SUSTAINABILITY PERFORMANCE OF INFRASTRUCTURE PROJECTS: THE CASE FOR LIFE CYCLE SUSTAINABILITY ASSESSMENT METHODOLOGY

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ABSTRACT

The contribution of the construction and infrastructure (C&I) industry to society's unsustainable consumption patterns remains legendary. The potential of sustainability assessment and rating systems to make significant contributions towards reversing this trend has been elucidated. Several variants of such systems have become prevalent in the C&I industry for deployment to projects and assets. Yet, it appears that they have focused mainly on developed countries, certain sustainability dimensions, and certain phases of the infrastructure asset's lifecycle. This observation makes this study a necessity considering the quest of countries within the developing country context such as South Africa to bridge the attendant infrastructure deficit therein. Adopting a desktop research design, an extensive review of literature was conducted to unravel the current situation concerning these systems. Relevant keywords were used to source literature from established databases such as Scopus. Accordingly, articles and conference papers pertaining to the subject matter were culled from these databases and analyzed through qualitative content analysis. Findings from the emergent data lend credence to the initial propositions concerning the paucity of sustainability rating and assessment systems for civil infrastructure projects in developing countries. Furthermore, other postulations concerning the inability of the extant systems to cater adequately for the three sustainability dimensions in an integrated manner as well as the overt concentration on certain phases of the infrastructure asset lifecycle were affirmed. Based on these findings, the study proposed the adoption of an all-encompassing methodology – the life cycle sustainability assessment (LCSA) methodology – in the development of sustainability assessment and rating systems for developing countries like South Africa.

Keywords: Civil infrastructure, Life cycle sustainability assessment, South Africa, Sustainability.

1. INTRODUCTION

The *Our Common Future* report has attracted global attention to the need for citizens, governments and businesses to engage in their activities in a manner that depicts adherence to sustainable development (SD) principles (WECD, 1987). Accordingly, SD and sustainability have gained acceptance among both economic and non-economic actors (Finkbeiner et al., 2010). A recent attempt to chronicle the evolution of sustainability science identified the existence of over 20,000 papers belonging to 37,000 distinct authors from 174 countries and 2,206 cities (Bettencourt & Kaur, 2011). This describes the intensity of the sustainability discourse. Yet, the implementation of the SD concept remains a daunting challenge for organizations, economic sectors and countries (Finkbeiner et al., 2010). The construction and infrastructure (C&I) sector has been associated with underwhelming performance in this regard (Gunnell et al., 2009).

The C&I industry's potential to destabilize the environment has been reported (Bourdeau, 1999; Du Plessis, 2007; Sev, 2009). Available statistics suggest that products of the C&I sector utilize 15% of the world's fresh water resources and 40% of the world's energy and are responsible for the production of approximately 23-40% of the world's greenhouse gas emissions (Gunnell et al., 2009). Additionally, Bribián et al. (2011) assert that the combination of civil works and building construction is responsible for the consumption of 60% of materials extracted from the earth's crust. Consequently, studies have sought to propagate new approaches to sustainable project delivery (Huovila & Koskela, 1998; Raynsford, 1999; Du Plessis, 2007; Shen et al., 2007). Reports from the C&I sector indicates varied levels of sustainability uptake within the industry (Bon & Hutchinson, 2000, Du Plessis, 2007).

Various assessment and rating tools have evolved for measuring the impact of the C&I industry on the environment since 1990. Examples include the Building Research Establishment Environmental Assessment Method (BREEAM), Leadership in Energy and Environmental Design (LEED) and Civil Engineering Environmental Quality Assessment and Award Scheme (CEEQUAL). These tools have since been deployed in assessing the sustainability performance of buildings and infrastructure projects. Considering the dynamic nature of the construction industry and society, these tools have undergone significant transformation over their lifetimes (Griffiths et al., 2015). A review of these tools indicates that a few of them focus on building construction processes and the buildings whereas the infrastructure subsector of the C&I industry remains under-served (Wong, 2010; Andreas et al., 2010). Furthermore, a paucity of tools seeking to assess and rate sustainability performance of infrastructure in developing countries such as South Africa is evident (Jayawickrama et al., 2013). This constitutes a significant gap, especially in the face of the rapid urbanization rates of developing countries (UN DESA, 2014; World Bank, 2013).

To bridge this gap, this study seeks to contribute towards stimulating the discourse on the need for assessment and rating tools for sustainability performance management in infrastructure projects in developing countries. Also, it highlights the significance of a LCSA theoretical methodology in the development of such assessment and rating tools. In this study, South Africa serves as an exemplar developing economy context.

2. LITERATURE REVIEW

2.1. The Concept of Sustainability Assessment and Rating

The SD mantra has suddenly become the goal upon which future development is premised (Klöpffer, 2003). The C&I sector's reputation for destabilizing the ecosystem through its products and processes remains legendary (Ortiz et al., 2009). Kibert et al. (2000) identify environmental effects of mass materials movement between the point of extraction and usage, reduction in quantity of high quality mineral stock for industrial use, and gradual dissipation of concentrated materials because of emissions as lending support to the development of such reputation. Also, they acknowledge the sector's efforts towards ameliorating such problems. These strides towards SD seem to have gone unnoticed owing to the absence of a widely accepted apparatus for measuring and managing implementation performance. Corroborating this view, Finkbeiner et al. (2010) and Berardi (2012) insist that the challenge confronting SD implementation was stakeholders' ability to agree on performance measurement and management procedures. Crawley and Aho (1999) reiterate the importance of such assessments for construction projects and materials used in their delivery.

Sustainability assessment has been described as a process through which the probable impacts of particular activities and their alternatives are identified, predicted, and evaluated (Devuyst, 2000; Zamagni et al., 2013). Shaw et al. (2012) maintain that increased uptake of sustainability assessment by various organizations for the delivery and operation stages of construction projects such as infrastructure will lead to the attainment of beneficial outcomes. The decision-making capabilities of a sustainability assessment mechanism has also been highlighted (Ding, 2008). Whilst reiterating the insufficiency of the C&I sector's reliance on project designs to either achieve SDGs or a reduction of environmental impacts, she explains that sustainable assessment tools can assist in arriving at decisions on whether a variant of a proposed project is capable of enabling the attainment of the SD ethos. Sustainability assessment and rating have evolved from the C&I sector's desire to contribute positively towards the attainment of sustainability. In apparent recognition of the impacts which various processes and products inherent in the industry had on the environment, stakeholders immediately sought to ameliorate these impacts.

Initially, such efforts were associated with the amelioration of environmental impacts. However, with renewed advocacy for the industry to look beyond the issue of environmental impacts, the attention of the sector was drawn to other pillars of sustainability, namely economic and social pillars. A combination of these aspects culminated in the development of sustainability assessment. Affirming the importance of these pillars in the C&I industry, Berardi (2012) refers to the description of 1SO 15392 of construction sustainability as the ability to accord adequate consideration of sustainable development in terms of its three primary aspects, namely economic, environmental, and social, whilst meeting the stipulated requirements for technical and functional performance within construction projects. According to Bond et al. (2012), instead of their assessment on an individual basis to yield better outcomes, the inherent potential of the systematic assessment of these pillars of sustainability in projects has made the option an attractive proposition for the C&I industry. Reflecting further on the attributes of effective sustainable assessment, Bond et al. (2012) suggest that the initiatives should be designed in a context-specific manner. In this way they highlight the peculiarities of the macro and micro economy in the assessment. Resulting from a combination of individual assessment schemes for environment, economic and social impacts respectively, the following attributes are considered imperative for effective sustainability assessment initiatives, namely a comprehensive and systematic nature; improved stakeholder engagement; the ability to span intergenerational periods; and immediate as well as long-term consequences of alternative options evaluated systematically for informed decision-making (Bond et al., 2012). According to Shaw et al. (2012), sustainability assessment strives to achieve certain objectives such as presenting credible data to reflect the degree of sustainability in the early stages of the construction project lifecycle; providing guidance to the project design decisions; employing a set of criteria and indicators for assessing the project's monitoring tools; ensuring adequate utilization of the plan-do-check-act procedure through constant monitoring, measuring and interpreting of data; and benchmarking such data against best practices.

Reiterating the salient nature of sustainability assessment and rating systems, various studies attribute the progress made in the building subsector of the C&I sector to the prevalence of such systems within the subsector (Larsson, 1999; Mateus & Bragança, 2011; World Green Business Council, 2013; Poveda & Young, 2015). Relying on information from the Building Research Establishment (BRE), Poveda and Young (2015) admit to the existence of approximately 600 assessment and rating systems which are focused on this subsector globally. However, a paucity of sustainability assessment initiatives within the infrastructure subsector has been observed (Jayawickrama et al., 2013; Wong, 2010; Clevenger et al., 2013). This paucity happens to be pronounced in the developing world where only two countries, namely South Africa and Brazil, have assessment and rating schemes, albeit for buildings and building processes (Berardi, 2012). This study is predicated on this observation. Developing countries are currently embarking on aggressive infrastructural development programmes in their quest to increase their standing on the national competitiveness rankings as well as the Human Development Index (HDI). Consequently, such development programmes will have tremendous impact on the attainment of SD principles; hence the imperative nature of assessment and rating mechanisms for measuring and managing such potential impacts. Furthermore, the use of such mechanisms as decision-making tools will allow these economies to decide on how to attain infrastructure sustainability.

2.2. Sustainable Infrastructure Assessment and Rating Systems: State-of-the-art

The term 'sustainable infrastructure' continues to defy widely accepted definition. Yet attempts to create a dichotomy between sustainable infrastructure, sustainability of infrastructure, and infrastructure sustainability have been noticed in relevant literature (Stapledon, 2012; Vanegas, 2003; UN ESCAP, 2007). For instance, Stapledon (2012) avers that whereas infrastructure sustainability is concerned with the design, delivery, operation and final deconstruction of the infrastructure asset, sustainable infrastructure deals with an asset's 'fit-for-purpose' nature. Vanegas (2003) describes the sustainability of infrastructure as concerning what the infrastructure asset does (products, goods and services), how it does it (operations, procedures, and practices), and with what resource (natural resources requirements). Also, the UN ESCAP (2007) report entitled 'Greening Growth in Asia and the Pacific' observes that any attempt at improving the sustainability levels of any infrastructure asset must accord prime attention to eco-efficiency. Andreas et al. (2010) argue that the critical factor for the attainment of sustainable infrastructure systems lies in the ability of such systems to address inter- and intra-generational demands within the confines of extant resources. Summarily, sustainable infrastructure can be used to connote infrastructure assets which are aligned to the principles of sustainability and sustainable development.

The construction and operation of infrastructure does possess a reputation for intensive energy consumption and other aspects of environmental degradation (Park et al., 2003). Alam and Kumar (2013) lament the paucity of assessment schemes for civil infrastructure, especially as it pertains to road infrastructure. They reiterate the useful nature of such schemes in the integration of various aspects of sustainability into the distinct phases of infrastructure project design, construction, and operation. Griffiths et al. (2015) reaffirm the inadequacy of literature on the assessment and rating of infrastructure projects. They state that these assessment tools are indeed necessary as they provide a platform for measuring sustainability performance in civil infrastructure projects whilst also providing project stakeholders with a road map on how to attain successful performance. The introduction of the foremost version of CEEQUAL in the United Kingdom in 2003, thirteen years after the adoption of BREEAM (1990) further serves as a testimony to the negation of infrastructure sustainability assessment and rating. According to Griffiths et al. (2015), the systems focusing on infrastructure can be delineated along the lines of their approach to the assessment and rating exercise. They identify two major categories, namely assessment and rating tools that rely on self-assessment approaches and those that can avail themselves of third-party verification and certification. Nevertheless, they add that the tools requiring third-party verification are usually more rigorous. Some of these schemes have been described as generic and can be applied towards assessing and rating civil infrastructure projects; others have been acclaimed to be sector specific (Alam et al., 2013). An example of the latter is the GreenRoads assessment and rating system whereas the CEEQUAL represents the former in this regard. Whilst it must be acknowledged that a flurry of activities has started to occur within the realm of civil infrastructure assessment and rating in recent times, such initiatives are still absent in developing countries such as South Africa.

3. RESEARCH METHODOLOGY

This study relies on a qualitative desktop research design. This method has been suggested as being instrumental to the conduct of literature synthesis research projects such as this (Suri, 2011). Accordingly, relevant databases such as Science Direct, Scopus, and ISI Web of Science were identified and consulted. The authors relied on a combination of a set of keywords such as sustainability assessment and rating, lifecycle thinking, lifecycle approach, lifecycle costing, lifecycle analysis, lifecycle assessment, social-lifecycle analysis, lifecycle sustainability assessment, project lifecycle, material lifecycle assessment, and South Africa. Following from a cursory search of these databases, a plethora of relevant articles and technical reports was identified. Most of the articles utilized emanated from the following journals: *Lifecycle Assessment*, *International Journal of Project Management*, *Cleaner Production*, *Construction and Building Materials*, *Building Research and Information, Ecological Indicators* and *Environmental Technology*. Further to this, a number of conference papers were discovered from the search and utilized. A qualitative content analysis was conducted on the preselected publications. Data was sought from these publications based on pre-set themes derived from the study's objectives.

The following civil engineering assessment and rating system were identified from the articles consulted: CEEQUAL, GreenLITES, GreenRoads, EnVision, Infrastructure Sustainability (IS), LEED for Neighbourhood Development (LEED-ND), Infrastructure Voluntary Evaluation Sustainability Tool (INVEST), BE^{2}ST-In-Highways and Illinois Livable and Sustainable

Transportation (I-LAST). These tools only focused on the developed country context. The features of these tools are provided in Table 1.

4. FINDINGS

The findings from the qualitative content analysis of selected articles, technical reports and conference papers were structured according to the objectives of the present study. Therefore, the authors identified the various lifecycle assessment and analysis tools presently being deployed in the assessment and rating of civil engineering projects and assets globally. The presentation of these tools enables an understanding of the shortcomings of the extant tools, especially as it concerns the underpinning methodology for these tools (LCA, LCC, S-LCA, and the like); the country context for which they are developed (developed and/or developing country context); the economic sector in which the asset is deployed and others.

Furthermore, the section deals with discussions on the need for the assessment and rating tools to truly embrace the concept of lifecycle thinking as well as conducting a review of the South African assessment and rating context for civil infrastructure.

Table 1. Features of Various Infrastructure Sustainability Assessment Systems

Number	Assessment and Rating system	*Infrastructure Lifecycle phases covered*					*Type of Infrastructure*						**Percentage of Concentration (100%)**			*Country Context*	
		Planning	*Design*	*Construction*	*Operation and Maintenance*	*Decommissioning and End of Life*	*Highways*	*Water Storage*	*Water Treatment*	*Energy Generation*	*Landscaping*	*Information and Communication Systems*	*Social*	*Economic*	**Environmental**	*Developed*	*Developing*
1	**BE2ST-IN-Highways**	**X**	**X**	**-**	**-**	**-**	**X**	**-**	**-**	**-**	**-**	**-**	**N/A**	**N/A**	**N/A**	**X**	**-**
2	**Envision**	**X**	**X**	**X**	**X**	**-**	**X**	**X**	**X**	**X**	**X**	**X**	**22%**	**38%**	**100%**	**X**	**-**
3	**Green guide for Roads**	**X**	**X**	**-**	**-**	**-**	**X**	**-**	**-**	**-**	**-**	**-**	**45%**	**55%**	**100%**	**X**	**-**
4	**GreenLITES**	**X**	**X**	**X**	**X**	**-**	**X**	**-**	**-**	**-**	**-**	**-**	**10%**	**25%**	**100%**	**X**	**-**
5	**Greenpave**	**X**	**X**	**X**	**X**	**-**	**X**	**-**	**-**	**-**	**-**	**-**	**12%**	**50%**	**100%**	**X**	**-**
6	**Greenroads**	**X**	**X**	**X**	**-**	**-**	**X**	**-**	**-**	**-**	**X**	**-**	**25%**	**53%**	**100%**	**X**	**-**
7	**I-Last**	**X**	**X**	**O**	**-**	**-**	**X**	**-**	**-**	**-**	**-**	**-**	**19%**	**39%**	**100%**	**X**	**-**
8	**INVEST**	**X**	**X**	**X**	**X**	**-**	**X**	**-**	**-**	**-**	**-**	**-**	**30%**	**65%**	**100%**	**X**	**-**
9	**CEEQUAL**	**X**	**X**	**X**	**X**	**-**	**X**	**X**	**X**	**X**	**X**	**X**	**25%**	**45%**	**100%**	**X**	**-**
10	**STARS**	**X**	**X**	**X**	**X**	**-**	**X**	**-**	**-**	**-**	**-**	**-**	**N/A**	**N/A**	**N/A**	**X**	**-**
11	**Infrastructure Sustainability**	**X**	**X**	**X**	**X**	**-**	**X**	**X**	**X**	**X**	**X**	**X**	**N/A**	**N/A**	**N/A**	**X**	**-**

(X) = applicable; (-) = not applicable; (o) = under development; and (N/A) = not available
(Source: Adapted from Griffiths et al., 2015; Simson et al., 2015; Shaw et al., 2012)

Table 1 is self-explanatory, and the limitations of extant sustainability assessment and rating mechanisms can be deciphered. Such limitations include the inability of the various systems to cover the entire life cycle of the infrastructure asset; the non-consideration of the social and economic impact assessments; the non-generic nature, and non-consideration of the developing world context. These observations have been corroborated by Shaw et al. (2012) and Diaz-Sarachaga et al. (2016). These limitations are capable of undermining the efficiency and effectiveness of sustainability assessment and rating mechanisms. Also, they can cause these mechanisms to deliver incomplete assessments, subsequently leading to poor decision making and sustainability performance management in infrastructure projects.

4.1. A Life-Cycle Thinking Approach

Admittedly, society's desire for an amelioration of the impact of the C&I sector's activities on the ecosystem requires a credible methodology. Such methodology should take into consideration the whole-of-life impact on the environment of not only the final asset, but also the processes and products contributing to the development of the final asset. Infrastructure assets are analogous to living organisms as they all possess a life cycle, usually a cradle-to-grave cycle. The life cycle of products is delineated across the following facets, namely product design, raw material extraction and processing, manufacturing of the product, packaging and distribution to the consumer, product use and maintenance, and the end-of-life management: reuse, recycling, and disposal (Udo de Haes & Van Rooijen, 2005). The use of a life cycle thinking (LCT) approach stems from the need to appraise various interactions which occur between the ecosystem and the activities and materials applied during the assets' delivery stages. The UNEP report categorizes life cycle approaches into two distinct aspects, namely the analytical and practical aspects. The former is concerned with the scientific assessment of the effects of planned decisions whereas the latter focuses on the use of policy or corporate programmes in the assessment of such effects. According to Guinée (2016) and Neugebauer et al. (2015), LCT approaches are increasingly being relied upon to analyze various scenarios available to society for catering for the needs of future generations. The features of an LCT approach are elucidated in the life cycle analysis (LCA) (Heijungs et al., 2010; Corominas et al., 2013). The LCA remains the most commonly used assessment approach within the vast array of LCT assessment methodologies mentioned previously (Berardi, 2012). This is as a result of its professed suitability for the appraisal of environmental impacts of civil engineering and building works as well as the materials applied therein (Glass et al., 2013). This suitability is premised on its ability to delineate primary activities and the materials utilized within the project development and delivery processes, assessing the impacts of these activities and materials individually on the environment from exploration and extraction to decommissioning at the end of life (Berardi, 2012).

However, for credible, comparable and transparent LCA assessments, the stakeholders within the various sectors need to arrive at a consensus on sector-specific indices to be applied (Santero et al., 2011). Alam and Kumar (2013) define LCA as a systematic set of procedures for compiling and examining the inputs and outputs of materials, energy and associated environmental impacts directly attributable to the functioning of a product or service system throughout its life cycle. A UNEP report on the LCA describes it as a procedure for assessing the impacts which a particular product may have on the environment over its life cycle (UNEP, 1996). Corroborating this view, Ghumra et al. (2009) add that the LCA seeks to provide a whole-of-life understanding of the entire processes and products applied towards the realization of an asset. These processes usually assume the cradle-to-grave or cradle-to-cradle dimension (Ortiz et al., 2009). In reiterating the role of the LCA in fostering effective decision making, Ghumra et al. (2009) state that the approach can be directed towards making decisions concerning resource utilization during project delivery. The UNEP report (UNEP, 1996) lends credence to this observation as it views the LCA as capable of affecting decisions on material selection, based on the material's potential impact on the environment during project planning and design stages. Alam and Kumar cite a variety of sources that allude to the scientific disposition of the LCA in the optimization of whole-of-life usage of resources and minimization of emissions during project delivery (Alam & Kumar, 2013). Furthermore, the ability of the LCA to serve as a platform for comparing various products on the basis of the same functional quality endears it to potential assessors (Berardi, 2012; Corominas et al., 2013). The LCA's capability to prevent problem shifting between various stages of a project's life cycle has also been observed (Udo de Haes & Van Rooijen, 2005). Buttressing this assertion, Klöpffer (2003) reiterates the futility of engendering improvements in one phase of a product's life cycle when such improvements may lead to negative consequences in the subsequent phases of the product's life cycle as such negative consequences may outweigh whatever improvements might have been attained earlier.

Within the C&I sector, the application of the LCT-based methods occurs along two different dimensions: the building material and component combinations (BMCC), and the whole process of the construction (WPC) (Ortiz et al., 2009). LCA assessments have been applied severally across facets of the C&I sector such as dwellings, commercial buildings and civil engineering. However, more tools and methods have been developed for the assessment of dwellings and commercial buildings in comparison to the few tools and methods applied to infrastructure projects. Tools and methods applied towards the assessment of dwellings and commercial buildings include BREEAM, LEEDS, SEDA, ATHENA, BEE, and Green Star.

The review of assessment and rating tools in the preceding section shows that most of the tools applied towards the appraisal of civil engineering projects did fully not rely on the LCT methodology. Such non-reliance on a given methodology negates the credibility of these methods (Crawley & Aho, 1999). According to Crawley and Aho (1999), methodological transparency is critical to the success of any assessment and rating method, particularly as it pertains to the philosophical and practice-oriented perspective. It remains to be seen how the civil engineering-related assessment and rating tools can deliver credible and objective impact assessments, especially within the developing economies context where the challenges border on the triple bottom line (TBL) of sustainability and not just environmental concerns (Gibberd, 2005). Because of this, the UNEP has once more assumed a leading role in championing for the development and subsequent adoption of a life cycle-thinking approach that integrates aspects of economic, social and environmental criteria in the conduct of sustainability assessments for products, processes and materials respectively (Ciroth et al., 2012). The life cycle sustainability assessment (LCSA) framework has since resulted from this advocacy.

4.2. Understanding the South African Infrastructure Sustainability Assessment and Rating Context

In admitting to the global utilization of sustainability assessment and rating systems with the exception of Africa and Latin America, Berardi (2012) singles out South Africa and Brazil as countries in the aforementioned regions that have embraced the use of these systems. But in South Africa available assessment and rating tools have concentrated on residential, educational and commercial buildings (Gunnell et al., 2009; Gibberd, 2005). This focus on buildings can be attributed to the country's strategic proclivity towards engendering SD in the aftermath of the World Summit for Sustainable Development in 2002. This proclivity for SD and the development of the green buildings concept in South Africa notwithstanding, events relating to the need for energy and water security, increasing global awareness of climate change, and increased demand from multinational corporations operating within South Africa which occurred between 2007 and 2008 heightened the level of awareness among the populace, leading to increased demands for sustainable buildings (Gunnell et.al., 2009; Ampofo-Anti, 2012). Furthermore, Ampofo-Anti (2012) attributes the rise in SD awareness to the role of the media and the government through the effective communication and enactment of pro-SD legislations by successive governments in the country.

Environmental labelling and rating systems were introduced into the building sector as the demand for sustainable buildings among clients increased. Some of these tools include Green Star SA, Sustainable Building Assessment Tool (SBAT), EcoStandard South Africa, Energy Labelling standard for buildings, South African National Eco-labelling Scheme, the Materials Manufacturing Industry Initiative and the Built Environment Sustainability Tool (BEST) (Gibberd, 2008; Gibberd, 2015; Ampofo-Anti, 2012). The first version of the Green Star SA system, which was modelled after the Australian Green Star rating system, was launched in 2008 (Gunnell et al., 2009). It focuses solely on the environmental performance of buildings and is premised on a point-scoring system. This is seen as a shortcoming and the SBAT was subsequently introduced to correct this anomaly. The SBAT incorporates aspects of the social, economic and environment criteria in assessing the sustainability performance of buildings. The social criteria applied consist of the following: occupants' comfort, inclusive environments, access to facilities, participation and control, and education, health, and safety. On the other hand, the economic criteria include local economy, efficiency, adaptability, on-going costs, and capital costs. The environmental criteria assessed include water, waste, energy, site, materials and components (Gibberd, 2008). Retief (2007) argues that the concept of sustainability assessment is non-existent in South Africa, admitting that strategic environmental assessment (SEA) was prevalent and enabled by the country's legislation. He posits that the National Environmental Management Act (NEMA) 1998 and the National Framework for Sustainable Development were established to ensure that all environmental assessment activities carried out within South Africa are premised on SD attainment. Accordingly, South Africa's leading position in the conduct of strategic environmental assessment (SEA) is based on the legislative support and the cases of successful SEA assessments conducted therein (Patel & Giordano, 2014). But Patel and Giordano (2014) bemoan the lack of documented information pertaining to the use of SEAs and other forms of environmental assessment mechanisms such as environmental impact assessment (EIA) in South Africa.

However, the environmental labelling, assessment and rating systems available in South African seem to neglect infrastructure projects. To date, there is no assessment and rating system for assessing the impact of infrastructure projects and assets on the ecosystem within South Africa known to the authors. Wall and Rust (2015) emphasise this observation when they reiterate the absence of rating tools for evaluating South African infrastructure. This gap poses a challenge to the country's infrastructure development aspirations. In recent times, the South African government has not minced words about its determination to invest strategically in infrastructure. This aspiration has seen the establishment of the Presidential Infrastructure Coordinating Commission (PICC) and the development of the National Infrastructure Development Plan (NIDP) as part of the National Development Plan. Strategic Integrated Projects (SIPs) are an integral part of the NIDP. These SIPs are aligned to the attainment of social, economic and environmental aspects of SD. According to the report of the Development Bank of South Africa (DBSA) on the state of infrastructure in the country, five questions were considered in the choice of projects to be integrated into the SIP programme. These questions comprise the following: the extent to which the infrastructure is aligned to the socio-economic context; the ability of the project to demonstrate its economic potential; the viability of the project; the extent to which the cost of delivering the infrastructure asset can be equitably covered, and the presence of adequate implementation competencies. Although the list shows that certain aspects of SD were taken into consideration, it would appear that a significant proportion was not considered. More so, the absence of a structured approach for carrying out sustainability assessment on these projects poses considerable concern regarding their ability to achieve enhanced sustainability performance.

Patel and Giordano (2014) lament the shortcomings of the Infrastructure Development Act (2013), an Act upon which the SIPs are anchored concerning environment assessments, despite the belief that South Africa was reaching its environmental boundaries. The Act mandates that environmental assessments for SIP must be done according to the terms prescribed in the NEMA and fails to distinguish between SEA and EIA. An example of the shortcomings for which the Act has been heavily criticized includes the abridging of the project life cycle in such a manner that it curtails the environmental assessment process (Patel & Giordano, 2014). Also, the Act is silent on social impact assessments of potential projects. These shortcomings negate the drive for a green economy within the country context from a sustainable infrastructure perspective. Obviously, without effective assessment and rating systems in place, these projects would sustain low sustainability performance, inadvertently affecting the country's desire to contribute immensely towards the attainment of a green economy. This need makes this study imperative.

5. DISCUSSION

The LCSA as a Veritable Assessment and Rating System for South African Civil Infrastructure

The growing advocacy for the integration of sustainability ethos into the design, delivery, and subsequent operation of infrastructure assets has been observed (Shaw et al., 2012). This advocacy has issued the challenge of providing an appropriate apparatus for measuring the sustainability performance of civil engineering assets, the processes involved in their delivery, and the materials utilized in these processes on a whole-of-life basis in a systemic manner. In what may appear to be a solution to this imbroglio, the concept of the LCSA has been proposed (Ciroth et al., 2012; Finkbeiner et al., 2010; Heijungs et al., 2010; Guinée, 2016). This approach to sustainability assessment acknowledges the existence of various LCA approaches such as the Social Life Cycle Analysis (S-LCA) and the Life Cycle Costing (LCC) tools, and their utility within the realm of social impact assessment and economic impact assessment activities. However, proponents of the LCSA aver that the use of these assessment tools in the past have not been conducted in a reductionist manner. As such, the individual results obtained from the application of these alternative tools cannot be aggregated to constitute a sustainability assessment endeavour. Prior to these agitations for the systemic integration of these sustainability aspects, scholars have long observed the failings of the LCA and sought to integrate it with other tools such as the LCC (Norris, 2001), and economic and social aspects (Weidema, 2006; Klöpffer, 2003) to boost the effectiveness of the LCA by broadening its current scope beyond environmental impacts (Guinée, 2016; Heijungs et al., 2010). But proponents of the LCSA maintain that the new approach would avail stakeholders with the opportunity to carry out assessments whilst taking into consideration the sustainability triple bottom line in a systemic manner. It is expected that this systemic integration will engender effective life cycle sustainability performance management of a product or civil engineering asset (Ciroth et al., 2012). It is opined that the successful conduct of an LCSA for a particular product will provide results which will not only portray the product's negative impacts but also its benefits, thus allowing for trade-offs to be agreed upon during the planning and design stages (Ciroth et al., 2012; Neugebauer et al., 2015). This much is attested to by Klöpffer and Renner (2008). In making a case for the development of an integrated life cycle impact assessment and rating method, they proposed the formula presented below for the computation of the LCSA.

LCSA= Environmental LCA (E-LCA) + LCC + Social LCA (S-LCA)

The LCC is described as an apparatus for calculating the entire life cycle costs associated with an asset's whole-of-life (Udo de Haes & Van Rooijen, 2005). It has been known to assist in decision-making, particularly as it concerns the design and development of new products or assets. Judging from the foregoing, its affinity to the economic aspect of the sustainability TBL cannot be disputed. In terms of similarity, the process of conducting an LCC is identical to the processes highlighted in ISO 14040 for LCA analysis. On the other hand, the S-LCA focuses on the assessment of the social and socio-economic aspects of products and processes alongside their potential impacts, whether negative or positive, during various aspects of their life cycle (Ciroth et al., 2012). In their contribution, Benoît et al. (2010) assert that the S-LCA allows for the identification of key social and socio-economic issues occasioned by the production, use and disposal of products and assets. They opine that the technique is best suited for the purposes of increasing knowledge, informing choices, and engendering improvement of social conditions within product life cycles. Its recent prominence has been attributed to the need to improve upon the social conditions of stakeholders affected by the life cycle activities of a product being assessed. The absence of a standardized set of quantitative indicators is a major challenge to the S-LCA's effectiveness (Vinyes et al., 2013; Ostermeyer et al., 2013; Finkbeiner et al., 2010; Klöpffer, 2008).

Since this formula has since gained popularity among life cycle impact assessment scholars such as Finkbeiner et al. (2010) and Klöpffer (2003; 2008), there are still some reservations pertaining to its applicability. These reservations evolve from the perceived difficulty of potential assessors to carry out in-depth accurate and integrated life cycle inventories across the three different aspects (Heijungs et al., 2010). According to Finkbeiner et al. (2010), LCSA's potential to contribute to effective decision-making is challenged by the difficulty experienced in understanding and explaining its results to a non-expert audience.

There is no evidence yet to suggest that the C&I industry has embraced the LCSA concept in the assessment and rating of infrastructure projects through any of the extant tools thus far. Likewise, there is no indication of the adoption of any tool relying on this methodology within the developing country context. This much was admitted by Ciroth et al. (2012). In these reports, the absence of assessment and rating tools for civil engineering assets in developing countries was identified, prompting the advocacy for the development of such tools to be considered in the future.

As a developing country, South Africa lacks such tools. Studies have highlighted the fact that the country was pushing its environmental threshold and as such, any attempts at embarking on new infrastructure projects should be adequately considered from a sustainability perspective.

Furthermore, the country's socio-economic dimensions indicate a need for the social and economic impacts of proposed infrastructure projects to be considered at the inception stage. This would ensure that the infrastructure investments are made in such a manner that would augur well for society along environmental, social and economic sustainability dimensions. But the present NEMA legislation which serves as a platform for the application of SEA and EIA does not take these aspects, particularly the social dimensions, into cognizance. An LCSA-enabled platform will cater for this deficiency as it will integrate these dimensions into various phases of the infrastructure lifecycle, hence enabling an incomplete and holistic assessment and rating procedure. Furthermore, this will lead to effective decision-making based on complete data sets, unlike what is tenable under the SEA and EIA regime in South Africa. Additionally, proponents of the LCSA methodology acknowledge the high level of transparency which it brings to sustainability assessment exercises (Neugebauer et al., 2015; Heijungs et al., 2010). Furthermore, they assert that it enables the identification and adoption of possible trade-offs between the three pillars of sustainability in a product assessment. This attribute is indeed imperative within the South African infrastructure delivery context. Inasmuch as the country has been identified as pushing on the threshold of environmental degradation, a consideration of the country's history, the increasing levels of poverty in urban areas and the declining standards on the Human Development Index (HDI) accentuates the need for holistic sustainability assessment exercises to be adopted. This is especially so in the case of critical infrastructure delivery programmes such as the SIP.

Notwithstanding its merits, it must be acknowledged that the LCSA methodology is still at a nascent stage. As such, its application is somewhat limited (Neugebauer et al., 2015). This is particularly so in the context of the C&I sector where the LCA, EIA, SEA, and LCC have continued to play dominant roles in sustainability assessment and rating procedures. As is the case with new strategies or methodologies, implementation challenges are always posed to their successful uptake by relevant stakeholders. The LCSA fares no better. A review of thirty relevant articles resulting from a bibliometric analysis conducted by Guinée (2016) highlights twelve (12) challenges to the successful implementation of the LCSA. Of this number, challenges such as an absence of effective platforms or mechanisms for communicating LCSA results, lack of practical scenarios of LCSA application, and the absence of data for carrying out aspects such as SLCA were predominant. Similarly, Neugebauer et al. (2015) observe the variance in maturity levels between the LCA, LCC and SLCA components of the LCSA. Whereas the LCA has an established methodology as encapsulated in ISO 14040, the LCC and the SLCA are devoid of such established methodologies, thus lacking appropriate impact assessment criteria. Such variance, they admit, poses a challenge to the broad implementation of sustainability assessment as it makes the identification and selection of indicators difficult. Furthermore, they mention the absence of an appropriate indicator selection process which is duly accepted by all institutions within a geographical or sectoral context.

Summarily, it can be deduced that the LCSA would be most beneficial within the developing country context owing to its ability to enable a holistic assessment of environmental, economic and social impact factors, engendering necessary trade-offs between competing impacts. No doubt, these trade-offs would allow for the reflection of context-specific peculiarities and hence allow for accurate decision-making processes within the infrastructure subsector of the C&I sector.

6. CONCLUSIONS AND RECOMMENDATIONS

The C&I sector has been identified as one sector through which society can achieve its SD aspirations. Accordingly, the sector has made significant strides by changing processes and embracing innovative practices towards achieving pro-SD goals. The need for an effective and efficient decision-making process as well as the absence of an apparatus for the measurement and management of these sustainability-oriented efforts of the sector contributed to the introduction of the sustainability assessment and rating systems.

Such systems not only enabled the measurement and management of the impacts of the sector's activities and products but also sought to incentivise stakeholders who were able to achieve more with less impact on the TBL. Whilst the use of these systems has been most prevalent within the building subsector of the C&I sector, the infrastructure subsector has remained largely under-served. Also, from a list of eleven (11) pro-infrastructure sustainability assessment and rating systems identified from a review of relevant literature, none was applicable to the developing country context. This gap is obvious and needs to be addressed considering the increasing urbanization and demand for infrastructure in the developing world. Furthermore, these systems did not assess sustainability aspects in a holistic manner and failed to cater for various impacts which occur across the entire life cycle of the infrastructure project. This observation accentuates the need for an LCT approach which considers the TBL in a holistic manner, enabling as it were trade-offs between them. This was the premise upon which the LCSA methodology is being proposed.

Based on a review of the benefits associated with the LCSA, this study makes a case for its adoption as a platform for decision making as well as subsequent measurement and management of sustainable infrastructure endeavours in developing countries such as South Africa. In acknowledging the nascent nature of the LCSA, this study provides an overview of its shortcomings and efforts which are being carried out to towards resolving them.

This study seeks to contribute toward stimulating the discourse on the sustainability assessment and rating of infrastructure projects through a broadening of the LCA technique to encompass other parts of the TBL. Furthermore, it seeks to highlight the deficiencies of extant infrastructure sustainability assessment and rating tools concerning their applicability within the developing country context. Also, it is expected that this study would elicit increased awareness pertaining to the subject matter among relevant stakeholders in South Africa. Such stimulation of this discourse should inevitably lead to more studies focusing on the development of appropriate frameworks for selecting indicators for the not yet matured S-LCA as well as a context-specific LSCA-enabled framework for carrying out sustainability assessment and rating within the developing country context.

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