Lean Sustainable Indices: A case for South African Public Infrastructure Sector

Rasheed Isa,
Central University of Technology, Free State
(email: risa@cut.ac.za) Fidelis
Emuze,
Central University of Technology, Free State
(email: femuze@cut.ac.za)

Abstract

The interwoven nature of the goal of lean and sustainability points to synergy that can be created for industry, and societal benefits. The paucity of studies, which dwell on the impact of lean and sustainability on construction project performance is however notable. This is the case of public sector infrastructure projects (PSIP), which form the focus of this research. This exploratory study assesses the indices required for measuring the integrative implementation of lean and sustainability concepts in an infrastructure project. The study is qualitative in nature, based on interpretative theoretical framework that is grounded in lived experiences of project stakeholders. Emergent findings indicate that although the generic internal project key performance indices (KPI) of cost, time and quality is of major concerns to the stakeholders, indices required for integrative implementation of lean and sustainability are more broader in satisfying various stakeholders concerns, which would match business and environmental excellence, energy efficiency and optimum indoor environment, minimized resource consumption, minimized emissions, increase health and well-being, user productivity, reduced noise and dust pollution, stakeholders collaboration, and community social benefits. Such benefits include employment and enhanced industry competitiveness. It can be argued that a focus on these indices could lead to project delivery with limited impact in terms of sustainable development.

Key words: Construction, Lean, Infrastructure, Sustainability, South Africa

1. Introduction

The last decades witness a lot of innovation and transformation in its expedition for an improved built environment. Infrastructure development is crucial to drive the economy and advance civilization (Mirza, 2006). Achieving a sound and well-functioning infrastructure is essential for continuous economic growth, international competitiveness, public health and overall quality of life, as demanded by the current generation within the available social and natural context. However, this interrelationship between social and natural boundaries could alter the ecosystem. Environmental symptoms such as worsening climate change and huge emission of greenhouse gases (GHG), as a result of the depletion of natural resources because of the need to consumption is a global reality. As a result, sustainability has emerged in construction lexicon (Abidin and Pasquire, 2007).

The World Commission on Environment and Development (WCED, 1987) propounded the definition of sustainable development. The definition, which has been widely adopted by multiple agencies, says that sustainable development is meeting the basic needs of the present and the right for a better life without compromising the ability of future generations. The import of this definition is placed on the balance between social development, economic development, and environmental sustainability (Shen et al., 2007). Based on this, the primary goal of infrastructure development has now expanded from been mere economic viability to social and environmental concerns. Major infrastructure procurement now involves expert considerations regarding major spheres of sustainability. The triple bottom line (TBL) of economic, social and environmental dimensions qualifies for legislative, financial, and professional backings necessary for procurement success (Opoku and Ahmed, 2015). Infrastructure sustainability has grown from being technical based perspectives into social-political dimensions, attracting the attentions of multi-disciplinary experts, nations, and pressure groups in an attempt to negotiate the best way for sustainable development. This has been furthered by the recent adoption sustainable development goals (SDGs) by the United Nations (UN). The goals are premise on the need to build safe and resilient infrastructure, and combats climate change. The goals also include sustainable use of resources, promotion of inclusive and sustainable industrialization, which foster innovation.

This new concept focuses on the impacts of infrastructure development and resource use. The focus is on how efficient management can be brought to bear on energy consumption, dust and gas emission, noise pollution, waste generation, water discharge, water use, land use and pollution, and consumption of non-renewable natural resources, and its effect on the needs of current and future generations (Ghosh et al., 2014). Various researchers have shown that the construction industry and its activities have significant effects on the environment (Ding and Lanston, 2004; Griffith, et al., 2005; Low *et al*. 2009). Several work (Kibert, 1994; Hill and Bowen, 1997; Madu and Kuei, 2012) have proposed the thinking that underpins sustainability for the construction industry in order to engender wastes minimization and prevention of environmental hazards through basic principles of 5Rs (rethink, reduce, reuse, recycle and report) to achieves long-time economic and social benefits. Sustainability goals can only be achieved if construction activities are informed and directed by new thinking, new resources and expertise. Some of this comes in the form of innovative practice, tools and enhanced process models, but much will have to come from situated and contextual appreciations of sustainability goals and local practices in the industry (Pathirage et al., 2007).

Similarly, lean as a concept was developed as an industry process of eliminating waste by adapting production process in construction to enhanced performance (Howell, 1999; Forbes and Ahmed, 2011). Rybkowski et al. (2013) look at lean construction as respecting stakeholders in the value chain through a holistic pursuance of continuous improvement, while minimizing waste and maximizing value to the customer. Howell (1999) sees lean construction as a production process that mainly redresses project KPIs balance by 'increasing value while reducing waste' in construction. This production process is often anchored on waste reduction and normally practiced in the segregation of construction process breakdown of project lifecycle. Most works on lean construction have been premised on the five principles of lean thinking that serve as a pathway for continuous improvement. These principles are: value, value stream mapping (VSM), flow, pull, and perfection (Pasquire and Connolly, 2002; Terry and Smith, 2011). These principles are used to mitigate the current practices in infrastructure procurement that often hinders the attainment of the criteria for sustainability (Vieira and Cachadinha, 2011).

The interwoven nature of the goal of lean and sustainability points to a synergy that can be created for industry, and societal benefits. Construction industry can leverage on the synergy between lean and sustainability to achieve infrastructure development. Lean concepts align with sustainability concept of doing more with less. What is not clear though and is worthy of further investigation is; how can lean and sustainability indices be used to promote stakeholder engagements in the built environment? The paucity of studies which dwell on the impact of lean and sustainability on construction project performance is notable (Novak, 2012; Campos *et al*., 2012). This is the case of public sector infrastructure projects (PSIP), which form the focus of this research. Monitoring progress towards lean and sustainability (LS) practices, thus, requires the identification of operational indicators that provide manageable units of information on economic, environmental, and social conditions that can be measured. A full disclosure of this new paradigm and the ability to fully map out its performance indices will be beneficial to the industry, and enhanced the process of continuous improvement and attainment of ecosystem equilibrium for sustainable development. The proposed will assist developers and others stakeholders gain a more comprehensive view of the lean and sustainability in the construction context.

2.Sustainability in Construction

Over the last three decades, sustainability concept has been growing in significance in the areas of developments in the built and natural environments (Edum-Fotwe and Price, 2009). After probing for answers to the challenge of sustainable development, most nations refocus their attentions on the construction industry. The construction industry is important to the achievement of the sustainable development agenda. The South African government has made progress in establishing policies that favour energy savings in the built environment. Appreciation of the major impacts of construction activities on sustainable development has led to the development of various management approaches and methods to guide construction participants in achieving better project sustainability performance in South Africa (Du Plessis, 2007; Thomson and El-Haram, 2011).

Kibert propose 7 principles to implement sustainable construction practice in 1994. These principles cover most aspects of the TBL and the concept of “doing no further harm” to the built environment. These construction principles speak to: conserving, to minimise resource consumption; reuse, to maximise reusable resources; renewing/recycling, to optimise renewable or recyclable resources; protecting, to conserve the natural environment; eliminate toxic materials, to create a healthy and non-toxic environment; economic benefits, to apply life cycle cost analysis; and technical, to provide quality products. Adopting these principles will ensure the reduction / elimination of adverse effects of construction activities on the built environment through efficient use of resources. The outcomes of sustainability principles could be regarded as a vital ingredient of improved competitiveness in construction industry (Opoku and Ahmed, 2015). Sustainable construction fosters interaction and protection of natural and social environments and ultimately helps to reduce energy usage, enhanced healthy and improved condition of living, and promote stakeholders productivity.

3.Lean in Construction

Stakeholders' concern about inefficiency in the construction industry is well known. The monumental wastes accompanying the use of resources (energy, water, materials, and land) have contributed immensely to climate change. Business as usual can no longer be sustained in the construction industry, if the industry is to assure biophysical sustainability while maintaining competitiveness (Womack and Jones, 2003; Holton et al., 2010). Lean offers an alternative that allows construction activities to thrive within environmental and socialeconomic constrains. Based on lean principles, major sources of waste, inefficiencies and pollution within the construction processes are identified and eliminated through collaborative approaches and processes to create value. For instance, planning, measurement, adjustment, and improvement ("Plan, Do, Check, Act") have also prove to be a veritable framework for value creation beyond specification (Ng et al., 2012).

Various lean principles and tools have been developed for use in construction with varying degree of success. San Martin and Formoso (1998) state that lean performance indicators include value chain efficiency, process efficiency, production flexibility, improved skills, material diversity, standardization, and optimization of components weight. Generally, the collaborative and continuous improvement principles inherent in lean practices made it not only a wastes reduction philosophy, but catalysts for business competitiveness, productivity and profitability. Lean principles engender effectiveness and efficiency in production processes by systematically examining the value chain for non-value activities through critical thinking and planning improved projects performance (Corfe, 2012; Novak, 2012).

4.Lean and Sustainability in Construction

The emergence of sustainability issues calls for a more innovative approach for the world to survive within the present constrains. The construction process generally contributes to the total energy use, GHG emission, and waste generation. Utilizing lean tools bring forth the predicted variable of efficiency and waste reduction, and the responsive variable of environmental benefit through reducing construction wastes at source, minimizing resource depletion, and preventing pollution. Integrative deployment of lean and sustainability could increase the pace of broader enhanced value (Larson and Greenwood, 2004; Ghosh et al., 2014).

Despite the sustainable construction drivers reported in the literature - resource efficiency, competitive advantage, reputation, increased productivity, reduced wastage, reduced materials cost, and preservation of natural environment (Yates, 2003; Zhou and Lowe, 2003) , the uptake of sustainability is still limited in the industry. This limitation may not be unconnected with the complex and fragmented nature of the construction industry. Common challenges perpetrating the limitation are the lack of understanding, perceived costs, and inadequate expertise (Opoku and Ahmed, 2015). However, lean reputation for promoting collaborative working arrangements, coordination, waste and cost reduction, and continuous learning and improvement serves as an opportunity for the industry to mitigate barriers to sustainable construction and create value beyond specifications.

The opportunity for value beyond the specifications has emerged as construction process with highly developed lean practices have reliably broken through the traditional project constrains and serve as catalyst for sustainability and enhanced added value in meeting the needs of sustainability (Nahmens and Ikuma, 2009; Novak, 2012). Lean practice covers a wide range of infrastructure procurement practices: planning and risk management, collaborative working, problem definition and solving, and value stream efficiency. These lean approaches demonstrate the value stream (benefits in terms of cost, time, and sustainability) for infrastructure sustainable development that span the project life cycle. It is on this premise that governments are urging the industry to leverage on lean thinking for real value delivery whilst simultaneously achieving improved competitiveness and the objectives set out in the strategy for sustainable construction (HM, 2009 cited in Corfe, 2013). It follows that lean thinking could form a central part of organisations' sustainability strategies, as it could deliver sustainability objectives.

Lean sustainable construction therefore can be conceptualized as 'a proactive approach to project delivery practice that meets a broader sustainability concerns of environmental, economic, social and technical perspectives by leveraging on available effective and efficient concepts to attain sustained productivity'. Sustained productivity here means to exceed the status quo of project delivery practice and achieve infrastructure beyond specifications. This has been achieved through efforts to enhance infrastructure project performance, reduce resource use and reduce costs through lean tools such as BIM, just-in-time, 5R, 5W (Scanlon and Davis, 2011; Ahuja et al., 2014).

5. Research Methodology

The aim of this study is to develop holistic indices of integrative implementation of lean and sustainability in terms of infrastructure development. The indices could allow a better understanding of stakeholders' way of assessing public infrastructure project performance. Within the construction context, the understanding of KPIs serves as benchmark for improved productivity, and it is vital to the success of project goals. To resolve this challenge, an exploratory study was conducted in Bloemfontein, South Africa. The study relies on interpretative theoretical framework that is grounded in lived experiences of project stakeholders (Creswell, 2013). Purposeful sampling in which the participants are selected according to a defining characteristic that makes them a role player was utilised in the study (Nieuwenhuis, 2007; Leady and Ormrod, 2010).

In particular, nine stakeholders in infrastructure development were interviewed in six different entities (department of works, project managers, consultants, policy administrator, community representative and the academia) with semi-structured questions that were initially sent to them by e-mail and a follow up telephone call was used to confirm the actual date of the interview for consistency. The interviews were conducted over a period of two weeks. Interviews, generally, were between 20 to 30 minutes in duration. At the start of the interviews, each participant was reminded of the research question and of the interview process. Each interviewee was then provided with a covering letter to read, and a confidentiality agreement to sign; on demand. This process was then followed by the actual interview during which the interview protocol was utilized as a guide. Each interviewee was asked about his / her experience and perceptions of infrastructure performance indicators related to: economic, environmental, and social conditions. All interviews were recorded and transcribed. The emerging findings were then collaborated with a comprehensive literature review to explore the phenomenon in South Africa. Nine interviewees took part in the exploratory study. The interviewees were two women and seven men between the ages of 30 and 56. The educational levels of the participants ranged from a national diploma to a doctoral degree, and construction industry experience ranged from 3 to 32 years (Table 1).

Table 1: The demographic of interviewee

Descriptions / *S/N*	*Highest Level of Education*	*Entities*	*Designations*	*Years in Industry*
1	*Bachelor's Degree*	*Works department*	*Project supervisor*	*3*
2	*Master's Degree*	*Consultant*	*Project manager*	*24*
3	*National Diploma*	*Project managers*	*Site agent*	*11*
4	*Bachelor's Degree*	*Consultant*	*Architect*	*26*
5	*Honours Degree*	*Project managers*	*Managing director*	*25*
6	*Doctoral Degree*	*academia*	*Senior Lecturer*	*19*
7	*Honours Diploma*	*Works department*	*Junior manager*	*11*
8	*Honours Degree*	*Community rep.*	*User*	*8*
9	*Honours Degree*	*Policy administrator*	*Director*	*32*

6. Research Findings and Discussions

The findings are herein presented and discussed in line with natural and social concerns about biophysical, economic, technical and social dimensions of sustainability in order to cater for the concern of different stakeholder. This provides a platform to integrate the primary data and the literature for meaningful interpretation for the right indices to emerge.

7.1 Indices for Biophysical Dimension

Most environmental concerns appears to be the highly researched sustainability dimension, some of the issues of the environment are predicated on the interaction between natural and social issues. Most interviewees suggest that resource use is a global issue as concerns for global warming are not localised. Sustainable resource use and environmental impact assessment are considerations in any developmental agenda, where the goal is to achieve sustainable extraction of fossil fuels and minerals resources at a rate lesser or equal to the slow replenishment of the inert resources, and to reduce the use of 4 generic resources of energy, water, materials, and land.

An attempt to maximise resource reuse and / or recycling, use renewable resources in preference to non-renewable resources, minimise air, land and water pollution, minimized emissions. So as to maintain and restore the earth's vitality and ecological diversity; and minimise damage to sensitive landscape in order to achieve the expected continuum (Shen, et al., 2007). Interviewees were unanimous in saying "we all know the rate at which we depletes the natural resources is certainly not sustainable, and a stable weather condition is not only good for our health, it also good for future planning". This echoes the current unpredictable nature of the biosphere and it impact on the environment. The interviewees express preference for facility with efficient energy, good indoor environment, and limited noise and dust pollution that can aid productivity.

7.2 Indices for Economic Dimension

Cost and value for money are the main determinants between internal and external stakeholders in any potential infrastructure development of scale. The management of the inherent trade-offs between these parties determine the viability of the project. Most interviewees agree with Shen et al. (2007) that intending user's affordability, employment creation; enhanced competitiveness, environmentally responsible supply chains, and the capacity to meet the needs of future generations are the main fulcrum for economic sustainability. Interviewee 5 says "yes, we all want to put up an energy efficient building or green building as you call it, but those technology are beyond the reach of common man", while interviewee 8 says "any user will like to rent a sustainable built environment because it ultimately reduces energy and maintenance costs of the properties". These quotes demonstrate the significance of energy use to the economics of the stakeholders. Other economic aspects mentioned by the interviewees relate to: having a competitive edge over their industry rivals through organizational learning, innovative ideas, technological advancement; improved productivity for enhanced profits; and stakeholder's collaboration for sustained harmony that engendered business and environmental excellence.

7.3 Indices for Social Dimension

The social dimension of sustainability has been growing in importance as a criterion for evaluating the viability of projects in the construction sector, especially in developing nations where basic needs of life and the right skills for quality job remains a challenge. Social sustainability in construction is mostly premises on the need for improve quality of human life through implementation of skills acquisition and capacity enhancement of the disadvantaged, to seek fair or equitable distribution of construction social costs, and to seek intergenerational equity (Shen, et al., 2007; Edum-Fotwe and Price, 2009). This social cost, according to the interviewees pertains to the health and well-being of the community. Most interviewees agree that "a lean sustainable project should be able to contribute to the community through local employment and improved skills development". A segment of the interviewees also echoes the need to match business goals with environmental excellence. This can only be attained through stakeholder collaboration and community involvement/development, proper site layout to reduce noise and dust pollution for work place harmony.

7.4 Indices for Technical Dimension

Quality is one of the traditional KPIs in construction management. Although relative in nature, it depends on technical competence and it outputs express 'value for money'. Sustainability in technical terms is to construct durable, reliable, and functional structures, which creates the built environment; humanize large buildings; and revitalize the existing urban infrastructure (Shen et al., 2007). Most interviewees agree with Emuze (2015) that the new model of sustainability must include regenerative, adaptive and resilient initiatives in order to achieve a broader sustainability agenda. The quality of the design, material selection, production process and the level of finishes most at times determine the functionality and the price clients are willing to pay for the products. Also, poor quality of work in projects may lead to reworks which certainly compromise other performance indices.

7.5 Indices for Lean and Sustainable Projects

The traditional KPIs have evolves overtime from the dated tripod of cost, time and quality. Projects success are now evaluated through performance measures to include critical factors of; health and safety and related sustainability criteria (Khosravis and Afshari, 2011; Kylili, Fokaides and Jimene, 2016). The broader sustainability indices have been widely reported (Shen et al., 2007; Edum-Fotwe and Price, 2009; Emuze, 2015) to encompass the natural and socio-economic aspects of infrastructure development and its effect on various stakeholders in the industry.

These cut across the project value chain in relation to processes, resources, leadership, people, financial, environmental and the entire ecosphere through project lifecycle. Lean principles as a waste reduction tools, is an effective ways of enhancing the various spheres of KPIs for infrastructure development (see sections 3 and 4). It can then be infer that indices for lean and sustainability (LSI) are those indices that can be seen as a standard of judgement by which lean and sustainable values can be measured. Hence, the LSI went beyond traditional indices to accommodate external inclusiveness that address industrial harmony and the need of future generations. As illustrated in Table 2, these indices set a benchmark for measuring project performance holistically and provide significant insights into developing a comprehensive base for future developments.

Table 2: Stakeholders project performance indices

Types / *Indices*	*Traditional*	*Lean (L)*	*Sustainability (S)*	*LSI*
Cost	✓✓	✓✓	✓✓	✓✓
Time	✓✓	✓✓	✓✓	✓✓
Quality	✓✓	✓✓	✓✓	✓✓
Health and Safety	✓✓	✓✓	✓✓	✓✓
Environmental responsible value chain		✓✓	✓✓	✓✓

Energy and resource consumption		✓✓	✓✓	✓✓
Pollution and emission		✓✓	✓✓	✓✓
Matching Business and environment		✓✓	✓✓	✓✓
Social cost/benefit			✓✓	
Industry competitiveness		✓✓	✓✓	✓✓
5R / Renewable resources		✓✓	✓✓	✓✓
Flexibility and adaptability		✓✓	✓✓	✓✓
Organizational learning		✓✓	✓✓	✓✓
Dispute	✓✓	✓✓	✓✓	✓✓
Stakeholders collaboration		✓✓	✓✓	✓✓
Employment and Skill development		✓✓	✓✓	✓✓
Continuous improvement		✓✓	✓✓	✓✓
Planning and risk	✓✓	✓✓	✓✓	✓✓
management				
Value stream efficiency		✓✓		
Technological advancement		✓✓	✓✓	✓✓
Affordability		✓✓	✓✓	✓✓
Indoor environmental quality			✓✓	

Adopting these new sets of performance measures as a base for planning and executing future projects could lead to evolution of sustainable built environment. To do so, a clear understanding of the LSIs, as a sub-set of biophysical, economic, socio and technical dimensions will be needed.

This can come to fruition through further research and stakeholders' engagement in term of standardizing LSI measurement methods (Ali, Al-Sulaihi and AlGahtani, 2013).

7. Conclusions and Recommendations

The purpose of the research reported upon in this paper is to develop lean sustainability indices that are grounded in stakeholder's projects experience with the view of creating a consistent and holistic way of assessing public infrastructure project performance. The compilation of the indices is relevant as projects performance criteria are often hedged around the traditional KPIs and TBL of sustainability, measured both objectively and subjectively, in order to achieve success expectations. To sum up, the emergent findings indicate that although generic project KPIs of cost, time and quality is of major concern to the stakeholders, indices requires for lean and sustainability are however, broader and far reaching in engendering efficiency and effectiveness in infrastructure development. These include matching business and environmental excellence, energy efficiency and good indoor environment, minimized resource consumption, minimized emissions, increase health and well-being, user productivity, reduced noise and dust pollution, stakeholders' collaboration, community social benefits, and enhanced industry competitiveness. It can therefore be argued that a focus on these indices could benefit project delivery with limited whole life cycle impact in terms of sustainable development. The indices could provide all stakeholders the same information and knowledge of the overall goals, creating cooperation, coordination and better understanding of the key issues affecting the value chain, towards achieving better project performance.

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