industry.

METHODOLOGY

The methodology presented in this paper aims at assessing, in measurable terms, the impact of implementing sustainability policies on construction markets. While policies are decided and implemented by authorities, their real impact is correlated with the response of concerned stakeholders. Therefore, the presented methodology targets modeling of the interactions among stakeholders at the project level as well as the diffusion of sustainability on the market level. Figure 1 highlights

the main components of proposed under this methodology and the following subsections provide insights on the different steps involved.

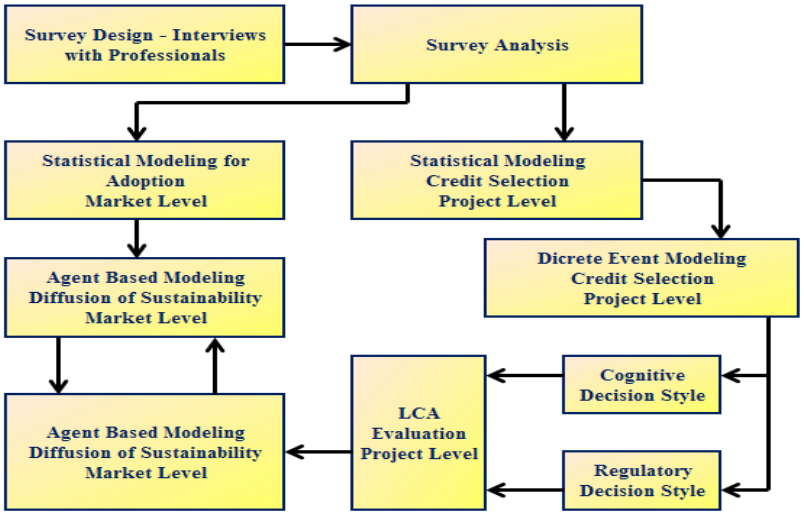

Figure 1: Framework of Policy Impact Assessment

Survey Design and Structured Interviews with Industry Professionals. The first step in the presented methodology is designing survey questions and holding interviews with industry professionals where the survey questions are covered with the objective of exploring the different features of the process being modeled. The target outcomes of this step are (1) identifying the stakeholders who are affected by implemented policies and whose decisions on projects' level affect the overall results on market's level; (2) determining the attributes of these stakeholders, which will be part of the independent parameters (attributes) of the stakeholders (agents) that are possibly affecting decisions whether related to adopting sustainability in projects or selection of specific credits; (3) identifying other influencing variables in the overall systems that affect decision making on both the projects and market levels.

The survey designed for Qatar has been used in interviews with representative construction companies including developers, consultants, project management companies and contractors. The survey used in the interviews included one section to explore the independent variables including company's type, size, number of employees, number of personnel certified by sustainability systems and other criteria that are expected to influence sustainability decisions. The survey also included a section on the criteria based on which selection of credits under different rating systems is being addressed. Another section included feedback of the interviewed professionals on the possible response of their companies in light of implementing different sustainability policies.

Survey Analysis and Statistical Modeling. The second step in the proposed methodology is to analyze results of the conducted interviews based on the described structured survey and carry statistical modeling to identify the significant parameters affecting decision making. Qualitative analysis is first carried to identify the stakeholders (agents) that will be modeled, their specific attributes and possible

behavioral interactions that will be stimulating decisions. Then, quantitative statistical modeling is done to serve two purposes.

The first purpose of statistical modeling is determining the variables showing significant correlation with the decision of adopting sustainability in construction projects. These independent parameters are used in the diffusion model, where the identified agents representing projects stakeholders are interacting together based on their own attributes and behavioral trends. The second use of statistical modeling is to determine the significant independent parameters that affect selection of credits under sustainability rating systems over others, which has effect on the overall achieved potential reduction of environmental impact. Majority of the survey questions were designed to get responses from interviewees on an ordered scale ranging from "strongly agree", through "agree", "neutral", "disagree" to "strongly disagree". This motivates the use of ordered probability statistical modeling approach that can capture this ordered nature of data.

Agent Based Modeling for Adoption of Sustainability (Market Level). Based on the identified agents (projects stakeholders), the identified attributes, and the associated behavioral interactions, an agent based model is designed to map the process of adopting sustainability in construction projects. The target model is an agent-based model that can predict the rates of the adoption of sustainability policies based on the identified trends in the construction market. The model enables simulating and evaluating various scenarios by determining the influence of different set of sustainability policies on the adoption rates by projects stakeholders. Hassan et al. (2012) set the guidelines for this model based on the approach of "Diffusion and Innovation" by (Rogers 2003) where sustainability is considered here as a sort of technology that will be diffused in the market in a gradual way.

The first type of agents that are identified for this model is the project developers. Attributes of this type of agents include whether the company is environmentalist or non-environmentalist, their sustainability perceptions, size of projects, number of completed sustainability certified projects, strategic preferences, and risk tolerance. Consultants are represented by agents whose attributes include size of projects, experience in Qatar and internationally, number of certified professionals for implementing sustainability rating systems, influence on developer agents, number of completed sustainability certified projects, flexibility to adopt changes, quality control systems. The third main agent type represent contractors with attributes including sustainability perceptions, size of projects, experience in Qatar and internationally, number of certified professionals, number of completed sustainability certified projects, and flexibility to adopt changes. The output of the diffusion model, which maps the spread of adopting sustainability in construction projects, is the rate at which stakeholders in the construction industry will be targeting certification under rating systems.

Discrete Event Modeling for Credit Selection (Project Level). Although there are different approaches to implement sustainability in construction projects, the most common approach is targeting sustainability rating systems, which are basically acting as bench marks to evaluate the performance of projects from sustainability

perspective. Leadership in Energy and Environmental Design (LLED) developed by the United States Green Building Council (UGBC) is one of the most used systems. In the state of Qatar, both LEED and Qatar Sustainability Rating System (QSAS) are alternatively used in projects. The presented methodology is built on the assumptions that the enacted polices or regulations decided by authorities will affect the level of adopting sustainability in construction project through targeting certification of these rating systems.

The referred rating systems are developed based on addressing different sustainability concerns under separate categories. Examples include energy, water and site categories. Each category is composed of different credits where every credit tackles a specific concern that represents negative impact of the project on the environment. Based on the score achieved by the subject project under each credit, the overall certification level is determined. Since each credit addresses different sustainability issue, there is different potential reduced impact due to achieving the objectives of this credit. Therefore, selection of credits plays an important role in the process of modeling the overall impact of adopting sustainability in the construction industry.

In this context, selection of the credits is a process done by individuals representing the different stakeholders. These individuals are typically from the design teams of the consultant and developer in addition to the technical team of the contractors. Similar to any multi criteria decision making, selection of credits can take several forms depending on different variables of the project and characteristics of stakeholders. For the purpose of the presented methodology and in light of the responses obtained from industry experts in relation to this objective, two main decision styles have been identified as possible approaches to model this decision process.

The first approach is the intuition-based approach, which is under the family of cognitive decision styles. Under this style, decisions taken by an organization are based on the formulated cognitive map that depends on the epistemological predisposition of the decision makers including their contentious about what is knowable, how it can be known and the standards upon which the truths can be judged. The second is ELECTRE III approach, which falls under the category of regulatory or procedural styles. These families of decision style focus on the extent to which decision makers engage in a comprehensive collection of the relevant information, analyze all that information, and attempt to select the best of all generated decision alternatives in the presence of incomplete information and bounded rationality. Therefore, the first style represents higher degree of freedom while the second is restricted more by set procedures and data collection. The framework describing application of the first decision style on the case of credit selection is clarified in Figure 2. The application of the second decision style involves specification of thresholds as guided by the ELECTRE III approach along with categorization of credits based on weighted criteria.

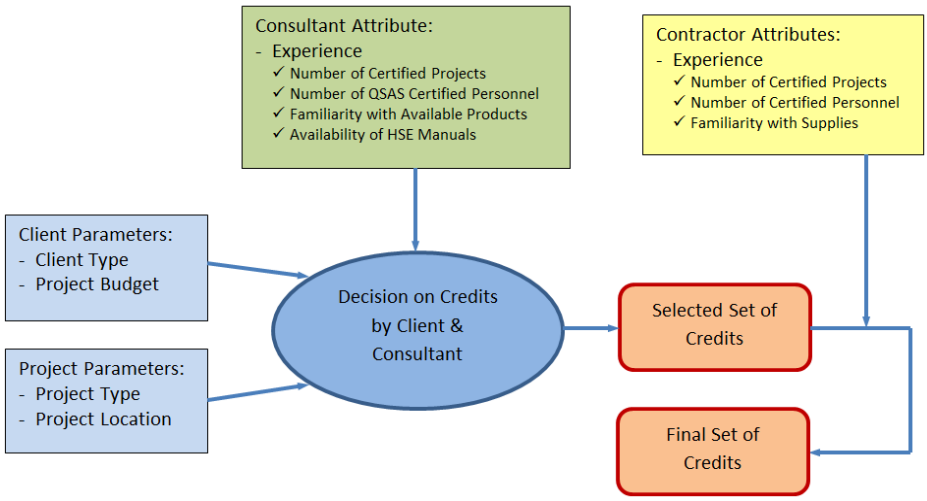

Figure 2. Framework for Applying the Intuition based style on credit selection

LCA Evaluation of Selected Credits (Project Level). Although the use of rating systems have assisted project stakeholders to improve performance of construction projects from a sustainability perspective, there is no sufficient evidence yet that the practices recommended by these rating systems and all the concepts addressed under rating credits achieve optimum reductions of environmental impact. This is due to unavailability of information on the actual reduced impact on the environments. Therefore, Life Cycle Analysis (LCA) is proposed under the presented methodology to address this gap. As defined in ISO 14040, "LCA address the environmental aspects and potential environmental impacts (e.g. resource use and environmental consequences of releases) throughout a product's life cycle from raw material acquisition through production, use, end-of-life treatment and disposal", this is called as cradle-to-grave evaluation. LCA is proposed here as an objective measurable tool that reflect the actual potential reduction of environmental impact.

The procedure for this evaluation methodology is illustrated in Figure 3. Complete analysis of the documentation involved in implementing the respective rating system is required in order to determine the design options and the assessment criteria for achieving scores under each credit. Then, the actual impact of implementing each credit in this proposed methodology is defined through the identification of the critical parameters according to the requirements of each credit. These parameters are then translated into inventory data that can be evaluated using the LCA analysis. The inventory data is composed of material or energy quantities that can be analyzed by LCA impact assessment tools. The final output of this methodology is the potential reduction in environmental impact due to use of selected credits. This can be presented in single score measures through normalization and weighting procedures of the LCA technique. Further details of the methodology and implementation on Qatar's QSAS system are revealed by Attalla et al. (2013).

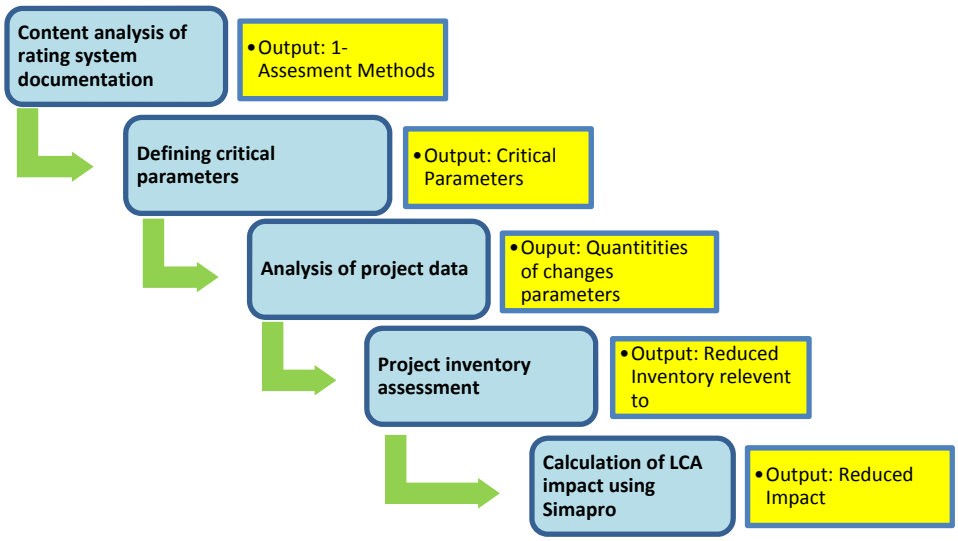

Figure 3: Framework of the LCA Evaluation Methodology

Overall Model for Assessing Policy Impact (Market Level). In order to assess tactual impact of implementing sustainability policies, the discussed models and methodologies are integrated. The input of the overall model is scenarios of sustainability policies that are decided by concerned authorities. Based on the defined agents, their attributes and behavioral interactions defined under the diffusion model, adoption rates of implementing sustainability in construction projects are determined. Using this output and data available on forecast projects in the construction market under study, set of projects targeting different certification levels is formed. On a project level, selection of credits is carried through the discrete event model using either cognitive or the regulatory approach. Choice of the decision style is dependent on the attributes related to companies' experience in record of sustainability projects. Then, the LCA evaluation methodology is utilized to quantify the potential reduction in environmental impact as a result of implementing the selected credits. Accordingly, the potential reduction of impact on the environment on individual projects can be assesses. This reduced impact is then aggregated to present the total environmental reduced impact due to implementation of a given sustainability policy.

CONCLUSION

The presented methodology is designed to assess the possible consequences of implementing sustainability policies in terms of measurable reduced impact on the environment. Diffusion model, which is done through agent based simulation, is used to map the spread of sustainability in the construction market. On a project level, discrete event modeling along with two different decision styles are used to determine the credits that are possibly selected in light of the different project's and stakeholders' attributes. These selected credits are then evaluated through the technique of LCA to identify potential reduction of impact on the environment. Finally, the total effect on the construction market is calculated by aggregation of the potential reduced impacts in projects in the market. Although the interviews with industry professionals were done in the state of Qatar, the methodology can still be

applied to any other market especially the ones that are still in early phases of introducing concepts of sustainability in construction projects.

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