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GUIDELINES FOR PRACTICE AND EVALUATION OF SUSTAINABLE CONSTRUCTION SITES: A LEAN, GREEN AND WELLBEING INTEGRATED APPROACH

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ABSTRACT

Sustainability is addressed through the triple bottom line concept, bringing together economic, environmental and social issues, related management actions and their impacts for better building sites. Lean concepts are incorporated into the economic side of the model, while a new concept – wellbeing – expands the social pillar. Green attributes render themselves naturally to the environmental part of the triple bottom line approach. A model to evaluate how and in what degree lean, green and wellbeing concepts are being applied in site layout managing is developed using Design Science Research (DSR) propositions. This procedure is tested in three different sites in the city of Fortaleza, in the Brazilian northeast region. Results point out that the model artifact obtained through DSR is capable of synthesizing a huge number of variables both in terms of possible management actions and in terms of their sustainability outcomes. Graphical displays help to guide how sustainability might improve over time, either evaluating individual sites against their previous records or benchmarking different building projects.

KEYWORDS

Sustainability, triple bottom line, lean construction, green, wellbeing, performance evaluation.

INTRODUCTION

Construction industry is characterized by a huge consumption of natural resources and its potential environment degradation. While in the course of transforming the natural environment into a built environment, many hazardous impacts can be identified throughout a project life cycle (Agopyan and John, 2011). At its onset, a

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sustainable site might be a first good step towards an overall better project performance.

A sustainable site would provide a more significant impact on society if the triple bottom line approach is taken, bringing together its economic, environmental and social benefits. Further down, once the building site is handed over, after its several construction stages are completed, the triple bottom line approach should be enforced throughout commissioning, operating, refurbishing and finally dismantling the building after its service life (Piccoli, Kern and González, 2008).

Customers growing demand for sustainability has been introduced as a strategic concern to higher levels of developer's managerial staff and gradually spread to operations on site (Pardini, 2009). However this effort has generally narrowed down to green concepts, to building product design, to waste control on site and to the adherence to public or private codes of practices as the LEED assessment. A truly systematic triple bottom line effort as proposed by Elkington (1999) aiming at establishing guidelines for a sustainable building industry is still lacking. Further down this research work discusses why disciplines like Lean Thinking, Green Building and Social Impacts of the construction activity, taken individually or as combinations, are not enough to support the more encompassing triple bottom line view. Wellbeing concepts are brought to light in order to fill this gap.

LEAN, GREEN AND WELLBEING: AN INTEGRATED APPROACH TO CONSTRUCTION SITE

The Lean Thinking research community spread its academic reasoning's to different areas like supply management, design management, health and safety, building maintenance and building refurbishment, widening initial concerns restricted to production planning and control. It was a natural step to accommodate the concurrent green concept under its value umbrella. This is equivalent to credit environmental concerns to clients' needs in the previous Quality Movement research thrust. A more careful research methodology is first to identify similarities between Lean and Green, Lean and Sustainability, Lean and Health & Safety, and Lean and Social Responsibility and then proceed towards the meritorious scientific goal of identifying a common or a leading knowledge discipline.

Ng, et al. (2010) related lean and safety using a set of indicators to assess safety performance, demonstrating the positive impacts of a lean environment to the reduction of hazards on site. At that moment, Slivon, et al. (2010) claimed a deeper human concern in Lean Thinking. Benefits to internal human employees or to external human needs and desires should be taken as the primary end result of managerial efforts and not just as another issue that should be systemically contemplated, whatever its relative importance in a building company strategy.

Chronologically in the following year, papers by Alarcón, Acuña and Diethelm (2011); Antillón, et al. (2011) and Leino and Elfving (2011) elected the positive impacts of Lean Construction to Health & Safety as a testimony of the former wide-ranging effects. On the other hand Salvatierra-garrido and Pasquire (2011) and Vieira and Cachadinha (2011) contributed with Lean and Green evidences on conceptual interactions.

Wellbeing, according to Ryan and Deci (2000) and Sen (1993) encompasses motivational and self-determination, both individual and collective satisfaction, involvement with company's values and shared vision. It derives from anthropological findings on how humans have evolved, but accepting psychological views on how man behaves according to a specific culture. It has been incorporated into managerial techniques through psychologist and sociologists observations on how man is motivated and reacts while performing work. It might be comprehensively addressed with guidelines derived from the discipline of Quality of Working Life (Walton, 1973).

For the purposes of this research work Wellbeing concepts are needed to provide a proper building site, according to the following reasoning. Lean guidance would organize a site with a rational layout while green (and sustainability) would minimize the consumption of resources and adequate discharge of them. Quality of Working Life would dictate the provision of a legally sound, socially encouraging, individually defying environment. This is not enough according to Wellbeing: a proper site is a place where individuals want to be, feel at home, and find out the necessary support to develop their selves. This is the kind of atmosphere that is associated with craft work of self-employed artisans, being illustrated by Sennet (2009; 2012).

Failing to obtain relevant literature on the interaction of Lean, Green and Wellbeing it should be mentioned, in the search for methods of integrating different knowledge disciplines, the recent works of Rosenbaum, Toledo and Gonzalez (2012), Carneiro, et al. (2012) and Campos, et al. (2012) provide a performance assessment model to evaluate the maturity of use of sustainability and LC.

Reinforcing the methodological approach rather than the quantitative findings on possible interactions Valente, Mourão and Barros Neto (2013) proposed a coherent application of lean and green concepts on building developments at the strategic, tactical and operational level. Salem, et al. (2014) analysed the commanding role of Lean Construction on a triple bottom line approach to sustainability, but social impacts on sustainability are again restricted to Health and Safety issues.

It is clearly necessary to step further in this social perspective, and this is where the Wellbeing concept might provocatively help. For example cell production promotes employee's empowerment, what can be introduced as one more item in a triple bottom line checklist using the already mentioned Quality of Life at Work concepts. Wellbeing would go further, expressing the positive feelings related to the possibilities of alternatively using power or accepting a subordinate relationship at work. Moreover, wellbeing would suggest investigating how much cell production workers feel comfortable performing teamwork.

Degani (2003) puts forward a matrix to evaluate environmental actions and their corresponding impacts on a building development. Araújo (2009) employed this matrix to contemplate best practices found in a number of building sites and their possible effects on sustainability. This research work uses the matrix and checklist techniques to address the problem on how to evaluate lean, green and wellbeing actions on building sites. However, it recognizes that such approach leads to extensive lists of actions and extensive lists of impacts, magnified now for this endeavour of comprehensively addressing a more balance view on economic, environmental and social aspects.

METHOD

Design Science was used as a research strategy to create a solution to the following management problem: how to create a method to integrate a list of actions derived from Lean, Green and Wellbeing with their potential impacts in economic, environmental and social outcomes, leading jointly to a more sustainable building site. Such administrative tool should take into account that site administrative personnel might freely hypothesize actions and associate impacts. They might choose actions and outcomes according to what is deemed adequate to different stages of progress on a building site and what such management personnel understand as appropriate to obtain sustainable outcomes. Moreover, if site personnel decide to embark in less time-consuming evaluations, they should feel free to choose a restricted set of actions and impacts.

Design Science (DS) is a research strategy that creates and evaluates artifacts intended to solve identify organizational problems (Hevner, et al., 2004). This approach is eminently focused in solve practical problems instead of analyzing nature laws or compartmental theories (Collins, Joseph and Bielaczyc, 2004). Even if this artifact is not entirely sound in theoretical terms, one of the key issues is its operability in practice. The latter is adhered to through a research process containing seven steps, as suggested by Hevner, et al. (2004) is showed in Figure 1.

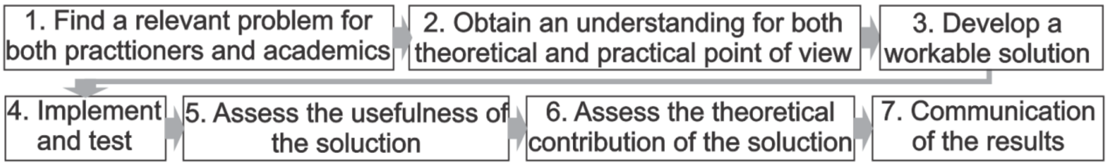

Figure 1: Designed Research Process

MODEL FOR EVALUATION TO SUSTAINABILITY OF CONSTRUCTION SITE

The proposed model is characterized by four different parts: 1) Building Company Characterization; 2) Building Site Characterization - Creation of a Matrix to relate site management actions and sustainability impacts; 3) Calculations and Comparative Graphical Display of Results.

Building Company characterization Styles – Headings

This just a formal procedure to elicit recent developments in the areas of lean production, green building and social awareness of the building company that might be useful to further indicate how far a specific building site is expected to practice sustainability principles. This section might contemplate former strategic plans, TQM procedures, compliance to Quality, Environment and Safety certifications and data and image banks of recent developments with successful implementation of sustainable efforts.

Construction Site Characterization - Matrix of Economic, Environmental and Social Impacts

Following Degani (2003) and Araújo (2009) a list of management actions related to lean, green and wellbeing is produced, taking the form of the vertical axis in a Matrix, like the one displayed in part on Table 1. Note that for the sake of space restriction, this paper produces only part of the management actions connected to environmental actions. On the same token general lean practices are not mentioned apart from the three initial lines related to the management of resources: they are presented in full in Vasconcelos (2013), a M.Sc. Dissertation. Similarly, the last three lines area a short version of the Wellbeing/Social management actions: two of these lines are related to local development, while the central line maintains the tradition of referring Wellbeing/Social actions only to Health and Safety, what was heavily criticized in the initial parts of this research paper.

Table 1 - Part of Matrix of relevant aspects versus environmental impact of construction site (A x I Matrix)

Company:		Interviewed/ fuction:										
Construction Site:		Type of construction project:										
MATRIX OF ENVIRONMENTAL IMPACT OF CONSTRUCTION SITE		Economic, Social and environmental impacts										
		Physical environment										
		Soil				Air		Water				
Category	Sustainable aspects	Impact on physical properties	Chemical contamination	Induction of erosive processes	Depletion of mineral reserves	Deterioration of air quality	Noise Pollution	Impacts on surface water quality	Increase of solid quantity	Impacts on groundwater quality	Impact on flow regimes	Water scarcity
Management of Resources	Consumption of Resources (includes built-in loss and packaging)											
	Consumption and waste water											
	Consumption and energy waste											
Nuisances and pollution	Generation of dangerous waste											
	Generation of solid waste											
	Vibration emission											
	Sound emission											
	Release of fragments											
	Emission of particulate matter											
	Risk of sparks generation about dispersed gas											
	Release of gases, fibers and other											
	Air renewal											
	Management of dangerous materials											

The Matrix of relevant aspects versus environmental impact of construction site (A x I Matrix) shows a list of 34 possible management actions divided into 5 major subcategories: management of resource, nuisance and pollution, construction waste, infrastructure of the construction site and social issues.

Calculations and Comparative Graphical Display of Results

Table 2 exemplifies how scores are obtained within the matrix format. First, a notation is used to subjectively assess impacts of a line into a row. A circle describes a substantial impact while an X implies that just a simple impact is expected. If nothing is added to a cell it means that no relationship is foreseeable for the pair of line and row variables. A management action described by a line will have a really significant (superior) impact on the array of sustainability variables if the number of circles is greater than the number of Xs (and this scores 3). An intermediate impact is associated with the number of circles equal the number of Xs (and this scores 2). A basic impact is associated with the number of circles smaller than the number of X (and it scores 1). This scoring scheme is subjective and might be changed by prospective users; care should be taken to maintain the same scoring system when comparing different building sites.

Table 2 – Example of matrix of environmental impact of construction site

MATRIX OF ENVIRONMENTAL IMPACT OF CONSTRUCTION SITE		Economic, Social and environmental impacts												
		Anthropic environment												
		Employee		Neighbourship								Society		
Category	Sustainable aspects	Change in health and wellbeing	Change in safety conditions	Change in landscape quality	Change in health conditions	Nuisance to Neighbourship	Change in traffic on local streets	Pressure over public urban services (except drainage)	Changes in security conditions	Damage in others buildings	Interference in urban drainage	Pressure over public urban services (except drainage)	Increase the volume of waste in landfills	Interference in urban drainage
Social Issues	Development of labor-hand own, subcontractors or suppliers	O	O		X				X					
	Development of Safety and health	O	O	X	O		X		O					
	Local development		O	X	X	O	O	X	X	X	O			

The comparative graphical display of results is obtained like follows. Abscissa values represent how much management actions might impact sustainability. They are taken as the sum of all scores for possible management actions. For Figure 2, with 34 possible management actions maximum score, will be 34 * 3 = 102 and minimum will be 34 * 1 = 34. An interpretation for this range of values is: if all management actions are expected to have a number of substantial impacts greater than just simple impacts, this building site is characterized, potentially, by a substantial outcome in terms of sustainability. On the other hand, if all possible management actions (lines) are classified as 1, basic impacts, not very much can be expected in terms of sustainability outcomes. Note that abscissa values cannot be smaller than 34 for figure 1. If a management action has no impact in any sustainability variable it should be removed from the check-list, as all cells combining this line and the respective rows for impacts will be empty. Further to that abscissa values are standardized in the range zero to 100, taking for this case 34 as zero and 102 as 100.

Ordinate values represent what is being achieved on a particular building site in terms of sustainability. It is based on the GBC accreditation scheme (Silva, 2007) using a Likert scale with 6 points as proposed by Backer (1995) and Siqueira (2008). Site administrative personnel will fill again Figure 1 matrix, now evaluating actual impacts of every management action into row sustainability variables. As before, each management action might have a superior, an intermediate or a basic actual impact. Unlike the previous abscissa discussion, it might happen that a particular management action, deemed to impact some sustainability variables is not showing any impact: in this case, actual impact is represented by empty cells throughout this management action line. This would be associated with a zero score.

A relative scoring scheme is illustrated as follows. It might be that a management action line that is supposedly of basic nature (score 1), now is actually producing a greater number of substantial impacts (score 3). Its relative score would be +2, that is (3-1). Contrariwise, a theoretical superior management action line (score 3) might be actually producing a greater number of simple impacts (score 1), what would be associated with a relative score -2, that is, (1-3). In the case of a management action line not actually showing any impact (with all line with empty cells), its relative score would be -3, -2, and -1, respectively if it was initially associated with a potential superior impact (score 3), an potential intermediate impact (score 2) or a potential basic impact (score 1).

RESULTS AND DISCUSSION

Figure 2 plots global scores for sites A, B and C. Site A has a minimum standardized score of 75 and was able to achieve an actual standardized score of 79. It means that site management was of the view that potentially this site could positively affect 75% of all sustainability variables presented in Table 1.

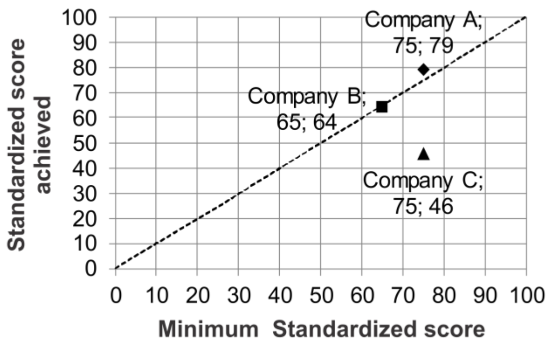

Figure 2: Comparative analysis to each company

This figure is either what could be theoretically possible for this site and its characteristics, both in terms of sustainability requirements and management actions that were under course, or alternatively, management actions and sustainability requirements this site is committed to address. This second option is an interesting methodological characteristic of the proposed method: while analysing individually a site, standards are set by its own managerial staff, instead of following a checklist that is externally imposed.

Site B committed itself to pursue a set of management actions that would theoretically impact 65% of the sustainability requirements set in Table 1. In actual terms, this site was able to achieve 64% of the sustainability requirements, just under the figure it was committed. Note that in actual terms it might be, for example, that this site is getting better than committed impacts due to lean actions, and worse than committed for the other areas: in sum, notwithstanding some differences between theoretical and actual performance, the site is delivering sustainability as planned.

Site C is not sustainable according to its own standards. Its management staff committed itself to affect positively 75% of all sustainability requirements in Table 1 but it was able to deliver only 46% of them.

Radar charts as presented in Figure 3 allow site personnel to depict weaknesses and strengths of its sustainability management system at a glance. Moreover, they call attention to the lack of balance between what was theoretically envisaged and actually achieved. For project A infrastructure of the construction, for project B this and construction waste and for project C all subcategories apart from infrastructure of the construction site are unbalanced. It might be said that projects A performed well and project B was just under what it was committed to, but they were able to achieve their results due to performance counterbalance between subcategories.

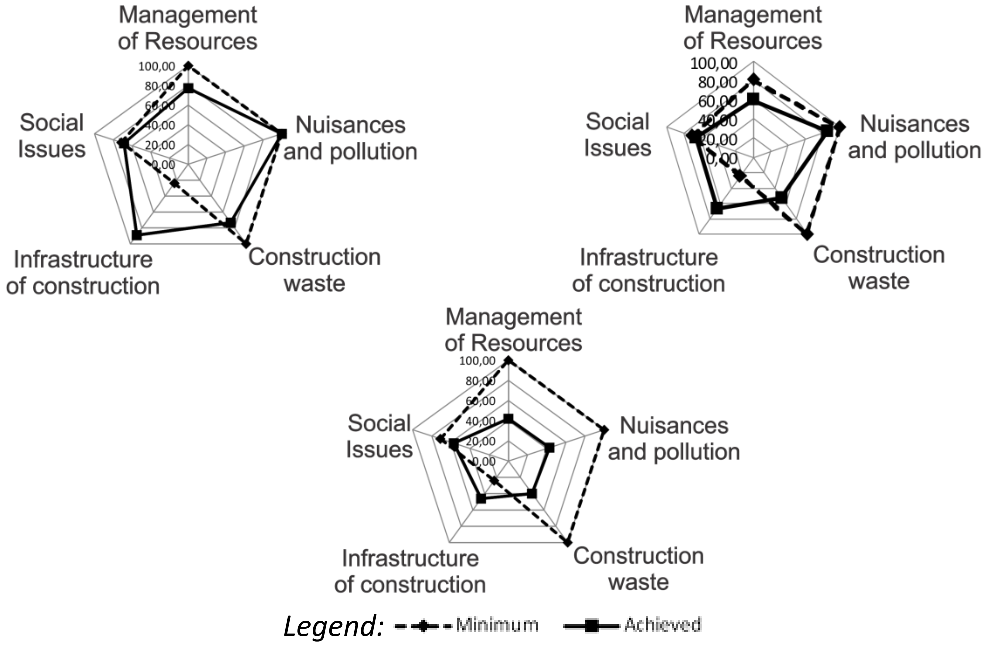

Figure 3: Scores to each category for company A, B and C respectively

FINAL REMARKS

This research work demonstrated the construction of a new artefact to evaluate sustainability on construction sites, following the triple bottom line approach. Suggestions were made to incorporate lean management actions into the economic triple bottom line pillar. Management actions leading to a green site were naturally associated with the environmental pillar, while a new concept, wellbeing, was introduced to expand the social pillar.

Design Science Research provided the methodological background to build a matrix like kind of tool to make it simple the amalgamation of an overwhelming number of possible site management actions and their impacts on sustainability requirement. A synthetic view allows one to evaluate the degree of sustainability a site is able to achieve according to what it commits itself to achieve. This perspective of judging performance according to commitments, weaker or stronger as they might be, is deemed appropriate to help introduce such evaluations on site, without the imposing requirements of external control, whereby standards are set by actors that are not responsible for the daily site operations.

A suggested scoring scheme induces management to select a balanced set of management actions than otherwise it would be possible by just summing cardinal scores for the potential impact of management actions into sustainability requirements.

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