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Modeling a transformational route to infrastructure sustainability in South Africa

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Abstract

Purpose – The purpose of this paper is to propose a model for operationalizing the integrated use of lean and sustainability concepts for infrastructure delivery. This model is premised on the need for the attainment of a sustainable built environment through efficient infrastructure delivery.
Design/methodology/approach – A case study research design was used in assessing five purposively selected cases within Gauteng province in South Africa. These facilities attained Green Building Council of South Africa ratings of 5- to 6-star, for the rating of green buildings and available evidence of integration of lean principles at the developmental stage. Questionnaires were administered to project's role-players and semi-structured interviews were conducted with the users and facility managers, in order to elicit data for the model development. Questionnaire survey was adopted for the model validation.
Findings – The lean-sustainability platform for infrastructure delivery demonstrates features such as resources, drivers, barriers, activities, outputs, the results, and the ultimate impact. The findings give insight into various components of the model. It validates its robustness and highlights leadership among other critical factors necessary for successful operationalization of the lean-sustainability ethos required to transform the delivery of infrastructure.
Practical implications – The developed model provides a transformational route for achieving infrastructure sustainability. The lean-sustainable indicators identified will serve as evaluation tools for assessing lean-sustainability ethos during the delivery phases of infrastructure projects.
Originality/value – The model provides a new way of thinking about infrastructure project delivery regarding the need to promote sustainability in the built environment.

Keywords Sustainability, Infrastructure, Construction, Lean, South Africa, Transformation

Paper type Research paper

1. Introduction

Over the last decades, society has witnessed a lot of innovation and transformation in its drive for a balanced ecosystem. Infrastructure sustainability was considered critical for the development of the economy and improved living conditions. Environmental challenges such as worsening climate change and huge emission of greenhouse gasses, resulting from the depletion of natural resources due to over consumption, is a global reality (Mirza, 2006; Abidin and Pasquire, 2007; Isa and Emuze, 2016).

The relevance of creating an operational synergy between lean and sustainability for infrastructure development is evident. The demand for comprehensive frameworks that

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can draw both tangible and intangible values accruing from such integration has become prevalent within project delivery environments. This reasoning is also supported by the benefits associated with such concepts when applied to the construction context (Ogunbiyi, 2014; Abd Jamila and Fathia, 2016). Accordingly, increased advocacy for the adoption of innovative practices toward changing the unsustainable, business as usual model of contemporary construction and delivery has been observed (Novak, 2012; Campos *et al.*, 2012).

Such advocacies have led to the clamor by industry stakeholders for the paradigmatic shift toward lean-sustainable construction (LSC). However, the effective adoption and utilization of this paradigm are dependent on the ability of various stakeholders to critically access the impact of interactions between social and natural systems on project delivery (Novak, 2012; Madu and Kuei, 2012). Indeed, the development of an operational framework for enabling such synergy will be beneficial to the industry (Novak, 2012; Ogunbiyi, 2014; Abd Jamila and Fathia, 2016).

Also, the review of management corpus in the area of sustainability highlights the need for a more comprehensive model for the construction industry (Du Plessis, 2007; Cuginotti *et al.*, 2008). The paucity of models for integrating lean with sustainability, especially within the developing country context, is noted. The reflection on what kind of model could engender the implementation of lean and sustainability concepts in an infrastructure project for the benefit of end users, led to the research's problem statement – the lack of an empirical (operational) framework for the integration of lean and sustainability as a catalyst for efficiency hinders continuous improvement within the public sector construction.

Therefore, the primary purpose of this research is to create an adaptive form of governance for socio-technical systems like infrastructure delivery systems toward the attainment of built environment sustainability. To this end, this paper highlights the utility of a lean-sustainability model for infrastructure (LSMI) delivery in providing such governance within the context of LSC and infrastructure delivery.

2. Literature review

2.1 Sustainable development

The concept of "Sustainable development" is primarily based on four interdependent principles related to meeting human needs, maintaining ecological integrity, attaining social sufficiency, and establishing social equity (Shah, 2002). The Brundtland report for WECD in 1987 has become the reference point from which sustainable development has been evolving (WECD, 1987). Clear indicators in the later stages of the last century suggest the need to take a second look on how society develops. Global climate change with its attendant effect on the safety, economy, and the global well-being have brought forth and continue to be drivers for sustainable development (Wu and Wu, 2012; Yao, 2013).

2.2 Sustainable construction practice

Sustainable construction is a process of adopting sustainable development principles to the realization of construction sector objectives in a holistic way to restore and maintain harmony between the natural and built environment, in a way that create settlements that affirm human dignity and encourage economic equity (Du Plessis *et al.*, 2002; Ogunbiyi *et al.*, 2013). The contribution of built-infrastructures to the society renders their delivery process imperative (Du Plessis *et al.*, 2002; Ogunbiyi, 2014). Madu and Kuei (2012) suggested that in the journey toward sustainability, the industry must change the culture of creating the built environment by adopting cyclic processes which will promote recycled, renewed and reused resources, and decrease the use of energy and new mining for natural resources.

2.3 *Infrastructure sustainability through lean-sustainability integration*

The effect of upstream activities such as construction is majorly responsible for the creation of a new ecosystem dynamics in local environments and the biosphere as a whole (Millennium Ecosystem Assessment (MA), 2005). Drives for improved standard of living and societal well-being are no longer localized, as it affects the capacity of other regions to engage with sustainable development ethos. Such connectedness calls for relevant stakeholders and institutions that govern human-nature interactions to work in unison, toward creating a model for an adaptive form of governance within social and ecological systems. By reflecting on the strength of internal connections (infrastructure platform) that mediate and regulate the influences between micro and macro systems, infrastructure sustainability can be attained (Holling, 2001; MA, 2005).

Corfe (2013) claimed that the adoption of lean practices during construction enhances the chances of attaining sustainability objectives. Such methods cover a broad range of infrastructure procurement and delivery practices like planning and risk management, collaborative working, problem definition and solving, and value stream efficiency needed for sustainable infrastructure development. However, it is pertinent to state that significant changes that could deliver high-value benefits regarding cost, time, and sustainability objectives are usually made at the concept or design stages, although opportunities remain throughout the project life cycle that must be considered in full or in part, based on the decision support needs of organization involved in the delivery of such assets (Pearce *et al.*, 2012; Corfe, 2013).

3. Theoretical perspective

Change consists of a transition from one stable state to another over a given period. To achieve change, the importance of understanding the concept of change from a theoretical perspective assumes prominence. Theory of change (ToC) can be considered a product of collaboration – a series of critical-thinking exercises – that provides a comprehensive picture of the first- and intermediate-term preconditions (changes) in a given thematic area (Anderson, 2005; Wyatt Knowlton and Phillips, 2013).

The evolution of ToC in lean and sustainability integration draws on two streams of development in natural and social systems theories: socio-technical and social-ecological change (Maru *et al.*, 2016). The socio-technical angle stems from the interface of stakeholders with social and technical systems. The technical aspect of the construction industry has developed to a dominant and stable state, where innovative technologies are available for use. However, the effective uptake of these innovations, in a way that is ecologically viable for now and the future, has somewhat been a hindrance. The development of this interface to maturity is imperative for value creation throughout the projects' life cycle. The social-ecological theory of adaptive change provides profound insights into how natural and social regimes work in theory and practice (Holling *et al.*, 2002). In socio-technical systems, organizations adapt to change by evaluating the political, economic, social, technological, legislative, ecological factors, in order to understand their stake within the higher scale of nested interest, whilst modifying their lower level sub-systems such as organizational structures, and innovative solutions to suit their overall vision and objectives, each undergoing adaptive cycles (Holling *et al.*, 2002). To achieve excellence across sustainability facets therefore, organizations must undergo transformational processes culminating to a sustainable state.

It is on this basis, that a review of sustainability management (SM) corpus has led to the adoption of the transformational process model (TPM) (Du Plessis, 2007; Cuginotti *et al.*, 2008; Denyer and Tranfield, 2009; Madu and Kuei, 2012). The TPM is an organization-wide SM initiative for stakeholders' interactions between social and natural systems, as a response to the competitive landscape in the new global economy (Madu and Kuei, 2012). Within this study's context, the TPM is relied upon for the development of a transformative framework for operationalizing the LSC synergy. This value-oriented model is premised on the scholarly work of Novak (2012). According to Lukowski (2010) and Novak (2012), a synergistic link between lean and sustainability principles was not only possible but necessary for the attainment of a sustainable state in projects. Accordingly, value creation through the integration of the lean-sustainability paradigm in infrastructure life cycle will lead to new competencies for continuous improvement and further innovation within organizations and projects.

4. Research methodology

This study proposes a transformational model for achieving infrastructure sustainability in the South African built environment context. In doing this, a case study research design was adopted wherein data were collected through self-administered questionnaires and interviews.The selection of cases was based on the Green Building Council of South Africa (GBCSA) criteria for the rating buildings. Such criteria were necessary as the study intends to extend the available knowledge on lean-sustainability constructs.

In particular, five cases were selected out of 25 cases from the GBCSA database through a mix of purposive and convenience sampling (Flick, 2009). This was done with the intention of achieving the needed repetitiveness within the context of the study. The five rated non-residential building office spaces attained GBCSA ratings of 5- to 6-star from 2012 to 2016. A 5-star and 6-star rating implied good and excellent rankings. The facilities employed sustainability consultants to conceptualize projects in a bid to meeting the GBCSA certification in South Africa.

The data collection was done sequentially for two main reasons. First, within case study, to develop the model (case study comprising of questionnaires and interviews and document reviews) and second, the questionnaire survey for model validation. The data collection process commenced with four interviewees in the first phase for the purpose of refining the research instruments, and to get insights into the lean-sustainable (LS) construct from practitioners, in conjunction with available archival data on the GBCSA platform. The interviewees comprised of two senior project managers, a consultant, and a senior policy administrator. With an average age and experience of 43 and 19 years, respectively, and a minimum of an Honors degree that indicate the interviewees are well qualified to give an informed information within the context. These interviewees are subsequently referred to as PS1, PS2, PS3 and PS4 in the data analysis section.

The second phase of data collection involved the self-administration of 32 questionnaires, and seven interviewee sessions within cases (C_1-C_5). The questionnaire respondents comprised of the project teams as indicated on the GBCSA platform, to draw from the lesson learnt during the production of the rated facilities. Whilst, the interviewees include occupants and the facility managers (FM), to elicit information's on the socio-economic and environmental benefits derived from LS infrastructure. The interviewees were purposively selected, and their demographics can be seen in Table I. Data saturation was easily attained

S. No.	Cases (non-residential buildings)	Position	Ownership structure	Qualification	Industry experience (years)
1	C_1	Occupant	Private	BTech	8
2	C_2	FM	Private	Honors	7
3	C_2	FM	Private	Honors	11
4	C_2	Occupant	Private	Honors	9
5	C_3	FM	Private	Honors	12
6	C_4	FM	Public	BTech	7
7	C_5	FM	Private	Honors	13

Table I. Interviewees' demographics

within the second phase of the sessions as interviewees seemed unanimous on the various questions posed, in line with Stringer (2014).

The quantitative data were analyzed statistically, and the qualitative data were transcribed verbatim and coded into a set of pre-set themes. The analysis of the questionnaires are presented using descriptive statistics based on the mean item score (MIS). The MIS of the variables along with its ranking is presented based on a five-point Likert scale (where 1 – never, 2 – rarely, 3 – neutral, 4 – often, and 5 – very often). The textual data were thematically discussed in line with the literature (see Figure 1) (Creswell, 2013; Nieuwenhuis, 2007; Leedy and Ormrod, 2010). The findings in line with the TPM and the literature informed the development of the model.

This validation process is aimed at testing and refining the model's components. The validation was expedited by surveying experts. Experts' survey is ideal for an in-depth analysis, as it helps to ascertain a cohesive consensus view, explore detailed opinions, judgments, and evaluations of particular subjects (Creswell, 2009; Fellows and Liu, 2008; Tracy, 2013). An expert sample was randomly drawn from the International Council for Building (CIB) database (www.cibworld.nl). Relevant CIB task groups and working commissions (W065, W098, W116, TG88 and TG93) were sampled. In all, 101 questionnaires were electronically administered to validate the model. The demographics of the sample are provided in Table II.

The model was assessed about its robustness for engendering LS integration in the industry. Also, the internal experts give the practicability angle to the final model. The validation questionnaire consisted of both structured and semi-structured questions, which covered the following aspects: the model's robustness, the reasoning (logic) of the model, suitability of the model's components, areas of strength, areas of concern, and suggested improvements.

5. Model development and validation

Pre-set themes utilized in this study are concerned with the identification of model components and the perception of stakeholders regarding their significance. Further, there is need to establish what constituted lean and sustainable construction practices as well as barriers and drivers of integration. The information helped in developing the LSMI.

The findings emerged from the analysis are discussed accordingly in the ensuing parts. These parts consist of preliminaries, model development, and validation aspects, respectively.

5.1 Preliminaries

5.1.1 Sustainable construction practices. Claims about the prevalence of sustainable construction practices within the projects were examined. This was carried out to evaluate sustainability features, the understanding of the elements of sustainable construction, and the levels of the sustainability concept adopted in the selected cases. Evidence emerging from the cross-case pattern shows that energy efficiency, material, and water reduction, and pollution reduction with MIS (4.39, 4.29, and 3.66) were ranked 1st, 2nd, and 3rd, respectively. Most of the interviewees corroborated the survey findings. They highlighted the importance of energy efficiency and reduced water usage to be paramount among the preferred value placed on a project by operators and the occupants. This fact was also reiterated by Interviewee 2 when he said:

> If the right technology that is efficient and durable can be deployed to reduce the energy and water consumption in our buildings, the built environment management encumbrances would have reduced substantially […].

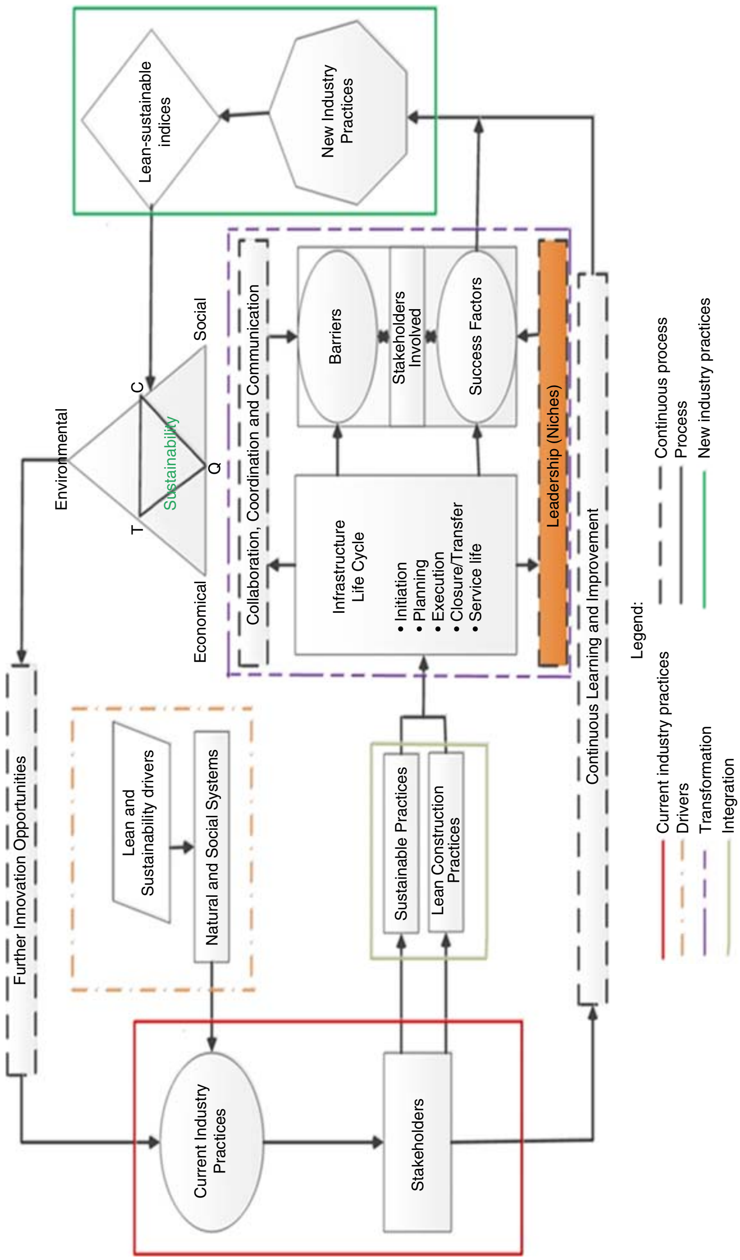

Figure 1.
Lean-sustainability model for infrastructure (LSMI) project delivery

This shows the importance of energy and water reduction to the attainment of sustainable targets of the built environment. Interestingly, Madu and Kuei (2012) and Rafindadia *et al.* (2014) made similar submissions that basic principles, such as energy modeling, reduce resource consumption, and use of sustainable material resources will promote the act of renewed and reused resources, and decrease in the use of energy and new mining for natural resources.

5.1.2 Lean construction practices. The lean principles are necessary for enabling sustainability (Novak, 2012). However, the development of this concept is still in its infancy: lean and lean-related concepts adopted within the industry are not acknowledged as lean principles. This state of understanding cannot be better placed than what PS1 and PS2 proffered. According to them:

> Lean isn't even a concept in this country. If you go to someone and say lean construction, they'd look at you and question, what are you talking about? It's just a concept that hasn't found its way into mainstream construction in the country (PS1).

> I would love to be one that would get lean construction as a good construction technology implemented in South Africa. I think it would make a huge difference and more importantly, I think especially in public sector construction it would bring enormous value to South Africa as a whole, I mean in some projects I deal with costs that are just ridiculous and that's pure because it doesn't have to be lean (PS2).

Although low adoption of the lean techniques within the cases was evident, the survey results indicate that concurrent engineering, just-in-time, visualization tools, daily hurdle meeting, and value analysis with MIS of 3.58, 3.50, 3.42, 3.18 and 3.11, respectively, were considered significant and possibly adopted across all the cases by the project teams. This is not surprising, as it is similar to the findings made by Simonsson *et al.* (2012) on the performance of two bridge projects, where "increased visualization" of materials, resources and information brought about work-flow improvement, ease of measurable lead time, and reduced production costs.

5.1.3 Barriers to lean-sustainability concept. Resistance to change is a common obstacle to the adoption of new concepts such as LSC (Smit *et al.*, 2011). Even though lean-sustainability premium (cost) was highly ranked as the greatest barrier in all the cases, the performance of other obstacles varies on the perception levels. This is not surprising as Wilreker (2011) and Windapo (2014) separately held that cost concept served as a limiting factor in the promotion and adoption of sustainable construction as they proffer a proper understanding of sustainable cost; economics can be of great benefit to the industry's innovative practices.

Various stakeholders appear to hold different perceptions concerning the sustainability premium within the industry, which does not resonate with the principle of collaboration that can enhance the pursuance of a typical project's goal (lean-sustainability). This was echoed by a consultant (PS3):

> Retrospectively, the main barrier to lean is the non-understanding of what it is there for. Many people see lean as something being driven by the clients as a way to save money on sustainable construction, and clients see sustainable designs associated with the premium. The problem […] primary barrier(s) to sustainable construction is cost […] whereas actually, the holistic philosophy around lean-sustainability is that all parties benefit, so you go into the process knowing that you are part of the process but having improved yourself financially. And the clients draw up a tender with a combination of both the best price and whatever wins the bid.

Table II. Demographics of validation sample

Participants' classification	Sources	Area of specialization	Coding
Internal	Cases	Project teams	I_1-I_{23}
External	CIB	Academia	E_1-E_{78}

5.1.4 Drivers for lean-sustainability concept. The salience of drivers in enabling the adoption of innovative practices such as LS integration within projects cannot be underestimated. Challenges such as global climate change, urban pollution, and environmental degradation with its attendant increment in global industry competitiveness have brought forth and continue to serve as drivers for sustainable development and by extension, the adoption of sustainable construction practices (Wu and Wu, 2012; Yao, 2013). Also, issues about industry competitiveness need for improved levels of efficiency and effectiveness, and inflow of innovative staff serve as drivers of the LS concept. Finch and Zhang (2013) alluded to these facts when identifying the drivers for sustainable practice in the construction industry to include competitive edge, winning more contract/financial incentive, and attracting and retaining good employees. The low rating attributed to demands, leadership, and legislation was echoed by the PS4:

> There's no sufficient drive for clients to embed sustainability thinking in projects yet. The building regulations don't go far enough yet in driving change. Once it becomes financially difficult for a client to avoid sustainability, then it becomes a much bigger issue.

5.1.5 Benefits (indicators) of lean-sustainability on project performance. This case-based exploratory study identifies LS indicators for South African construction industry. Based on the summary of the cross-cases, improved industry competitive edge, and continuous industry improvement are ranked the best (MIS – 4.30) benefits derived from the adoption of the lean-sustainability concept in the production of built environment infrastructure. This is in line with Madu and Kuei's (2012) assertion that proactive companies adopt sustainable management principles, knowing that the outcome leads to long-time economic and social benefits. Increased stakeholders' collaboration and increased organizational learning are also rated strongly. Followed by the dated indicators for project performance of an improved cost, time, and quality schedule management. Although this is a high performance for time and cost within the general variables, it is somewhat contrary to most of the commentators relating to their attached importance to the success of sustainable development. A sample of this view was demonstrated by the FM in C_3:

> Sadly a lot of these benefits are just there. Value is there. But value is often discussed, and the best value, unfortunately, is very often the lowest price. That's not always the best value. The best value in my mind is ensuring long-term benefits to the public as opposed to short-term goals or short-term benefits or cost.

5.2 Model development

The previous works of Milhram (1972) as cited in Fellows and Liu (2008) and Bernard and Ryan (2010) on model development detail stages of model development and validation. This study draws from the relevant principles espoused in these studies on model development, testing and validation in conjunction with the emerging data findings and the TPM basic principles to develop the LSMI. Therefore, the development of LSMI evolved along three distinct stages, namely, identification of parts, relationship between principal components and flow (logic), and its assessment.

5.2.1 Identification of parts. The operationalization of the lean-sustainability concept consists of essential components of lean construction, sustainable construction practices as well as expected outcomes. The proposed lean-sustainability platform for project delivery demonstrates features such as resources, drivers, barriers, activities, outputs, the results, and the ultimate impact. The proposed LSMI construct is made up of varying distinct but related parts, which include current state evaluation, the drivers for change, the lean-sustainability integration concept, and the infrastructure life cycle value streams (transformation), barriers (current challenges), infrastructure delivery, life cycle, stakeholders' involvement, and success factors.

5.2.2 Relationship between principal components and the flow (logic). The model is developed through a logical linking of multiple sequential areas of inquiry, which include: evaluating the current state of the industry and setting the future goal amidst the barriers and drivers for innovation; assessing the impact of lean-sustainability principles on stakeholder's interaction with natural and social systems; the critical evaluation and development of core sustainability competences for sustainable development; the correlation between increased cohesiveness of lean and sustainability with enhanced project performance and the impact on the project whole life cycle; exploring the relationship of a case – infrastructure values – with both internal and external community sustainability values; and examining the opportunity for this broad vision of sustainability to serve as a point of reference for organizations continuous improvement and further innovation possibilities in infrastructure development. The model is not an end in itself but the means.

Furthermore, borrowing from the "cause-effect" principle of the TOC (logic model) – an "if-then" sequence of interaction among the construct was assessed. When the sequence was applied within the construct to each component, its logic reads: "if we have stronger drivers for sustainability (change), then we can pursue lean-sustainability activities within the resources available for our infrastructure projects"; "If we pursue lean-sustainability activities, then we can create values in infrastructure life-cycle"; "If we have real values through infrastructure life-cycle, then we will secure lean-sustainability benefits"; and "If our infrastructures exhibit lean-sustainability indices, we will have sustainable built environment." Moving from the left to the right in a systematic manner. The various segments of this matrix to innovative thinking have to be considered in the model (for illustration purposes, please see Wyatt Knowlton and Phillips, 2013).

5.2.3 Assessment of the model. Assessment criteria are critical to successful implementation. They account for the importance attached to performance mapping of socio-technical change within the ToC as this will enable an understanding of the underpinning processes of what works and learning from it (Guijt, 2007). Assessment of LSMI involves the evaluation and understanding of short to intermediate/long-term outcomes (new industry practices, lean-sustainability indicators – toward its ultimate impact (sustainable development) and further innovative opportunities).

The testing and evaluation components complete the cycle in LSMI as shown in Figure 1.

The LSMI aims at offering a transformational route for sustainability industry leaders and their value chain for the attainment of sustainable infrastructure. Furthermore, the route-map for the LSMI, which elaborates on the various segments of the model is as presented in Table III.

The general idea behind LSMI for is that of a mixed sustainability perspective likened to a situation where a nation develops its infrastructure smartly within an ecologically balanced environment. This position was adopted in consideration of the measurable infrastructural gap and ever increasing population growth amidst limited resources. In pursuance of developmental goals, the critical natural capitals such as ozone layer, the carbon cycle, and the hydrological cycle cannot be traded for other forms of capital, as their depletion would endanger human survival since environment accounts for natural resources and ecosystem services needed for economic and social development.

Overall, the general feedback on the model presents a positive outlook. The experts surveyed from both internal and external participants gave positive remarks on the LSMI and its components, the systematic approach to its development applauded, as well as its applicability. The LSMI was classified as being a product of pioneering research with clear and comprehensive underlying relations, within its context or scope. Moreover, the

Stage	Brief description
Current industry state	Business as usual (BAU) where: the unsustainable ways that the stakeholders interact with the social and natural system in search of development persist with its attendance symptoms
Drivers	Issues concerning the environment, social and the economic have contributed significantly towards society's increased focus on the integration of lean-sustainability concepts
Stakeholders	The niche: the stakeholders meet to evaluate their current state, set future target and the template for the achievement of the target (Backcasting)
L-S Integration	Integration of lean and sustainable construction practices backed by the necessary frameworks that can move the integration towards tipping point
Transformation	Transformation (change) can occur in the infrastructure life cycle through collaboration, coordination, and communication (3Cs) in an integrated project delivery (IPD) manner among the niche; drawing from the experience of the role players for best practices
Leadership	Leadership which influences the uptake outcome and the management of the contingencies is needed to create robust partnership amongst various stakeholders (Niches)
Continuous learning and improvement	Completed projects or activities serves as a learning curve and a reference for future measurement and improvement
New industry practices	This is an industry state with new competences and new values. The stakeholders are more aware of what works and most importantly have the right competences to attain the set goals
New infrastructure	This stage engendered the production of building infrastructure that demonstrates lean-sustainable indicators (values)
Built – environment sustainability	It is expected that such infrastructure would produce a broader appeal for "sustainability" within the built environment by increasing the pace and depth of its implementation. This new value standard is expected to build a healthy economy, environmental quality, and social and cultural heritage within the built environment
Further innovation	The built environment sustainability then follows with the room for further innovative opportunities, as the sustainability infrastructure idea is not a "product" but a "process" that is subject to continuous improvement. The organization operates as an open system that evaluates the process maturity for sustainability at a point of reflection, receives feedback from its internal as well as external environments for further innovation and continuous improvement opportunities. This process involves evaluation of value creation about risks and costs

Table III.
The final routemap to LSMI

developed model was seen to be compatible with contemporary global thinking in an attempt for a new approach to sustainable infrastructure delivery. Some samples of the comments of the survey participants are given below:

> The model reflects the vision and aspiration of (the) South African construction industry and its implementation would engender sustainability in the built environment (I_3).

> LMSI looks holistically at how to engender sustainability in project life cycle (I_4).

6. Concluding remarks

This paper has adumbrated a transformational route for sustainable infrastructure delivery by explaining ways in which an integration of lean construction and sustainability principles can drive transformation in the sector. The use of five South African cases to develop a transformational model and the validation of the model by experts show a possible way forward regarding the promotion of sustainability in the built environment.

Sources such as the expert opinions, archival records, and literature review were utilized in developing an LSMI delivery for South Africa.

The proposed model was validated for its robustness in transforming infrastructure delivery toward sustainability status. This was achieved through feedback from internal and external participants to generate internal and external validity of the model. The model provides an adaptive form of governance needed for socio-technical systems such as infrastructure delivery systems, in response to the gradual deterioration of the global socio-ecological stability. In the process, it develops the lean-sustainability indicators for holistic evaluation of infrastructure performance. The indicators could assist developers and others stakeholders to gain a more comprehensive view of the lean and sustainability impacts on infrastructure project performance. However, the success of the model is not guaranteed as it depends mostly on the right leadership to engender the good cultural, structural changes as well as attitude among stakeholders. Therefore, the development of effective leadership for transformational change is recommended. There is scope for further work on what suitable procurement system could lessen the effect of its complexity by reducing stakeholder's conflicts.

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