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UNDERSTANDING COMPLEXITY WITHIN ENERGY INFRASTRUCTURE DELIVERY SYSTEMS IN DEVELOPING COUNTRIES: ADOPTING A VIABLE SYSTEMS APPROACH

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Abstract
Infrastructure delivery systems involve high complexity. This stems from numerous factors: a diverse range of skilled professionals, diverse cultural affiliations, incomplete contracts and complex contractual relationships among stakeholders, government policies, finance and regulatory issues, and high levels of asset specificity. The degree of complexity is enhanced in projects requiring high levels of specialization. Energy infrastructure projects can be described as possessing a relatively high degree of complexity. The ability to understand and manage such complexity directly affects project performance. Previous studies into the failure of most of these projects have traced project failures to several factors such as corruption, lack of transparency in the procurement process, lack of proper regulatory frameworks, and lack of political willpower. Surprisingly, few studies have attempted to spearhead a concise understanding of the inherent complexities in delivery systems. This paper attempts to contribute to the literature on project delivery process and its inherent complexities. This study proposes a viable systems model approach to understanding complexities in energy infrastructure delivery systems in developing countries. This is based upon the premise that a system must be understood properly to enable effective diagnosis. It argues that whereas the aforementioned factors adversely affect the performance of the infrastructure projects, a better understanding of the delivery process would allow for timely and appropriate solutions to be proffered. The viable systems model is premised on the concept of systems thinking and cybernetics-science of communication and control. It has proven effective in diagnosing organizations. It is hoped that this study, which forms part of an on-going PhD study, would elicit further discourse in the application of the viable systems model in diagnosing and re-designing infrastructure delivery systems within the energy sector of developing economies.

Keywords: Infrastructure Delivery Systems, Project Complexity, Viable Systems Model, Developing Countries

INTRODUCTION

The process of delivering infrastructure projects involves a high degree of complexity. Various factors such as the presence of diverse professionals and trades, the application of state of the art technology, multicultural nature of the project environment, incomplete contracts and several contractual relationships are prevalent within infrastructure project environments (Van Marrewijk et al., 2008). These factors contribute to the high degrees of complexity experienced in such projects. This degree of complexity is further enhanced in projects requiring high levels of specialization such as energy infrastructure (Baccarini, 1996, Gidado, 1996, Wood and Ashton, 2010 Vidal et al., 2007). Usually labelled megaprojects, Van Marrewijk et al. (2008) defines them as multibillion dollar mega infrastructure projects, commissioned by governments and delivered by private enterprise; and characterised as uncertain, complex, politically-sensitive and involving a large number of stakeholders. Flyvbjerg et al. (2003) have attributed the causes of megaproject failure to the following causes: lack of realism in initial cost estimates, motivated by vested interests; underestimation of length and cost of delays; very low contingencies; not enough consideration being given to changes in project specifications and design; fluctuations in exchange rates between currencies and price changes are grossly undervalued; environmental demands, expropriation costs and safety are grossly undermined. Megaprojects are also characterised by conflict, uncertainty and poor cooperation between partners (Van Marrewijk et al., 2008). They posit that project design and project cultures play a dominant role in determining how managers and partners cooperate to a greater or lesser extent.

Other studies looking specifically into the causes of project failure in developing economies particularly in Africa, have identified the following causes as leading to the failure of projects of similar magnitude: corruption, lack of transparency in the procurement process, lack of proper regulatory frameworks, lack of trust between project stakeholders and poor communication channels within the delivery systems ((Okonjo-Iweala and Osafo-Kwaako, 2007, Diallo and Thuillier, 2005). Arguably, these aforementioned factors result from ineffective management of complexity by project managers. This has led to the huge energy infrastructure deficit in developing countries hence reducing productivity levels directly and economic growth within those countries indirectly.

Wood and Ashton (2010) and Van Marrewijk et al. (2008) maintain that the level of complexity and the ability to manage such complexity significantly affects project performance.

Developing countries have witnessed slow economic growth despite being blessed with vast amounts of natural resources (Dessy, 2007). Inadequate energy infrastructure has contributed immensely to this slow growth. Many African nations, particularly Nigeria, have adopted intensive measures to develop their energy infrastructure to spearhead a return to productivity and economic growth. The adoption of Public-Private Partnerships is one of the major avenues being exploited by the Nigerian government to develop its energy infrastructure. This paper posits that unless a viable model, capable of ensuring an enhanced understanding and subsequent management of complexities, is developed for the delivery of energy infrastructure in developing countries, the current failed and abandoned project phenomena beleaguering such countries would continue to persist. Surprisingly, despite evidence that poor or inadequate management of project complexities affects project performance (Wood and Ashton, 2010), literature barely exists within the field of construction management on the management of project complexity in infrastructure projects in developing economies. Baccarini (1996) laments the absence of abundant literature treating project complexity from the project management perspective. Wood and Ashton (2010) whilst agreeing with Baccarini, attempt to assist with a front end based identification of factors of complexity in projects with the aim of developing a medium through which the attendant complexities can be managed for better project outcomes. Having discovered this gap in literature, this study, which forms part of a PhD research, seeks to make a case for the adoption of the viable systems approach as a guide to understanding the inherent complexities in the delivery of energy infrastructure in developing countries. It is hoped that given a proper understanding of these project complexities, project managers and project stakeholders would be able to successfully manage them and attain the desired project outcomes.

To achieve its objective, this paper reviews literature on the concept of complexity, highlighting the types of complexities encountered in projects and the factors responsible for such complexities.

It appraises the current state of energy infrastructure in Nigeria, highlighting as it were, the negative impact of energy infrastructure stock deficit on economic growth and measures being taken by government to remedy the situation. Next, infrastructure delivery systems are understudied from a complex systems perspective. A discourse on the concept of viable systems approach ensues. A case is then subsequently made for the application of the Viable Systems Model in understanding complexity within infrastructure delivery systems. This paper, part of an on-going study focusing on the attainment of a viable means of delivering infrastructure to the oil and gas industry, after a synthesis of literature concludes with the notion that the VSM remains a more robust approach to understanding complexity within the delivery process and subsequent design of such processes for project success.

WHAT IS COMPLEXITY?

The concept of complexity is one which has continually defied any universal definition ((Wood and Ashton, 2010, Mitchell, 2009). They agree that word complexity connotes different things to different people. Mitchell (2009) posits that in the absence of any definite science of complexity, various sciences of complexity could be said to exist. She notes that this has made the development of a universally accepted definition of the term 'complexity' impossible. Relying on the work of Seth Lloyd on how to measure complexity, published in 2001, Mitchell (2009) maintains that complexity can be defined on the basis of three distinct criteria namely: size, entropy, algorithmic information context, logical depth, thermodynamic depth, statistics, fractal dimensions and the degree of hierarchy. Within the realm of infrastructure delivery, defining complexity according the degree of hierarchies, size, and information processing capacity might be seen as apposite. Mason (2007:10) defines complexity as the measure of heterogeneity or diversity in internal and environmental factors such as departments, customers, suppliers, socio-politics and technology. Baccarini (1996:201-202) highlights two different dictionary definitions of the term 'complexity' which can be likened to projects.

He maintains that complexity could be used to describe endeavours which are (a) consisting of many varied interrelated parts, and (b) complicated, involved, intricate.

These definitions proffered in the dictionary and cited by Baccarini (1996) seems an apt way of describing the endeavour of delivering energy infrastructure. An energy infrastructure delivery system could be described as having several varied interrelated parts consisting of several tasks, professionals and non-linear sequences which must all be co-ordinated effectively to attain a specified goal. The prevalence of varied stakeholder interests, application of cutting edge technology, and huge expenditure incurred by the project sponsors makes the process a complicated, involved and one fraught with intricacies. Hence, Baccarini (1996:202) defines project complexity as "consisting of many varied interrelated parts". Furthermore, he stated that it can be operationalised in terms of differentiation and interdependency. Caution should be exercised in comparing project complexity to project size and the levels of uncertainty as the concept of project complexity is entirely different.

Types of complexity encountered in infrastructure projects

Gidado (1996) identifies two perspectives of project complexity within the construction industry; the managerial and the operative/technological perspectives. Similarly Baccarini (1996) highlights the existence of two perspectives to complexity within the project environment: organisational and technological complexity perspectives. Whereas Baccarini advises researchers and project mangers alike to be explicit on the perspective of complexity they are interested in, it is appreciable to note that both perspectives are applicable to energy infrastructure projects. Whereas organisational complexity bothers on the existence of varied differentiated parts of the infrastructure delivery system, by differentiation, technological complexity is concerned with the variety of some aspects of a given task and by interdependency, comprising of all the interdependencies between tasks, within a network of tasks, across teams and multi-stakeholders (Baccarini, 1996).

Factors Causing Complexity in Infrastructure Projects

Wood and Ashton (2010) identified a total of forty-six factors leading to increased complexity in projects. They grouped these factors under five themes namely: Organisational factors (people involved/relationships); Operational and technological factors; Planning and management factors; Environmental factors; and uncertainty factors respectively. For a full rendition of the forty-six causal factors, see Wood and Ashton (2010).

These factors are responsible for the increasing degrees of complexity within project environments especially megaprojects and if not properly managed, capable of undermining their performance.

Baccarini (1996:201) emphasizes the significance of understanding project complexity by project managers, stating that project complexity was capable of: determining planning, co-ordination and control requirements; hindering clear identification of project goals; playing a central role in choosing an appropriate project organisational form from a league of alternatives; influencing the selection of project inputs such as the expertise and experience requirements of specialist tradesmen and professionals; being applied as a principal criteria in selecting a suitable project procurement arrangement for a particular project; affecting the project objectives of time, cost and quality especially given that the higher the project complexity the greater the time and cost. Thus the significance of project complexity to project success or otherwise cannot be underestimated, hence the compelling need to allow for a thorough understanding of the inherent complexities in an infrastructure delivery system. Although project complexity is only but one dimension of attaining project success (Baccarini, 1996), it still poses a huge threat to the successful delivery of energy infrastructure in developing countries especially Nigeria. The absence of a universally acceptable way of enabling an understanding of complexity such as is experienced within infrastructure projects becomes a major hindrance to effective and efficient planning and subsequent management of such projects.

This study becomes imperative as it seeks to propose an approach to understanding complexity in infrastructure projects within the energy sector thus leading to project tailored project management strategies for these projects, especially within the comity of developing countries. This is due to the fact that the authors have argued severally elsewhere, (Awuzie and McDermott, 2012), that the main reason for poor delivery of viable infrastructure in developing countries stems from the organisational arrangements and the poor management of the interrelationships between the various parties to a delivery process.

They argue that most of the organisational strategies and the management modes adopted for such activity do not take cognisance of critical issues like culture, normative values and effects of social capital on the project environment. This view is supported by Van Marrewijk et al. (2008) given their perception of construction project environments as being socially constructed wherein social actors (project participants) develop a more or less stable working environment for themselves with consequently greater or lesser cooperation between themselves. Hence, they lament that whereas these contractual provisions seek to address all the existing interests which are at stake in complex megaprojects such as energy infrastructure, they do not fully capture the complexity of the multiple, fragmented subcultures at work in a project culture.

Bertelsen (2003) argues that the incomplete understanding of the construction process by its various stakeholders has been the cause of the declining performance of delivered products despite improvements on the engineering perspectives. Having studied several megaprojects, Van Marrewijk et al. (2008) discover that the managerial rationalities within the projects are limited in understanding their own complex project realities which are themselves bound by limits imposed by overall governance structures and strategies.

STATE OF ENERGY INFRASTRUCTURE IN DEVELOPING COUNTRIES-THE NIGERIAN CASE

The significance of energy in our contemporary society can never be overemphasized. According to UNIDO (2010), the world's prosperity rests on its ability to maintain a guaranteed supply of energy for production and industrialization purposes. Given that energy remains a very crucial input in production processes, most developing countries have been unable to harness energy from diverse sources due to the lack of energy infrastructure. This deficit in infrastructure has rather led to a decline in productivity levels in these countries, thus reducing their competitiveness.

Several studies have highlighted the relationship between energy infrastructure stock availability and investments and the economic growth in countries, see (Agénor and Moreno-Dodson, 2006, Foster, 2008, Agenor, 2009). For instance, the Spanish power generation capacity equals the entire power generation capacity of the entire sub-Saharan Africa- a region comprising of a total of forty-nine (49) nations (UNIDO, 2010), despite the fact that this region plays host to large mineral reserves necessary for energy generation. Nigeria belongs to this sub-Saharan Africa community. The country still imports most of all its petroleum products and is grappling with incessant power shortages, thus frustrating industrialization and undermining productivity levels. In a recent study carried out by Foster and Pushak as part of a world bank sponsored initiative, they successfully catalogued the current state of Nigerian infrastructure ranging from telecommunications to power and energy, from transportation through to water projects (Foster and Pushak, 2011). A proper picture of the state of Nigeria's infrastructure stock can be obtained in Foster and Pushak (2011). The energy infrastructure is presently being procured by the Federal government through its MDAs and their private sector partners. In the last decade, the Nigerian government initiated several energy infrastructure projects including the construction of oil and gas pipelines. In order not to allow these projects to fail like their predecessors, it becomes pertinent to develop ways of tackling the complexities which have haunted the success of previous projects. This is the aim of this paper.

INFRASTRUCTURE DELIVERY SYSTEMS AS COMPLEX SYSTEMS

Infrastructure delivery systems can be described as complex systems. Previous studies have shown that the failure of most infrastructure projects has resulted from the inability of the project management personnel to understand the process of delivering infrastructure projects as a complex venture (Bertelsen, 2003). He states that the failure of project management has resulted from its tendency to treat projects as ordered and linear activities as against what it actually is, a complex and dynamic, non-linear phenomena. As a system's complexity increases, the ability to understand and process information for planning and predictions become more difficult, hence problematic in adapting to its external environment (Mason, 2007, Rhee, 2000). This scenario is not new to the energy infrastructure delivery process.

Systems theory tells us that complex systems are deterministic in nature and evolve through a phase of instability, which eventually reaches another threshold where a new relationship is established between its internal and external environments and itself. This external environment comprises of elements such as: competition; the economy; socio-cultural-demographic factors; political-legal-government aspects; technology; and the natural environment (Beeson & Davis 2000:183). An organisation such as an infrastructure delivery system as a complex system, ultimately learns from its environment and changes its internal structures and procedures accordingly thus changing the behaviour of the individual elements (Sherif 2006:77; Paraskevas 2006:901). Mason (2007:13) admits that an understanding of the dynamics and behaviour of an organisation can only be effectively done by managers who understand these complex interactions. The infrastructure delivery system is no different as only an understanding of the inherent complex interactions can guarantee better delivery and subsequently successful performance.

Bertelsen (2003) agrees that the construction process is a complex system. He states that construction projects are managed by engineers and advised by economists, professionals who derive their knowledge from the understanding of our world and its living systems, which is fundamentally aged more than 300 years old. He states that a new understanding of life, living systems, and by that the understanding of social systems such as organisations, societies, and, indeed even Mother Nature and the Universe in general has gained more and more foothold in science. He maintains that the complex systems theory had come to stay insisting that the Newtonian systems theory applicable to the construction process (linearity) exists only in theory and thus is not capable of bringing about change due to the sort of mess which the real world connotes. We agree with Bertelsen's views on contemporary project management practice as it concerns linearity of work process and organisation.

VIABLE SYSTEMS MODEL

The evolution of the Viable Systems Model (VSM) can be traced to systems theory and cybernetics. Espejo (1994) insists that system thinking entails a comprehension of how parts interact with each other to form a whole through a self-organizing process.

Polese et al. (2009) restate that the concept of system thinking refocuses attention from the part to the whole, suggesting that the individual qualities of the parts become vague whereas their relationship with other parts becomes important. This theory is based on the postulation that every system is made up of subsystems and that the conglomeration of these systems leads to a whole (Checkland, 1981). The inherent individual characteristics of these subsystems diffuse into the system leading to a generic characteristic of the whole and not a summation of the characteristics of the individual subsystems making up the parent system (Checkland, 1981).

The VSM was derived from this concept of wholes, drawn from the biological sciences, the human nervous system particularly by Stafford Beer in 1971(Leonard, 2000). Espejo and Bendek (2011) assert that the VSM enables observers to see beyond formal institutions, the existence of the social organizations where they can interact and participate in the decision making process. They highlight the powerful nature of the law of variety postulated by Ashby, which is a relational platform catering for how we relate with our situations in changing times and upon which Beer's VSM is premised. The VSM is dependent upon the concepts of complexity and recursivity (Espejo and Gill, 1997). Given the nature of complexity, the mere fact that cybernetic principles are focused on the management of complexities in organizations makes the VSM an attractive tool for anyone trying to manage complexities within an organization. The principle of recursivity acknowledges the existence of subsystems within every whole and is premised on the fact that each subsystem does possess self-regulatory and self-organizing traits and that this process continues until the last single cell available thus making them effective absorbers of the inherent complexities which might arise out of the systems interaction with its external environment (Espejo and Gill, 1997). Leonard (2000:711) posits that the recursive characteristic of the VSM ensures that "each independent viable system is embedded in other more comprehensive systems". She opines that this recursive nature of the VSM enables policies, goals, and modes to be investigated and evaluated for improvement purposes. It is not a new idea having been employed as a conceptual tool for appraising organizations, redesigning them and rendering the much needed support for change management within organizations (Brocklesby and Cummings, 1996, Espejo and Gill, 1997).

The VSM is not a widely applied phenomenon within the realm of management due to the perceived difficulty in coming to terms with its operability and the fact that they run contrary to the grounded norms of organizational thinking (Espejo and Gill, 1997). Brocklesby and Cummings (1996) argue that the VSM remains a tool for the anticipation, planning, and implementing of large scale organizational change. To be viable, organizations must possess the ability to improve upon their existing processes and procedures to satisfy the stakeholders/customers/clients, and also adapt to the ever dynamic operating environment and this is what the VSM tries to achieve.

Under a VSM approach, the control points are spread throughout the whole system thus allowing for the effective manifestation of the self-organizing capabilities of the subsystems and their efficient utilization within the system of the whole. It is widely believed that this decentralization of control engenders efficiency (Jackson, 1988).

The VSM is structured in such a manner that it has five subsystems, all of which are self-regulatory and self-organizing in line with recursivity. These five subsystems have been identified as comprising of the following, namely; (a) Policy-This is the last function of a VSM. It is responsible for the policy making duties of the organization. Its major functions include the provision of overall clarity and purpose for the organizational unit and to prepare a concrete and tenable design for organizational efficiency. (b) Intelligence- This functions as a connection between the VSM and the external environment. Whilst it is responsible for the projection of the organization's image and message to the external environment, it is also responsible for the obtaining information from the external environment. It is future focussed but maintains a communication loop with the control subsystem to complement the control function on areas such as maintaining the definition, adjustments and implementation of the unit's identity. (c) Control and Monitoring*- This subsystem serves as a channel through which resources are negotiated and the issuance of direct line management takes place. The monitoring function is also domiciled within this subsystem serving as a corroboration agent to the control function so as to ensure accountability. (d) Co-ordination- These are the systems put in place within a VSM to co-ordinate the interactions between the support functions and between the autonomous units.

(e)Implementation- This system is responsible directly for the production or provision of services to the customer/clients (Devine, 2005, Brocklesby and Cummings, 1996, Espejo and Gill, 1997, Jackson, 1988).

DISCUSSION

Understanding Organisational Complexity – the Viable Systems Model

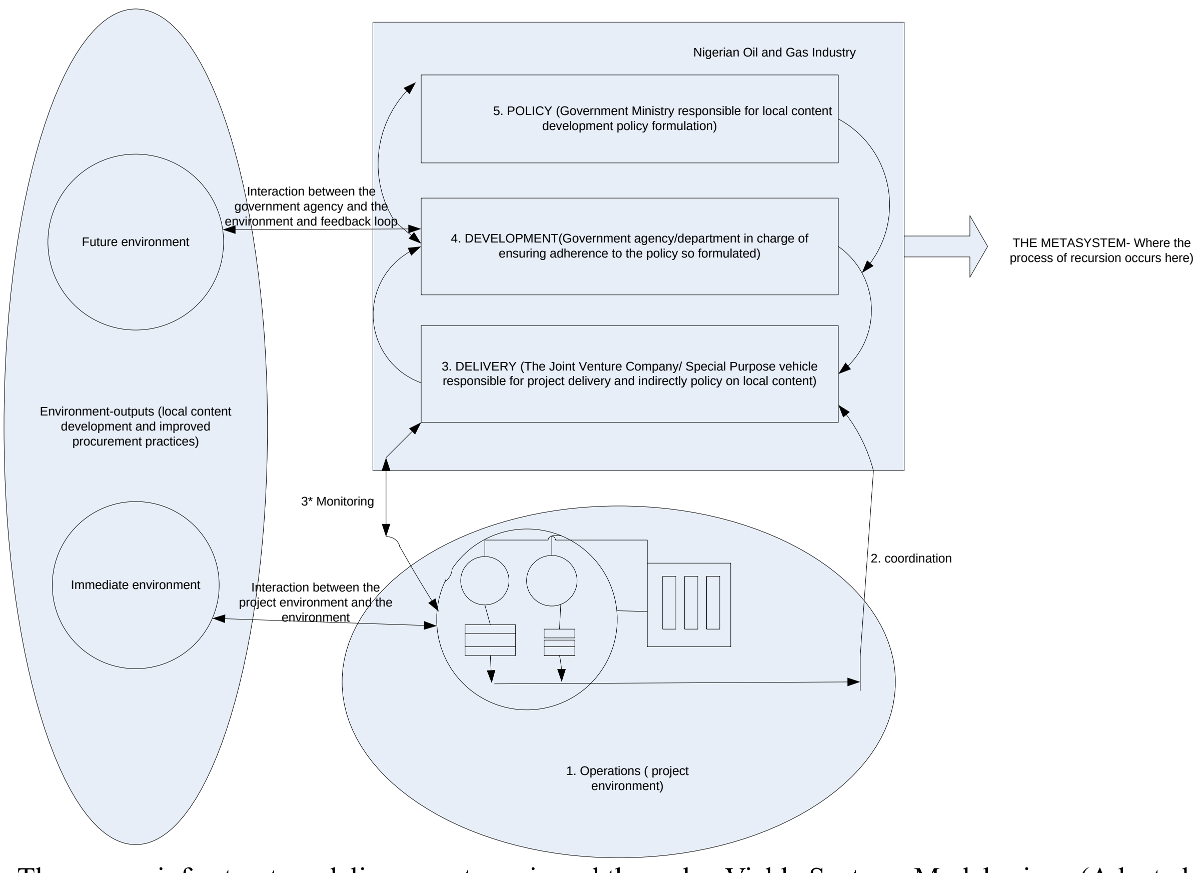
We make a case for the adoption of the VSM in enhancing an understanding of complexity in infrastructure projects. Schwaninger (2006) asserts that the VSM provides a formal apparatus for dealing with complex systems of all kinds and is therefore being adopted increasingly in many fields of inquiry. It has also grown to become recognised as a new language that allows synergetic interaction between different disciplines, thus increasing the possibility of innovative, trans-disciplinary solutions to complex issues. He describes organisational cybernetics as the application of the science of control and communication in complex systems and maintains that it furnishes the structure –theoretic underpinning for humanistic postulates such as autonomy, meaningful work, and human self-realization (Schwaninger 2001: 208). He states that from a cybernetic stance, organisational intelligence should enable an organisation to: adapt to changing situations; influence and shape its environmental milieu; if necessary, find a new playing field or to reconfigure itself anew with its environment; to make contributions to the larger wholes into which it is embedded (209).

That the infrastructure delivery process consists of immense organisational complexity is not new knowledge. The poor management of organisational complexity on the performance of the project is widespread knowledge and has been deduced as being the reason for the failure and incessant abandonment of several energy infrastructures in developing countries. The main issue with the management of complexity remains the development of a methodology that would enable effective understanding of the type and degree of organisational complexity affecting the projects. Organisational complexity can only be managed for optimal benefits only if they are better understood at the early stages of the project (Wood & Ashton, 2010).

The VSM offers a platform for enabling this understanding. It has been proven as giving social systems the capability to deal with dynamic complexity along with all the related organisational and even ethical challenges (Schwaninger, 2001). He posits that the propositions behind the VSM can be summarized as follows: an enterprise is viable if and only if it disposes of a set of management functions with a specific set of interrelationships, identified and formalized in the model. Although several approaches have been applied in the management of complexity in project organisations, they have failed to yield any result as they have only led to optimization in one single dimension leaving the complex organisational issue unsolved (Schwaninger, 2001, Bertelsen, 2003). In lending his support to the VSM, Schwaninger(2001:212) maintains that "the result of an organisational process cannot be better than the model on which the management of that process is based, except by chance". He adds that systems and complexity models can offer more promising avenues from which organisational leaders can appreciate and address complex organisational dilemmas. The VSM models the organisation as a set of interrelationships and allows for the application of several modes of management and governance approaches. It recognises the delivery process as a social system, constructed by the participants (Van Marrewijk et al., 2008). It brings the issues relating to organisational complexity to the fore thus allowing the project manager and other stakeholders to know what they are required to do to reduce the uncertainty associated with increasing complexity.

In using the viable systems approach to understand energy infrastructure delivery, the energy infrastructure delivery process is likened to an organization. Within the model, the government ministry-in charge of policy formulation- being situated at the strategic level, alongside the agency or department responsible for the implementation of policy. This agency oversees the formation of SPV/JV for the purpose of executing the proposed infrastructure development. It plays an administrative role, ensuring that the SPV/JV abides by the tenets required to attain the policy goals behind such an investment. The ministry, its agency and the SPV are situated within the meta-system section of the Viable Systems Model (VSM) responsible for coordinating, auditing, supervision, and monitoring functions. Beneath this aspect of the VSM is the implementation section which consists of the project environment proper where the actual delivery activity occurs.

This would enable an understanding of what it entails to plan and manage an energy infrastructure project. The impact of the project on its host environment can also be evaluated with ease and improved upon. The VSM also enables organisational change within the delivery chain allowing for effective and efficient coordination, monitoring and control. Given its project organisation specific nature, the VSM allows for project peculiarities to be taken into consideration thus allowing for the application of relative strategies for optimisation of the work processes and the interrelationships between the several participants within the project environment.



The energy infrastructure delivery system viewed through a Viable Systems Model prism (Adapted from Beer's Viable System Model)

This part, theoretically, impacts directly upon the external environment, delivering policy objectives behind the investment to that environment.

CONCLUSION AND FUTURE RESEARCH

This article set out to make a case for the adoption of the viable systems approach for studying organisational complexity within energy infrastructure delivery systems in developing countries. It discussed the concept of complexity, especially as it concerned projects and its impact on project performance. A typology of project complexity was also highlighted. An identification of factors responsible for the increasing complexity within projects was also mentioned. An extensive review of literature on the viable systems approach ensued after a narration of the state of energy infrastructure in developing countries. Nigeria was adopted as a typical case of a developing country and its huge energy infrastructure deficit was highlighted through a synthesis of literature. The essence of effective front-end complexity understanding and management was buttressed and the need for a methodology for understanding this phenomenon was stated.

Summarily, after having carried out an extensive synthesis of literature on the core issues of this paper, we conclude by making a case for the adoption of the viable systems approach as an effective mode for understanding the inherent complexities in the delivery of energy infrastructure in developing countries. This study is part of an on-going PhD which proposes to utilize the VSM to diagnose the current infrastructure delivery system case studies in a developing country-Nigeria, and to redesign the delivery system for optimal viability.

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