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CONCEPTUAL TRANSFORMATION PROCESS MODEL FOR SUSTAINABILITY IN THE INFRASTRUCTURE SECTOR

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ABSTRACT

Business as usual (BAU) model of infrastructure delivery is contrary to the needs of sustainability in the built environment. This difference necessitates a South African study that is focus on sustainability in the infrastructure sector. A review of the management corpus led to the discovery and review of a transformation process model, which was thereafter integrated with core lean and sustainability principles. Through the analysis and synthesis of collected data from a case study design approach, it was discovered that a transformation model could serve as a purposive vehicle for embedding sustainability in the delivery of infrastructure projects in South Africa. However, confirmatory evaluation of the proposed model is required to ascertain its applicability in the sector.

Keywords: Infrastructure, Lean, Transformation Model, Sustainability, South Africa

1.0 INTRODUCTION

The emergence of sustainability concerns in the built-environment calls for a more innovative approach to development for the world to survive within the present constrains of the global operating environment. Construction industry in several developing countries has undergone a lot of innovation and transformation in a bid to cope with their national economic goals to align production (and consumption) practices with the growing global sustainability trends (Mousa, 2015). Infrastructure sustainability has proved to be crucial for the development of the economy and improved living conditions of modern society. Achieving a resilient and sustainable infrastructure in developing nations is essential for the region continuous economic growth, international competitiveness, public health and overall quality of life. The current built-environment challenges such as worsening climate change and huge emission of greenhouse gases (GHG), as a result of the continuous depletion of natural resources in meeting the needs for consumption has becomes a global reality (Mirza, 2006; Abidin and Pasquire, 2007; Isa and Emuze, 2016).

Infrastructure development globally has served as measure for societal growth, however, is a major contributor to the proliferation of greenhouse gases (GHG), waste generation as well as the depletion of the inert resources (Forbes and Ahmed, 2011; Banawia and Bileca, 2014). More so, the approach adopted in meeting the current needs for infrastructure does not always conform to sustainability requirements. Business as usual (BAU) model of construction practice and infrastructure delivery is contrary to the needs of sustainability in the built environment. Infrastructure projects delivery can no longer be viewed in isolation, as it affects all sectors of the economy and accounts for about 50% of energy use. Construction activities have a major impact on physical development, government policies, community activities and welfare programme. In the United States of America (USA), buildings alone account for 40% of municipal solid waste, 30% of raw material use, 12% of portable water use, 49% of all energy produced, 77% of electricity produced, and 46.9% of carbon dioxide (CO_2) emission. These indicators do not only deplete the earthly physical resources, the transformation from mining raw material into the finished enclosure also requires huge amounts of embodied energy, with a potential contribution to the current planetary adjustment (Floyed and Bilka, 2012; Novak, 2012).

Sustainability is a growing economic development model based on the knowledge that aims to address the interdependence of economic growth and natural ecosystems and the adverse impact economic activities can have on the environment (Bangdome-Dery and Kootin-Sanwu, 2013). The limited nature of non-renewable natural resources also exposes the symptoms in the ecosystem of the unsustainable manner in which these resources are depleted. Therefore, the construction industry is anxious for the introduction of proactive measures that can spur the desired innovation in technology and resource management that will minimise the environmental burdens caused by infrastructure development and related activities (Crowford-Brown, 2012). That is, SC that will meet sustainable built environment in terms of socio-economic and environment dimensions can only be achieved through stakeholders' effective and efficient deployment of both material and techniques in the industry. The available models for sustainable construction have not been able to move the development of construction industry policies to establish recognized practices of sustainable construction (SC) in South Africa. It has also been argued that less effort has been geared towards the adoption of modern framework that can enhance knowledge and understanding of the issues that could foster SC in a developing country (Mensah *et al*., 2015).

Lean practices have primarily targeted reducing wastes in production process. Through the use of tools and techniques, lean practices have evolve to engender continuous improvement in the production process and provision of enhanced value for stakeholders (Koskela, 1992). The evolution of lean practices thus resonate with sustainable development goals. The relevance of creating an operational synergy between lean and sustainability for infrastructure development is evident. Such operation that can draw both tangible and intangible values of the broader concept accruing among stakeholders in construction organizations, especially when concentrated on the common ‘waste’ paradigm.

Increased advocacy for the adoption of transformative ways of moving away from the unsustainable, business as usual (BAU) model of traditional construction and practice has been observed (Novak, 2012; Campos *et al*., 2012). Such advocacies have led to the clamour by industry stakeholders for the paradigmatic shift towards lean-sustainable construction (LSC). However, effective adoption and utilization of this paradigm is dependent on the ability of stakeholders to critically access the impact of interactions between social and natural systems on project delivery. Industry stakeholders must therefore be equipped with the ability to evaluate their current practices in terms of LSC, and what is required to move towards the set target. Indeed, the development of an operational framework for enabling such synergy will be beneficial to the industry.

The society required new infrastructure that will exhibit lean-sustainable values. Such values should conserve material consumption, protect natural environment, eliminate pollution and toxic materials and create a balanced socio-economic environment, will be delivered for an overall sustainable development of the built environment (Kilbert, 2008; Corfe, 2013). However, despite the benefits of lean sustainable practices, the evolution of the right framework that can draw these values among stakeholders in construction organization have been a challenge. This gap necessitates a South African study that is focus on sustainability framework that could enhance balanced ecosphere and industry continuous improvement. In filling this gap, the next section of the paper presents the literature review, methodological choice, followed by a succinct account of the models used for sustainability studies. Thereafter, the paper presents the proposed model and concludes with preliminary findings to assess the robustness of the conceptual model.

2.0 AN OVERVIEW OF LEAN AND SUSTAINABILITY IN CONSTRUCTION

Creating a framework for operationalizing Sustainable Construction (SC) and Lean Construction (LC) concepts and practices in favour of continuous improvement and waste reduction would enhance positive environment and economic outcomes. Although lean and sustainability are capable of attaining significant socio-environmental and economic benefits, organizations are still experiencing difficulty regarding their integrative application (Abd Jamila and Fathia, 2016).

2.1 Sustainable Construction

Sustainable construction is comprehensive way of infrastructure delivery that meets sustainability three bottom line issues (TBL), of environmental quality, social equity and healthy economic. It can be seen as the adoption of sustainable thinking, practices and sustainable development principles to the realisation of construction sector objectives. In order words, it is that holistic process aimed at restoring and maintain harmony between the natural and built environments, in creating settlements that affirm human dignity and encourage economic equity. Sustainable construction is a subset of sustainable development which focuses on delivering infrastructure that creates value for customer and enhances the well-being of the society. It offers flexibility and the potential for retrofitting in meeting customers' future needs; provides and supports desirable natural and social environments; and maximise the efficient use of finite resources. It is pertinent to note that the adoption and attainment of sustainable design and construction in itself does not eliminate environmental impacts, as construction operations would continue to have environmental impacts albeit at a reduced rate (Du Plessis *et al*., 2002; Ogunbiyi, Oladapo and Goulding, 2013).

Sustainable construction however extends the key projects performance indices (KPI) from the dated triple KPI of cost, time and quality to other criteria such as; minimization of resource depletion, minimization of environmental degradation, and creating a healthy built environment among other objectives. The shift to sustainability can then be seen as a new paradigm where sustainable objectives are within the building design and construction industry considered for decision making at all stages of the facility life cycle. Sustainable construction as a concept, if successfully practice in construction industry, will lead to an array of stakeholders' benefits in terms of; long term cost savings, project schedule compliance, reducing environmental risk and uncertainty, ensuring legislative compliance, improving relations with regulators, improving public image, enhancing employee productivity and improving market opportunity. Good construction practice offers both environmental and economic benefits: reduce health and safety impacts on staff and local community, reduced liability costs in connection with waste disposal, minimal rework and reduced construction delays. Contractors for demonstrating environmental responsibility will improved its opportunity to tender, reduced money waste on fines, eliminates fund for restoring environmental damage, less money lost through wasted resources, harmonious relationship with host community and the improved environmental profile (Houvila and Koskela, 1998; Madu and Kuei, 2012).

However, the journey towards sustainability in socio-natural system of infrastructure delivery requires system and cultural changes and working with stakeholders in creating the built environment by adopting cyclic processes which will promote the act of recycled, renewed and reused resources, and decrease in the use of energy and new mining for natural resources. The new cultural changes in thinking, behaving, producing and consuming in the sector. Whilst a clear sustainability strategy, depends of stakeholders' commitments and improved knowledge that can only be enhance through continuous and proper education and training towards improved knowledge at every level (Abdullah *et al*., 2009; Madu and Kuei, 2012).

2.2 Lean Construction

The discuss around lean construction has been anchored on a way of generating maximum possible value for the client through designed production systems that minimise wastes in term of materials, time and effort. The goal has often been pursued by critically assessing the value stream (VS), putting more effort into maximizing value added activities (VAAs) as against non-value added activities (NVAAs) in the production process (Pasquire and Connolly, 2002; Forbes and Ahmed, 2011; Inokuma *et al*., 2014). The scholarly work of Rybkowski, Abdelhamid and Forbes (2013) define lean construction as:

> "*The holistic pursuit of continuous improvement with a goal to deliver customer value, while minimizing waste and maximizing value to the customer throughout a project's delivery process and life cycle, and while respecting all stakeholders in the value chain (p84)*".

Lean construction sustains continuous improvement throughout project life cycle in pursuance of client satisfaction by creating a more effective, efficient and profitable construction industry. The lean concept effectively engendered value and risk managements into construction industry and in doing so, effectively challenge the dated belief that key performance indices (KPI) of cost, time and quality cannot be pursued simultaneously. In eliminating this barrier, the Construction Industry Institute (CII) in their study PT191 premised lean concept on five basic principles which are; 1) Customer focus, 2) Culture and people, 3) Workplace organization and standardization, 4) Elimination of waste, and 5) Continuous improvement and built-in quality. These principles can be achieved by critically exploring three connected opportunities of impeccable coordination, organizing projects as production system and seen project as collective enterprise in design and construction (Dulaimi and Tanamas, 2001; Salem and Zimmer, 2005; Forbes and Ahmed, 2011; Suresh, Bashir and Olomolaiye, 2012).

The seemingly connectedness between lean construction and sustainable construction on basic principles surrounding waste and value proffer the clear synergy that could be developed into a new paradigm in the industry.

2.3 Lean-Sustainable Construction

Researchers in the built environment have laid credence to the contributions of construction activities to total global energy use, GHG emission, and waste generation. Sustainability management (SM) on one hand has highlighted the need for 'system' and 'cultural' changes and working with stakeholders in the ways to pursue the societal need. The lean concept on the other hand has bring forth the predicted variable of efficiency and waste reduction through responsive variable of environmental benefits by; reducing construction wastes at source, minimizing resource depletion, and preventing environmental pollution. Integrating and operationalizing of lean-sustainability within construction industry could therefore increase the pace of broader enhanced value (Larson and Greenwood, 2004; Ghosh *et al*., 2014; Madu and Kuei, 2012).

Lean practice as a catalyst for enhanced sustainability in construction practice impacts on a wide range of infrastructure delivery processes such as; planning and risk management, collaborative working within stakeholders, problem definition and solving, and value stream efficiency. The lean thinking demonstrates 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 pre-set goals for sustainable construction towards some broader sustainability objectives (HM, 2009 cited in Corfe, 2013; Isa and Emuze, 2016).

Lean-sustainability concept in construction can therefore be hypothesized 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 based on project schedules by achieving infrastructure beyond clients' specifications (Scanlon and Davis, 2011; Ahuja *et al*., 2014).

3.0 RESEARCH METHODOLOGY

Within the construction context, a sound model serves as a template for improved infrastructure and it is vital to the success of sustainability goals. To meet this target, the methodological choice was based on a qualitative research approach. The study relies on interpretative theoretical framework that is grounded in obtrusive measures and perspectives of industry experts (Creswell, 2013). Firstly, a comprehensive review of the management corpus in the fields of sustainability and organizational learning approaches were carried out to elicit an inform decision on a suitable model to meet the industry demands. This was followed by semi-structured interview of the industry experts in a selected case study to gain expert opinion on the modified model. Modification in this case means the infusion of core principles of lean and sustainability through the projects life cycle. Purposeful sampling in which the participants are selected according to a defining characteristic that makes them experts was utilized in the study (Nieuwenhuis, 2007; Leady and Ormrod, 2010). In particular, seven interviewees which include two each of project managers and consultants (of at least twelve years of industry experience), an academia, and two officials of government agency forms the panel of experts. The proposed model and it propositions guiding the logical linking of multiple sequential areas of inquiry was introduced and explained to the participants before the commencement of the interviews. This allows the interviewees to have a full grasps of the expected working of the transformation processes model.

4.0 HIGHLIGHTS OF SUSTAINABILITY CORPUS

The previous work on sustainability recognizes that the scope for possible futures is broader than BAU, which invites reconsideration of the current sustainability model and is a potential springboard for action. Multiple sustainability models are drawn upon to arrive at the proposed model for future South African sustainable infrastructure development. Some of the frameworks developed over time for achieving sustainability necessary for the industry's advancement, especially as relates to developing economy are presented.

4.1 Backcasting Model of Sustainable Development

The time lags between causes and symptoms of upstream and downstream activities explained the delay mechanism and complexity of the ecosphere. This characteristics running into decades, increases the complication for sound analysis and judgement of the ecosphere. Sometimes, this state reduces the concept to a matter of trade-offs in triple bottom line (TBL) of economy, environment and society. Dealing with this complexity in a comprehensive and systematic way requires an in-depth thinking into cause-effect chains of upstream activities by applying 'Backcasting' in the planning process (Holmberg and Robèrt, 2000; Cuginotti, Miller and Pluijm, 2008). Backcasting comprises of four basic steps, which are; awareness, baseline analysis of what the condition is, compelling vision of where to go, and series of action to get there. Cuginotti, Miller and Pluijm (2008) state that backcasting is particularly useful where there is a need for major change and a complex context, where dominant trends are part of the identified problem, when the problem to a great extent is a matter of externalities, and where the scope is wide enough and the time horizon long enough to leave considerable room for a deliberate choice that make sustainability a suitable context for backcasting. For holistic advancement in the industry to take place, industry management must be able to look ahead and set an achievable goal guided by the entities compelling vision. In doing this, a probable futuristic position can be envisioned and the means of attaining such milestone dynamically fashioned overtime. These make sustainability a suitable context for backcasting adoption as has been widely used, particularly in Asia and the Netherlands.

4.2 Relational Model of Sustainable Development

The relational sustainable development model is based on balancing of upstream activities (demand based) and the environmental limits of the eco-system for which human species depend for its survival. This delicate relationship between the natural and social system is determined by a number of intrinsic factors (Du Plessis, 2007). The first is 'needs' that have to be met by the society, which is usually dependent on the quality of life available within the immediate domain. This is followed by the preferred mode of technological, political, and economic considerations that guides the upstream activities of the mainstream society. These two factors are significantly linked to the inherent value system of the society. The manner in which constituents of a given society relates with one another vis-à-vis the biophysical environment has a strong correlation with the prevailing value system in the society. The carrying capacity of the environment and the non-renewable nature of the biosphere, in turn, limit the choices available to the society (Figure 1).

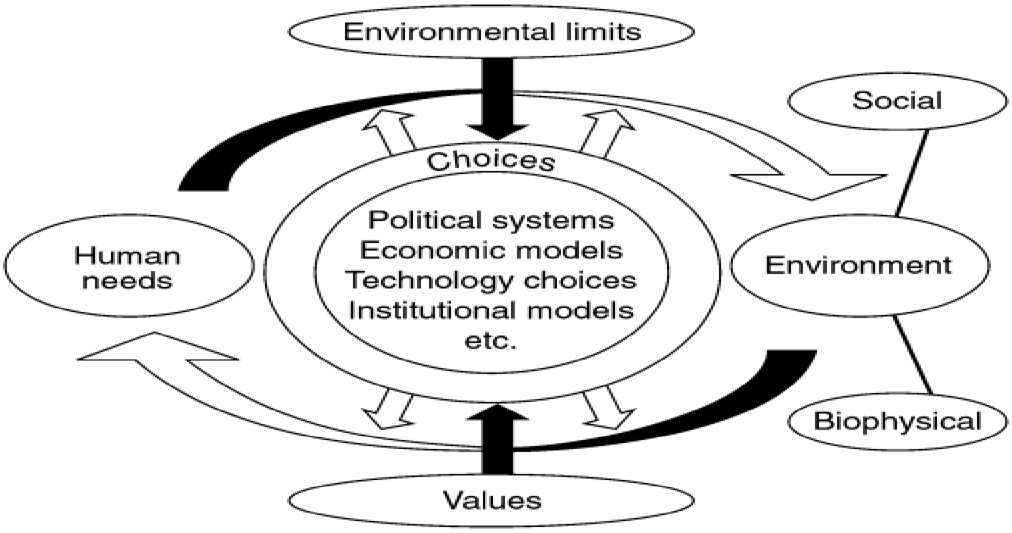

Figure 1: A relational model of sustainable development (Source: Du Plessis, 2007)

4.3 CIMO Model

CIMO model is a systems approach with a focus on the context-intervention-mechanism-outcome (CIMO) logic (Denyer and Tranfield, 2009). CIMO model is built around sustainable management (SM) in order to adopt a holistic perspective to sustainability. CIMO model consists of four basic components of SM, which include context (institutional/social/natural setting), intervention (behavioural/managerial/technical/structural), mechanism (process improvement/innovation (5W + 1H), and Outcomes (social/environmental/economical).

The robustness of CIMO model was established in the work of Esquer-Peralta *et al*. (2008), using 24 experts in the field of sustainability for the purpose of discovering concepts with respect to SM. The model was found desirable for any innovative organization to prosper.

4.4 Transformation Process Model

The transformation process model (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). Sustainability strategies and capabilities are increasingly important and complex for innovative enterprises in competitive environments around the world. For an organization to simultaneously achieve excellence in sustainable development dimensions of economic, environmental, and social performance respectively, it must undergo a transformation process. Such a process would engender a change from the BAU approach to SM. The TPM (Figure 2) is a theoretical framework for sustainability leaders and their value chain partners.

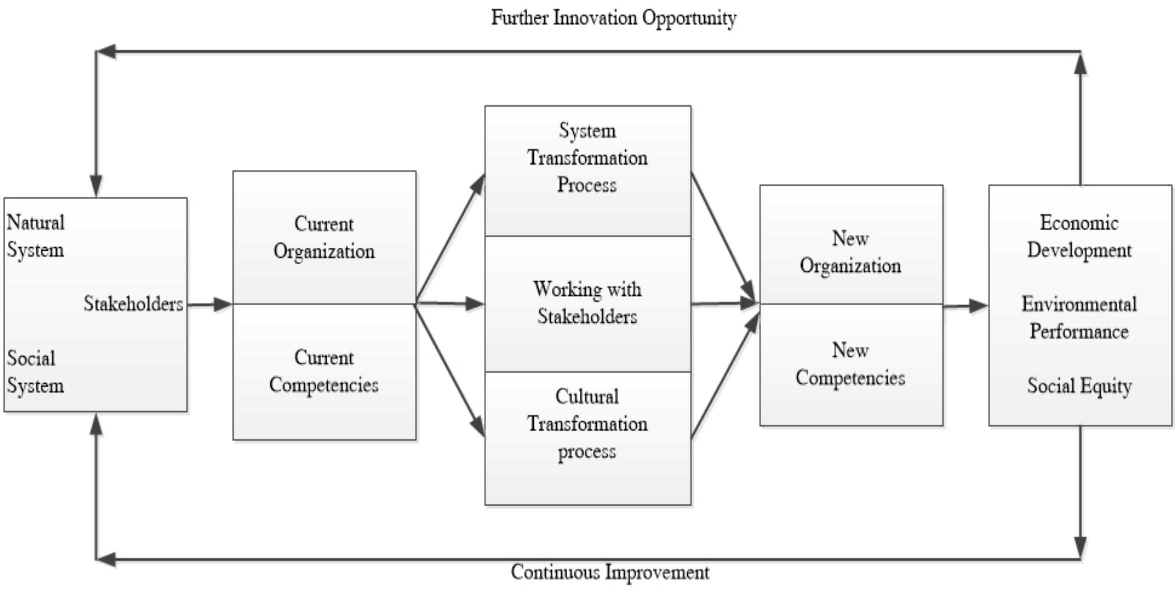

Figure 2: The transformation process model (Source: Madu and Kuei, 2012)

As illustrated in Figure 2, stakeholders interact with both natural and social systems. This interaction speaks to the all-inclusive nature of stakeholders' needs and requires a delicate balancing of sustainability requirements. For example, core competencies for sustainability need to be recognized and evaluated for interventions over time. The target here is to move the current situation into a more effective and efficient one. This transformation stage highlights the three main areas where the process of change will impact upon a system transformation process, working with stakeholders, and a cultural transformation process. These are the critical principles required to transform the current organization at a point of reflection to a competitive state. The community management involving leadership, employee fulfilment, conflict management, and cultural acceptance have economic, environmental, and social impacts (Epstein's, 2009). This implies that organizations must take into consideration these concerns throughout project whole life cycle and commit the necessary resources to ensure the attainment of sustainability. Once this transformation is achieved and a process for sustainability is mature, new competencies are attained leading to the birth of a new organization. However, the transformational process assumes a continuous cycle. 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 relative to risks and costs.

For the purpose of this study, the approach to industry innovation and learning adopted for the delivery of sustainable public infrastructure is proposed to be situated in TPM. The choice of the TPM approach arises because TPM principles resonate with lean-sustainability philosophy and expectations. The TPM provides the rudiments for self-evaluation, cooperation, continuous improvement and opportunities for further innovation in all critical segments of transformation processes of system and culture, and working with stakeholders.

5.0 PROPOSED TRANSFORMATION PROCESS MODEL

Sustainability indicators 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 (Bilec, *et al*., 2010). Lean principles as a waste reduction tools, is effective ways of enhancing the various spheres of KPIs for infrastructure development. It can then be inferred that indicators 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. Value can be the template through which stakeholders navigate between natural and social systems to achieve a broader vision of sustainability. The challenges of global infrastructural issues can be untied, using value as an appropriate construct of change in the context of the construction process improvements (Du Plessis, 2007; Novak, 2012). It is on this premise that the TPM is infused with core principles of lean and sustainability using value as construct for industry transformation (Figure 3).

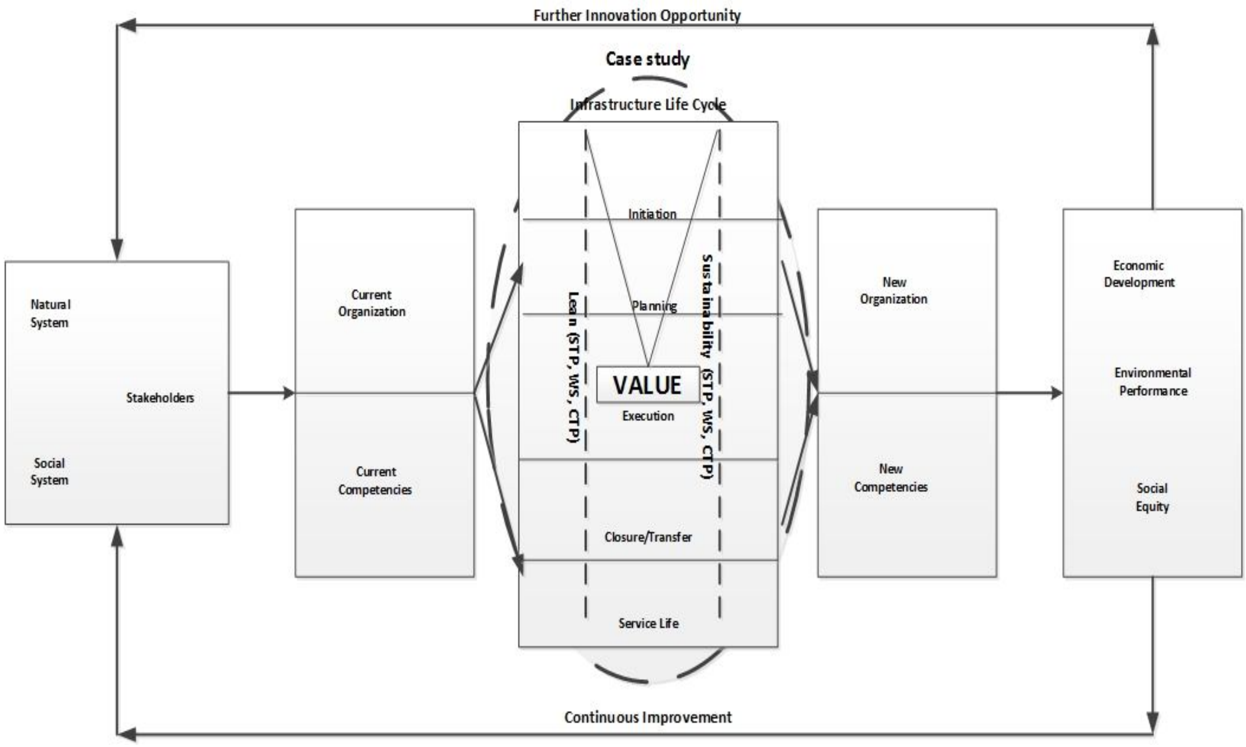

Figure 3: Transformation Model for Infrastructure Development (TMID) (Adapted from: Madu and Kuei, 2012; Novak, 2012).

Establishing value as an appropriate construct for industry transformation in the context of the infrastructural development provides a focal point for the built environment sustainable development. The proposition is that there can be a synergistic link between lean construction and sustainability expressed through the construct of value. Value creation through lean-sustainability paradigm in infrastructure life cycle could lead to new competences and new organizations for continuous improvement and further innovative opportunities. This is then presented for evaluation from expert opinion for preliminary findings.

6.0 INTERVIEW FINDINGS AND DISCUSSION

The transcribed interview data were analysed and inferences were drawn on the proposed transformation model. The outcomes of the semi-structured interviews are presented herewith.

Needs - the interviewees largely cohere in their agreement in recognising the need for a framework for transformative processes in the construction industry, especially in relation to sustainability targets. A framework that is holistic in its approach to transformative and collaborative actions towards meeting stakeholder's demands and future expectations of planetary order. The recent COP21 indicates that stakeholders crave for a framework that will guide the industry to attain the global goals of improved health and well-being, industry productivity, and attaining the target of reducing the global worming by 2^{o}C and building related emissions by 80 gigatonnes by 2050 (Green Building Council South Africa (GBCSA), 2016). These can only be achieved by a holistic model that is all encompassing, well research, and adequate in creatively guiding / measuring of the interrelationship between natural and social sphere, in the construction context.

Requirements – for any model to be effective in meeting the construction industry need, it must be complete in revising the culture adopted by stakeholders in the fragmented industry. The interviewees emphasized that promoting sustainable construction in this culture would entail a significant collaborative effort on several fronts, namely: governmental, professional, academic, and the community. This should happen in the face of varying motives for industry collaboration. The model must also highlight the expected role of each stakeholder in a systematic manner to eliminate bureaucratic experience associated with a fragmented value chain. The interviewees affirmed that the model must have two distinguished characteristics: on one hand, the ability to address some fundamental sustainability barriers such as; culture - the flawed market practices, inadequate construction legislation, absence of the governmental role - lack of supervision and law enforcement, stakeholders' demands, and knowledge gap. On the other hand, promote sustainability enablers such as; education, competitiveness, demands, leadership, and legislation for sustainable development.

Suitability - in meeting the aforementioned requirements, the interviewees affirm the robustness of the transformation process model to address the ills militating against uptakes of sustainability practices in the infrastructure sector. They point at its potential to engender the needed efficiency and effectiveness of the industry and seem feasible for industry transformation. As the model draws from popular sustainable development concepts of looking at the world in a futuristic manner - a going-concern by;

- determining the future target – sustainability development,
- evaluating the present position – resources and stakeholders, and
- process of transforming the industry overtime – synchronising lean-sustainable principles with it inherent principles over the projects life cycle.

It is on these findings as demonstrated by the needs for framework, its requirements and industry suitability that a concluding thought is formed.

7.0 CONCLUSIONS AND FUTURE WORK

The aim of this paper is to present the preliminary findings of a case study used to assess the robustness of proposed Transformation Process Model for infrastructure development. The model is an attempt to respond to a need for a framework that will guide the industry towards sustainability conscious systems to attain the global goals as exemplified by the recent COP21 in France. Various models have been developed and adopted to promote sustainability in the construction industry. Such models include backcasting model, relational model, and CIMO model. Whilst these aforesaid model have advantages, the transformation process model (TPM) appear to be more suitable regarding current competences in relation to social and natural interactions.

The proposed TPM model highlights core areas for industry transformation process; cultural, system and working with stakeholders that serves as a natural appeal for lean-sustainability principles. The core components of the transformation process model are: awareness - baseline analysis of interaction between natural, social and human resources; the compelling vision of future industry – sustainable infrastructure; and in between, is the series of action to reach the vision – composed of internal and external enablers that focuses on three main areas where the process of change will impact upon; a system transformation process, working with stakeholders, and a cultural transformation process (Figure 2). Human agency is at the centre of transformation in this model making it a perspective to be considered. Lean and sustainability concepts was infused through the projects life cycle to derive both tangible and intangible values used as a construct for stakeholders' benefits (Figure 3).

Through the analysis and synthesis of collected data, it was discovered that the model could serve as a purposive vehicle for embedding sustainability in the delivery of public sector projects. The study also notes the need for further research that will develop the segments of the model to a more usable mechanism for the industry and also serve as confirmatory purposes for the proposed model.

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