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Factors contributing to non-value adding activities in South African construction

Fidelis Emuze
Department of Built Environment, Faculty of Engineering and Information Technology, Central University of Technology, Bloemfontein, South Africa
John Smallwood
Department of Construction Management, Nelson Mandela Metropolitan University, Port Elizabeth, South Africa, and
Sangwon Han
Department of Architectural Engineering, University of Seoul, Seoul, Korea

Abstract
Purpose – Non-value adding activities (NVAAs) are considered to be problematic in the management of projects. Reported research findings suggest that these NVAAs consume resources without necessarily adding value to completed tasks. The main aim of the research is to provide insights and plausible explanations concerning how NVAAs can propagate poor performance in South Africa.

Design/methodology/approach – The paper reports on a quantitative survey conducted among public sector clients, consulting engineers, and civil engineering contractors in South Africa. Using a framework that was developed from the literature reviewed, the study proposed three conceptual qualitative models that were based on system dynamics.

Findings – The study suggests that NVAAs that are prevalent in South African construction can impact project performance negatively in the form of cost and time overruns. It can also be argued that although there is commonality between NVAAs that are identified in South Africa and other countries, their frequency and effects on project performance differ.

Research limitations/implications – The findings provide further insights about NVAAs that are related to the South African infrastructure sector only.

Originality/value – The study, which is the first of such in South Africa, could lead to increased awareness among South African project stakeholders that are concerned about performance improvement from the lean construction perspective.

Keywords Performance, South Africa, System dynamics, Construction, Non-value adding activities

Paper type Case study

1. The background of the study

A comparative study that focused on two apartment complexes in South Africa shows that on the average, variation orders accounted for 8 and 4 per cent of the total contract sum of the two apartments, respectively, (Ndihokubwayo and Haupt, 2008). The findings noted that variation orders on both projects occurred mainly due to design related problems. These problems in turn contribute to non-value adding activities (NVAAs), and the attendant cost and time overruns that marginalised the performance of both projects. The sub-optimal performance recorded on these projects is not an isolated case. According to the Construction Industry Development Board (CIDB), the need to improve project

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performance in South Africa exists. A recent Construction Industry Indicators (CII) report indicates that clients were neutral or dissatisfied with the performance of contractors on 15 per cent of the projects surveyed in 2010 as health and safety (H&S), quality and other performance issues remain a concern in South Africa (CIDB, 2011).

Problematic construction projects are not peculiar to South African construction alone. For instance, examples of problematic construction projects in the USA include the Boston Big Dig project and the Kennedy Centre Parking Lot project that witnessed 460 and 210 per cent cost growth, respectively, at project completion (Forbes and Ahmed, 2011). It is the attempt to address similar issues that led to the introduction of performance improvement philosophies such as lean construction into the industry. According to Forbes and Ahmed (2011), lean design and construction involve the application of lean methods and/or techniques to the design and construction process so as to derive benefits that have been clearly established in manufacturing operations. Such benefits include lower costs, fewer delays, less uncertainty, less waste (NVAAs), more efficient buildings/facilities, and higher user satisfaction.

As an illustration, Forbes and Ahmed (2011) described a systems perspective of lean. Their description of the impact of value-added against non-value added time in a typical construction process revealed that move time, wait time, and setup time constitute non-value added time, while process time constitute value-added time. Their explanations show that "process time" represents the value-added phase in a construction process since it is the only time that a product is actually undergoing transformation. According to Koskela (1992), NVAAs can be defined as activities that take time, resources or space but do not add value. This definition, which is adopted in this study, indicates that NVAAs are wasted efforts that consume time and/or resources without directly or indirectly adding value to project requirements. Meanwhile, VAAs are operational efforts that realise project requirements that are defined in the contract and value supporting activities (VSAs) are supportive efforts that do not directly add value, though, they indirectly support other VAAs (Han, 2008).

In effect, the elimination or reduction of NVAAs is a key lean construction principle as they can occur in the handoff from one task to another or from one trade to another in the form of delays and defects that must be corrected (Forbes and Ahmed, 2011). Such NVAAs include work not done, rework, unnecessary work, errors, stoppages, waste of materials, deterioration of materials, loss of labour, excessive supervision, additional space, abnormal wear and tear of equipment, delays to schedule, lack of supervision, and loss of material on site (Alancon, 1997; Alwi *et al.*, 2002b). These NVAAs and certain VSAs (such as housing keep tasks that must be carried out on site after a heavy rainfall), may in turn be caused by defects, overproduction, unnecessary processing, unnecessary material movement, unnecessary people movement, waiting periods, inventories, design changes, lack of trade's skill, slow decision-making, poor coordination between project partners, poor planning and scheduling, delay in material delivery, poor construction methods, poor quality of site documentation, slow drawing revisions, unclear site design information, and inclement weather conditions (Koskela, 1992; Alwi *et al.*, 2002a). These causes can be categorised with respect to design and documentation, procurement, material handling, professional management, and physical factors (Alwi *et al.*, 2002a; Polat and Ballard, 2004). Hence, the argument proposed as the research problem statement contends that the prevalence of NVAAs may be contributing to reported poor performance in South African construction. The argument is supported by the fact that NVAAs are reportedly detrimental to project performance in the form of cost overruns, rework and poor productivity (Ndihokubwayo and Haupt, 2008; Alwi *et al.*, 2002a, b; Hwang *et al.*, 2009; Horman and Kenley, 2005; Abdel-Razek *et al.*, 2007; Han, 2008). It is notable that if these NVAAs are left unrestrained they can negate the intentions of organisations in the industry in terms of competitiveness (Alwi *et al.*, 2002a; Koskenvesa *et al.*, 2010).

The primary objective of the research is therefore underpinned by the need to investigate the dynamics that have seemingly engendered poor project performance due to the menace of NVAAs in construction (Han, 2008). The objective is predicated on the assumption that the traditional project parameters of cost, H&S, quality, and time have continued to perform poorly in South Africa (Manthe, 2008).

2. The research method

The theme for the proposed models is anchored on the importance of providing compelling explanations for how performance differences arise, persist, and disappear over time in South African construction. Due to the desire to identify NVAAs that are significant in the South African construction context, the causes of these NVAAs and their effects, a mixed-mode quantitative survey was conducted among key project stakeholders in the South African infrastructure sector. Specifically, a total number of 122 clients, 117 consulting engineers, and 108 civil engineering contractors were surveyed with a structured questionnaire that was initially sent by post and then sent by e-mail as reminders. Although a pilot survey was conducted four months before the start of the actual field work, valid responses that were received were limited to 88 at the end of the survey period. This equates to a 25.4 per cent response rate.

The clarity, understanding and interpretation of the questions were enhanced based on the feedback provided by the respondents to the pilot survey. Empirical publications such as Koskela (1992), Alancon (1997), Alwi *et al.* (2002b), Arbulu *et al.* (2003) and Polat and Ballard (2004) provided the basis for the questionnaire that was compiled for the survey. A total number of 40 NVAAs, 40 causes of NVAAs and 14 consequences of NVAAs were identified and used for the empirical study. Given that a number of these publications relied on data generated through quantitative surveys, the postal and e-mail survey method was used for collecting the primary data for the study. The method was deemed useful as one of the key heuristic principles of lean construction suggests that NVAAs can be reduced through identification, measurement, and redesign (Forbes and Ahmed, 2011). In particular, the 40 variables relative to NVAAs that contribute to poor project performance were separated into five classifications with eight variables assigned to each category. The classifications include NVAAs that occur due to rework, waiting periods, material, movement, and human resources. Similarly, the 40 variables relative to causes of NVAAs were separated into five classifications with eight variables assigned to each category. The classifications include the causes of NVAAs related to human resources, designers, information and documentation, material/equipment, and site operations. The survey questionnaire was designed by asking respondents to identify NVAAs that contribute to poor project performance, construction related activities that lead to NVAAs (causes of NVAAs), and the issues that occurs as a result of NVAAs (consequences of NVAAs) in construction.

At the end of the data collection and analysis phase of the study, system dynamics (SD) concepts were used for model development based on the debate that SD models provide excellent platforms for eliciting information required for identifying important managerial problems and their solutions (Gary *et al.*, 2008). Sterman (2000) suggests that SD, which is partly a method for developing management flight simulators in the form of simulation models, is a method for enhancing learning in complex systems. Sterman (2000) emphasized that SD models are developed to enhance learning about complex systems, understand the sources of policy resistance, and also to facilitate the design of more effective policies. In specific terms, Forrester (2007) is of the opinion that SD modelling can organise the descriptive information, retain the richness of the real processes, build on the experiential knowledge of managers, and also reveal the variety of dynamic behaviours that flow from different choices of policies. Therefore, the models proposed in this paper, which were developed with "Vensim® software", relied on data generated through empirical investigations, and the researchers' mental models based on construction site management experiences gained in developing countries such as Nigeria and South Africa. It can be argued therefore that the two basic sources of information used for the models are well known within the SD research community as SD researchers have always drawn on numerical, written, and mental databases to identify system structures that are responsible for a dynamic behaviour of interest (Gary *et al.*, 2008).

3. Results and discussion

In view of the fact that this paper forms an aspect of a larger research project, the use of hierarchy noted with ordinal data is considered appropriate for presenting the results. The measurement scales indicated in Table I are thus central to the discussion of the findings. In order to present the validity and reliability of the data, the Cronbach's α and Spearman's correlations were computed. The Spearman's correlations related to clients and consultants, clients and contractors, and consultants and contractors were computed and presented alongside the findings of the survey. Cronbach's α presented alongside the Spearman's correlations show that the individual mean scores (MS) recorded in a question can be reliably combined into a single mean, that is, it is used for combing items in Likert-type scale question that used each individual item to measure a phenomenon that has an underlying quantitative measurement continuum (Gliem and Gliem, 2003). Though, there is actually no lower limit to the coefficient, Cronbach's α reliability coefficient normally range between 0.0 and 1.0. In brief, George and Mallery (2003) provide the following rules of thumb: $>0.9 =$ excellent; $>0.8 =$ good; $>0.7 =$ acceptable; $>0.6 =$ questionable; $>0.5 =$ poor, and $<0.5 =$ unacceptable, for interpreting Cronbach's α coefficient.

In terms of the Spearman's coefficient, the value ranges from -1 to $+1$, with $+1$ indicating a perfect positive relationship, -1 indicating a perfect negative relationship, and 0 indicating perfect independence (Agresti and Franklin, 2007). In addition, it is instructive to note that all the inferential statistics computed were based on the 5 per cent level of significance.

Scale	Meaning
5	Major extent – always
4	Near major extent – often
3	Some extent – sometimes
2	Near minor extent – rarely
1	Near minor extent – never

Table I.
Terms used to discuss findings

3.1 Causes of NVAAS in South African construction

This section presents the perceptions of the respondents pertaining to tasks that could lead to the manifestation of NVAAs in construction. Tables II and III present the Cronbach's α and the correlation statistics associated with the causes of NVAAs that were evaluated in the study. It can be observed that the Cronbach's α ranged from good to excellent (Table II) and the correlations ranged from fair to good (Table III). However, the correlations between the responses of clients and consultants as well as the one between clients and contractors are better than the correlations between consultants and contractors (Table III).

In addition, Table IV indicates the respondents' perceptions of the extent to which causes contribute to NVAAs in South African construction in terms of percentage responses to a scale of 1 (minor) to 5 (major), and a MS ranging between 1.00 and 5.00. Given that the causes of NVAAs are ranked from first to fortieth based on responses received, the survey respondents can be deemed to perceive that 15 of these causes contribute more of a major than a minor extent to the occurrence of NVAAs in South African construction (Table IV).

These suggest that the respondents perceive that lack of appropriately skilled workers and repetitive revisions and changes contribute the most to the occurrence of NVAAs in South Africa (Table IV). The respondents further observed that delay in design approval, poor planning of construction, late dissemination of information, poor interaction (presumably among consultants), incomplete drawings/designs, bureaucracy, lack of leadership abilities, error in material specifications, unclear design/details, slow response to requests for information (RFI), poor decision-making abilities, inadequate design information (that leads to design revisions), and unrealistic project execution plan also contribute significantly to the malaise.

The findings suggest that at the very least on a project, the likelihood of occurrence of any of the top 15 causes of NVAAs in Table IV may be major. Therefore, relying on the data and common construction processes, a conceptual model is herein proposed. The variables identified in Table IV enabled the development of a qualitative causal loop diagram (Figure 1) for a hypothetical project A. In construction, it is normally

Table II. Reliability statistics related to the causes of NVAAs in South African construction

Classification	Cronbach's α	Number of items
Causes of NVAAs related to human resources	0.878	8
Causes of NVAAs related to designers (consultants)	0.923	8
Causes of NVAAs related to information and documentation	0.942	8
Causes of NVAAs related to materials/equipment	0.920	8
Causes of NVAAs related to site operations	0.918	8

Table III. Correlations related to causes of NVAAs in South African construction

Classification	Clients	Consultants	Contractors
Clients	1.0000	0.5397	0.4932
Consultants	0.5397	1.0000	0.2250
Contractors	0.4933	0.2250	1.0000

Table IV.
Extent to which causes contribute to NVAAs in South African construction

Causes of NVAAs	Unsure	Response (%) Minor 1	2	. . . 3	4	Major 5	MS	Overall	Ranking by group Clients	Consultants	Contractors
Lack of appropriately skilled workers	1.2	4.7	9.3	19.8	27.9	37.2	3.85	1	2	1	5
Repetitive revisions and changes	1.2	5.8	14.0	14.0	25.6	39.5	3.80	2	7	2	1
Delay in design approval	1.2	8.1	11.6	15.1	27.9	36.0	3.73	3	1	7	3
Poor planning of construction	1.1	4.5	12.5	21.6	33.0	27.3	3.67	4	4	3	6
Late dissemination of information	1.1	5.7	11.5	19.5	40.2	21.8	3.62	5	3	4	11
Poor interaction	2.3	3.5	17.4	20.9	29.1	26.7	3.60	6	5	12	2
Incomplete drawings/designs	0.0	9.2	13.8	17.2	29.9	29.9	3.57	7	8	8	8
Bureaucracy	2.3	8.0	17.2	18.4	25.3	28.7	3.51	8	12	6	12
Lack of leadership abilities	0.0	2.3	14.9	29.9	35.6	17.2	3.51	9	9	5	16
Error in material specifications	1.1	11.5	14.9	14.9	28.7	28.7	3.49	10	6	16	10
Unclear design/details	1.1	6.9	13.8	24.1	34.5	19.5	3.47	11	13	11	13
Slow response to RFI	15.3	9.4	7.1	23.5	24.7	20.0	3.46	12	14	14	9
Poor decision-making abilities	0.0	4.6	13.8	34.5	26.4	20.7	3.45	13	11	10	17
Inadequate design information	1.1	9.1	14.8	23.9	25.0	26.1	3.45	14	15	15	7
Unrealistic project execution plan	1.2	10.5	12.8	23.3	26.7	25.6	3.45	15	10	9	19
Inappropriate construction methods	1.1	4.5	17.0	30.7	27.3	19.3	3.40	16	16	13	15
Contradictions in design documents	2.3	12.6	12.6	20.7	29.9	21.8	3.36	17	25	20	4
Scarcity of materials	10.2	8.0	15.9	27.3	22.7	15.9	3.25	18	18	17	26
Accidents due to poor H&S	2.3	12.5	20.5	20.5	21.6	22.7	3.22	19	21	18	25
External influence on operations	13.6	5.7	15.9	33.0	18.2	13.6	3.21	20	19	28	21
Design revisions	1.1	8.0	18.4	32.2	25.3	14.9	3.21	21	28	24	14
Error in material specifications	6.9	11.5	14.9	23.0	32.2	11.5	3.19	22	20	21	26

(*continued*)

Causes of NVAAs	Unsure	Response (%) Minor 1	2	... 3	4	Major 5	MS	Overall	Ranking by group Clients	Consultants	Contractors
Poor document control system	2.3	9.2	17.2	34.5	24.1	12.6	3.14	23	26	27	22
Inadequate materials control	2.3	6.8	18.2	33.0	34.1	5.7	3.14	24	27	21	29
Poor site layout	5.7	6.9	20.7	33.3	26.4	6.9	3.06	25	30	19	36
Lack of cooperation among workers	3.4	8.0	22.7	33.0	21.6	11.4	3.06	26	22	25	35
Scarcity of workers	2.3	12.5	19.3	31.8	18.2	15.9	3.06	27	17	29	38
Poor team spirit among workers	3.4	9.1	21.6	30.7	28.4	6.8	3.02	28	33	23	31
Inadequate staging areas/platforms	11.4	8.0	20.5	29.5	23.9	6.8	3.01	29	32	31	24
Delays in material transportation	4.5	12.5	22.7	23.9	25.0	11.4	3.00	30	33	25	32
Design not requested by client	13.8	10.3	23.0	26.4	9.2	17.2	3.00	31	24	36	18
Scarcity of equipment	6.8	13.6	19.3	27.3	20.5	12.5	2.99	32	29	30	34
Low morale among workers	2.3	11.5	21.8	33.3	20.7	10.3	2.96	33	35	34	20
Over/under ordering materials	5.7	10.2	23.9	29.5	22.7	8.0	2.94	34	31	33	30
Over design	3.4	12.6	27.6	26.4	17.2	12.6	2.89	35	23	35	28
Inappropriate use of equipment	5.7	12.5	25.0	31.8	18.2	6.8	2.81	36	37	32	37
Lack of empowerment	4.5	14.8	28.4	29.5	18.2	4.5	2.68	37	36	40	32
Excessive control and inspection	2.3	20.7	21.8	34.5	12.6	8.0	2.65	38	39	38	23
Poor waste management practices	9.1	18.2	27.3	30.7	11.4	3.4	2.50	39	38	39	40
Removal of unspecified material	10.2	19.3	26.1	31.8	6.8	5.7	2.48	40	40	37	39

Table IV.

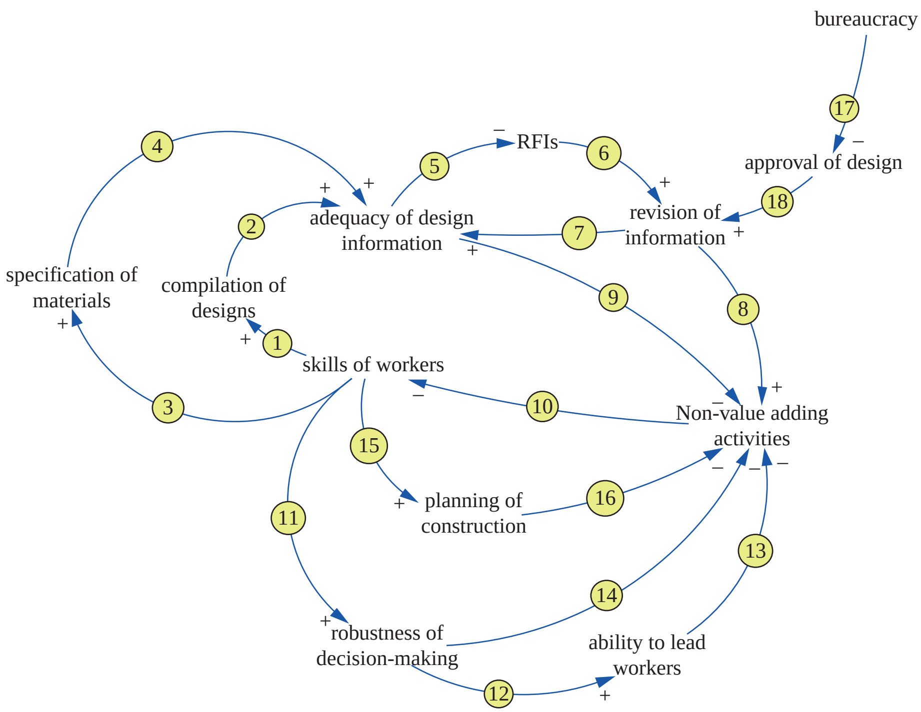

Figure 1.
Dynamics of the causes of NVAAs in South African construction

assumed that the skills of designers determine the standard of designs and specifications compiled for project activities, albeit at varying degrees due to skill/performance-based errors in the form of lapses and slips (Lopez *et al.*, 2010). Skill-based errors relative to lapses and slips that normally arise due to carelessness and/or neglect may lead to unanticipated outcomes when diligence is not observed in the execution of tasks (Love *et al.*, 2008). However, when the disruptive tendencies of errors are removed from the execution process, the skills of designers will significantly influence the adequacy of design information (1-4 in Figure 1).

When the design information provided to contractors is deemed to be adequate by the users, design related NVAAs may become minimal on the project (9 in Figure 1). However, as demonstrated in the construction management literature, design information is often inadequate (Love *et al.*, 2008). Whenever this inadequacy occurs, it can lead to increases in design changes, coordination problems, rework, and in extreme cases, fatalities may occur too (Lopez *et al.*, 2010). This perceived inadequacy can also lead to RFI that originate mostly from site management to designers (5 in Figure 1). The generated RFIs will unsurprisingly lead to revision of information (6 in Figure 1), which may be delayed by bureaucracy and/or approval of the design (17 and 18 in Figure 1). However, when the revised information is ready after the design processes have undergone proper quality assurance procedures in order to weed out errors, the design information may be deemed adequate (7 in Figure 1). According to Love *et al.* (2008), a significant factor that contributes to the production of poor quality design information is related to the reluctance of designers to diligently check for errors because of their high job demands. As a result of these shortcomings, revision of information that often increases the likelihood of NVAAs may occur on the project (8 in Figure 1).

Furthermore, the more time project participants spend on NVAAs, the less chance they have to improve their skills (10 in Figure 1), that is, it is only by engaging in meaningful activities that can add to the progress of the works (project) and also evolve relevant experiences that translate to skills gained by project participants. Similarly, the level of skills of construction professionals affects their ability to plan assigned work. It should be noted that proper planning of construction decreases NVAAs in a project (15 and 16 in Figure 1). Still within the same analogy, the levels of skills of foremen/supervisors could influence the robustness of their decision-making abilities as well as their ability to lead other workers, which may in turn diminish the frequency of NVAAs in a project (11-14 in Figure 1). To be succinct, this dynamic explains why the level of skills of workers, designers, and construction managers are considered important for project execution. For example, insufficient knowledge and the lack of necessary skills are factors that contribute to errors in design documentation (Sunyoto and Minato, 2003).

3.2 Consequences of NVAAs in South African construction

The consequences of NVAAs that are presented in this section amplify the need to address the causes of NVAAs that were presented in the previous section because of their far reaching implications in a project environment. To this end, Table V indicates the respondents' perception of the frequency that certain consequences of NVAAs occur in South African construction in terms of percentage responses to a scale of 1 (never) to 5 (always), and a MS ranging between 1.00 and 5.00. It is notable that 11 of the 14 consequences of NVAAs have MSs above the midpoint of 3.00, which indicates that in general these consequences of NVAAs can be deemed to occur in South Africa and possibly, the global construction industry.

It can also be observed that the Cronbach's α related to the 14 consequences of NVAAs examined can be considered as excellent, while the correlations ranged from very good to excellent (Table VI). The correlations between the responses of clients and consultants as well as the one between clients and contractors are better than the correlations between consultants and contractors (Table VI). The findings suggest that the respondents can be deemed to perceive that time overruns, cost overruns, and variations/claims may be taking place often in South African construction.

The ranking in the table suggests that the respondents were of the opinion that reduced productivity, client dissatisfaction, non-conformances, interruptions/disruptions to activity sequence, clash/overlapping of activities, overtime, additional resource allocation, time-space conflict, incidents and accidents, fatigue, and damage to the environment occur rarely or sometimes as a result of NVAAs in South African construction. It is instructive to note that despite the fact that the variables documented in Figure 1 may be significant in the South African context, due to different industry characteristics, they may not be significant in other countries. Specifically, the literature has extensively demonstrated the contributions of interruptions, rework, errors, and other variables to the occurrence of NVAAs in construction (Han, 2008; Park and Pena-Mora, 2003; Lee *et al.*, 2005). Therefore, Figure 1 is herein merged with the feedback process model proposed by Han (2008) as indicated in Figure 2. The figure is complemented with the consequences of NVAAs that are perceived to be significant in South Africa as indicated in Table V.

Table V.
Frequency of the consequences of NVAAs in South African construction

Consequence	Unsure	Response (%) Never 1	2	... 3	4	Always 5	MS	Overall	Ranking by group Clients	Consultants	Contractors
Time overruns	4.5	1.1	8.0	15.9	43.2	27.3	3.92	1	1	1	1
Cost overruns	4.5	1.1	12.5	23.9	40.9	17.0	3.63	2	3	2	3
Variations/claims	0.0	2.3	17.0	29.5	33.0	18.2	3.48	3	2	3	5
Reduced productivity	2.3	2.3	18.2	30.7	31.8	14.8	3.40	4	5	5	2
Client dissatisfaction	3.4	6.8	21.6	19.3	29.5	19.3	3.34	5	4	7	4
Non-conformances	3.4	2.3	26.4	26.4	33.3	8.0	3.19	6	6	6	10
Interruptions/disruptions to activity sequence	3.4	0.0	23.9	35.2	33.0	4.5	3.19	7	8	8	7
Clash/overlapping of activities	6.8	2.3	17.0	40.9	27.3	5.7	3.18	8	7	4	11
Overtime	8.0	4.5	23.9	25.0	28.4	10.2	3.17	9	12	9	6
Additional resource allocation	3.4	8.0	17.0	36.4	26.1	9.1	3.12	10	9	11	8
Time-space conflict	13.8	4.6	17.2	37.9	20.7	5.7	3.07	11	10	10	9
Incidents and accidents	4.5	13.6	27.3	21.6	22.7	10.2	2.88	12	11	13	13
Fatigue	8.0	9.1	23.9	34.1	21.6	3.4	2.85	13	13	12	14
Damage to the environment	5.7	11.4	29.5	31.8	14.8	6.8	2.75	14	14	14	12

Essentially, the table reveals that quality issues (changes, interruption and rework in Figure 2) as well as productivity issues (fatigue, overtime and overlapping in Figure 2) may arise due to NVAAs in South African construction. Using the same hypothetical project A as an example, and the illustration of Han (2008), the proposed extended feedback process model is herein explained. In the proposed model (Figure 2), it is important to note that revision of information, bureaucracy, and approval of design that were part of Figure 1 were subsumed by changes and rework in Figure 2. The red coloured arrows, which were the new additions to the model proposed by Han (2008), suggest that the occurrence of NVAAs may decline when their causes are adequately addressed. As an illustration, if in project A design information is inadequate, construction is poorly planned, decision-making is inappropriate and construction workers in the form of foremen/or supervisors cannot lead when they are supposed to do so, then it will not be a surprise if problems associated with cost, time, quality, and H&S begin to consume resources, slow down the progress of work, and in worst case scenarios, marginalise the realisation of project objectives.

Table VI. Reliability statistics and correlations related to consequences of NVAAs in South African construction

Classification	Clients	Consultants	Contractors
Clients	1.0000	0.9165	0.7846
Consultants	0.9165	1.0000	0.7451
Contractors	0.7846	0.7451	1.0000
Cronbach's α	0.903		
Number of items	14		

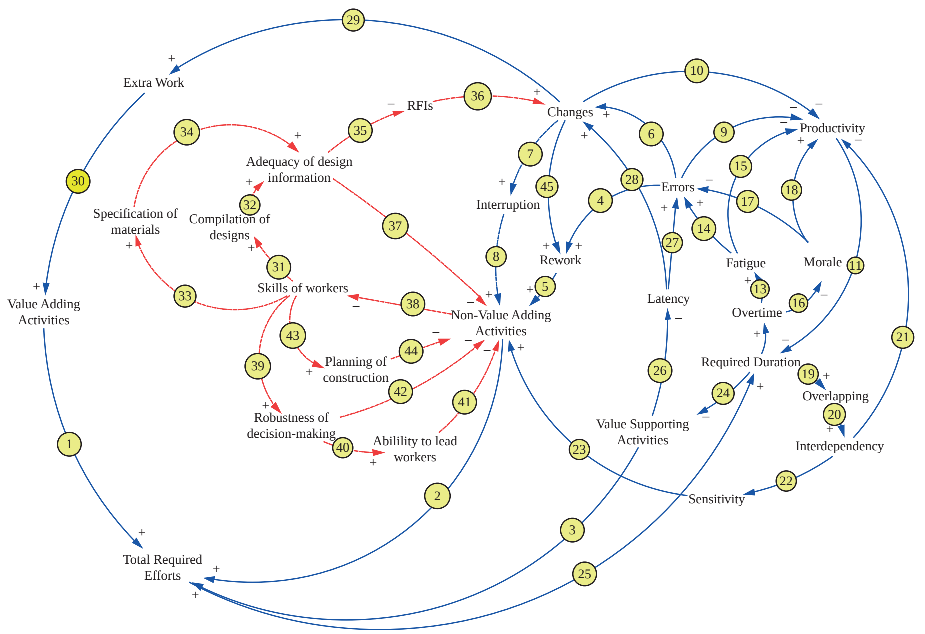

Figure 2. NVAAs in construction feedback process model

Conversely, if in the project, the quality of design information is determined to be adequate by the users, construction planning is proper, decisions are consistently robust and construction supervisors/foremen led fellow workers properly, then NVAAs in the project may become minimal on the project. Therefore, it can be deduced that the total amount of effort consumed in a project is the summation of VAAs, VSAs and NVAAs (Han, 2008; 1-3 in Figure 2). Given the nature of most project environments, it is not unusual to encounter errors during the execution of construction activities as humans are fallible due to a range of reasons such as loss of biorhythm and adverse behaviours (Lopez *et al.*, 2010). The moment errors are detected through inspection, rework that usually proliferate the amount of NVAAs may occur (Han, 2008; 4 and 5 in Figure 2). In addition, because rework may necessitate the demolition of what has already been built, construction managers may decide to avoid rework on problematic activities by modifying their design and specification (Park and Pena-Mora, 2003; 6 in Figure 2). Further, design change issues can also arise due to different site conditions or the owner's preference. In such a case, RFIs would be sent to the design team, and consequently the process would be interrupted until the requested information is ready for use (Lee *et al.*, 2005; Han, 2008). These inevitably generate NVAAs as indicated in Figure 2 (7 and 8 in Figure 2). And with respect to errors and changes, they may significantly lower productivity (9 and 10 in Figure 2). For instance, if a process is executed with lower productivity than initially planned, the process would require additional time and/or resources that may lead to delays and cost overruns (Hanna *et al.*, 2005; 11 in Figure 2).

When actual progress lags behind planned progress, it is most likely that the construction manager may not overlook the schedule slippage and instead take corrective actions in order to keep the process on track (Han, 2008). For example, in order to speed up a delayed schedule, an overtime policy is mostly adopted as it can result in a higher rate of progress without coordination problems (Hanna *et al.*, 2005). However, an overtime policy may introduce additional problems such as fatigue that may result in more errors and productivity loss (Lee *et al.*, 2005; Lopez *et al.*, 2010; 12-15 in Figure 2).

If not handled carefully, prolonged overtime may decrease the morale of workers to the extent that quality and low productivity problems may manifest themselves (Hanna *et al.*, 2005; Lyneis *et al.*, 2001; Lyneis and Ford, 2007; 16-18 in Figure 2). Apart from overtime policy, overlapping policy (concurrency) is also often used for schedule acceleration. Han (2008) suggests that while overlapping policy may not lead to fatigue directly, it usually increases interdependency with other related processes. The interdependency situation may not only decrease productivity in a given process, but it may also propagate detrimental effects of NVAAs on related processes (19-23 in Figure 2).

In order to reduce the amount of time required for a particular process therefore, the construction manager may also assign less effort for VSAs such as inspections as they do not really add value to the process (Park and Pena-Mora, 2003). In this case, the construction manager may temporarily decrease the total effort required for the process and may also reduce the duration of the process (3, 24, and 25 in Figure 2). However, this may hinder the timely detection of errors and changes, which may have additional detrimental impact on project performance due to sensitivity and latency.

In this context, sensitivity refers to an amplifier variable that captures the degree to which a given activity is interdependent on other related activities (Park and Pena-Mora, 2003; Lee *et al.*, 2005; Pena-Mora and Li, 2001). Whereas, latency refers to a delay variable used to capture the time spent in identifying NVAAs, that is, the difference in time between the occurrence of NVAAs and when they are addressed (Lee *et al.*, 2005). The reason for the increase due to the explained "sensitivity and latency" is that the longer it takes to identify errors and changes, the more serious is the potential damage (Lee *et al.*, 2005; Han, 2008). Therefore, a more complex and costly corrective actions may become necessary in order to remedy the situation (26-28 in Figure 2). Explained in this manner, it can be argued that such feedback mechanism suggests that the amount of NVAAs can be dramatically compounded by error and changes if they are not timely and thoroughly resolved (Han, 2008). Moreover, the amount of VAAs (work scope) may be creeping during execution, while schedule delays and cost overruns could be on the upswing (29 and 30 in Figure 2).

Though, these feedback mechanisms that Han (2008) proposed had identified variables that increases NVAAs, the model is arguably extendable since SD models are mostly developed in a robust manner so as to accommodate future considerations. Variables coloured in red dash arrows were thus incorporated into the model in order to explicitly include the influences that "competence" has on NVAAs. As aforesaid, in construction it is not unusual to assume that the skills of designers such as architects or engineers affect the standard of designs and specifications (design information) compiled for project activities to some extent (31-34 in Figure 2).

If the design information is deemed adequate, then design related NVAAs will be minimal on the project (37 in Figure 2). However, design information is often inadequate (Love *et al.*, 2008). This perceived inadequacy eventually leads to RFIs from construction sites (35 in Figure 2). The generated RFIs will unsurprisingly lead to changes (36 in Figure 2), which could necessitate rework (45 in Figure 2). It is notable that when due diligence is not observed in the execution of tasks, skills of designers will often not be enough to ensure the realisation of anticipated outcomes (Lopez *et al.*, 2010). But if the design information is adequate, the need for an RFI may not arise (37 in Figure 2).

Furthermore, the more time project participants expend on NVAAs decreases their chances of partaking in VAAs that could improve their skills (38 in Figure 2), that is, it is the engagement in meaningful activities (VAAs) that adds to relevant experiences and knowledge, which potentially translates to improved skills. Similarly, the level of skills of construction professionals determines their ability to plan assigned construction work since proper planning of construction decreases NVAAs in projects (43 and 44 in Figure 2).

The level of skills of workers also influences the robustness of their decision-making abilities as well as their ability to lead other workers, a situation which may in turn diminish/or increase NVAAs in the project (39-42 in Figure 2). The added variables may either increase the amount of NVAAs or decrease its amount in construction. The importance of the additional variables (31-45 in Figure 2) is underpinned by the assumption that the construction process is still largely human resource driven as in developing nations, and by implication the competence of everyone involved in project execution (clients, designers, contractors, and possibly suppliers) is critical to successful completion of projects regardless of type and/or size. In particular, this is important to the strategic management of projects as astute decisions based on the dynamics influencing performance may assist managers in making sure that construction tasks are completed successfully.

3.3 NVAAs in South African construction

This section shows the NVAAs that can engender poor project performance in the construction industry. The NVAAs, which may be caused by the anomalies that were presented in Table IV, can lead to a range of unpalatable project consequences as exemplified in Section 3.2. It can be seen that the Cronbach's α related to the 40 NVAAs examined in the study ranged from good to excellent (Table VII), while the correlations ranged from fair to good (Table VIII). The correlations between responses of clients and contractors as well as the one between contractors and consultants are better than the correlations between clients and consultants (Table VIII).

Table IX indicates the respondents' perceptions of the extent that NVAAs contribute to poor performance in South African construction in terms of percentage responses to a scale of 1 (minor) to 5 (major), and a MS ranging between 1.00 and 5.00. The ranking in Table IX suggests that lack of required competencies, inadequate supervision, waiting for critical tasks to be finished, non-conformance of materials to specification, waiting for materials, waiting for instruction/information, rework relative to design, human error/mistake, and poor coordination contribute significantly to poor performance in South African construction.

It is however important to note that while not down playing the importance of the other 31 NVAAs used as variables in the empirical survey, the results suggest that the likelihood of occurrence of the NVAAs ranked from 1 to 9 (Table IX) impacting on project performance may be major. In this sense, the possibility of poor performance being recorded on a project where these nine NVAAs are allowed to dominate is deemed to be high.

Relying on the data and common construction processes yet again, a conceptual qualitative model is herein proposed. The model presented in Figure 3 is an attempt to highlight the dynamics associated with NVAAs and their ability to either propagate poor performance when they are not properly addressed, or improve performance when they are properly addressed in South African construction.

Still on the assumed project A, it is possible for the accomplishment of assigned critical tasks to be preceded by coordination and supervision of resources as well as conformance to specifications related to project deliverables such as a "concrete slab" (2 and 3 in Figure 3). However, the coordination of resources and the standard of conformances achieved may be dependent on the level of competence and assiduity of those involved in the process (1 in Figure 3). For example, though a "plan" may be acceptable, its execution needs to be attentively followed in order to reap the anticipated

Table VII. Reliability statistics related to NVAAs in South African construction

Classification	Cronbach's α	Number of items
NVAAs related to rework	0.840	8
NVAAs related to waiting period	0.916	8
NVAAs related to materials	0.861	8
NVAAs related to movement	0.933	8
NVAAs related to human resources	0.889	8

Table VIII. Correlations related to NVAAs in South African construction

Classification	Clients	Consultants	Contractors
Clients	1.0000	0.4000	0.6333
Consultants	0.4000	1.0000	0.4333
Contractors	0.6333	0.4333	1.0000

Table IX. Primary NVAAs in South African construction

NVAA	Unsure	Minor 1	Response (%) 2	… 3	4	Major 5	MS	Overall	Ranking by group Clients	Consultants	Contractors
Lack of required competencies	0.0	2.3	8.0	18.4	31.0	40.2	3.99	1	3	1	1
Inadequate supervision	0.0	0.0	10.3	21.8	32.2	35.6	3.93	2	1	2	2
Waiting for critical tasks to be finished	1.1	6.8	13.6	19.3	26.1	33.0	3.66	3	8	3	9
Non-conformance of materials to specification	1.1	3.4	15.9	17.0	38.6	23.9	3.64	4	4	4	6
Waiting for materials	0.0	3.4	19.3	19.3	29.5	28.4	3.60	5	6	9	5
Waiting for instruction/information	0.0	6.8	17.0	20.5	21.6	34.1	3.59	6	5	15	3
Rework relative to design	1.1	13.6	11.4	15.9	23.9	34.1	3.54	7	2	10	8
Human error/mistake	3.4	4.6	16.1	26.4	29.9	19.5	3.45	8	10	6	7
Poor coordination of resources	2.3	5.7	15.9	25.0	33.0	18.2	3.43	9	14	11	11
Rework relative to foundation works	5.7	8.0	21.6	18.2	18.2	28.4	3.40	10	9	8	16
Poor sequencing of tasks	4.5	4.5	19.3	26.1	27.3	18.2	3.37	11	16	7	17
Ignorance	1.1	6.9	20.7	21.8	28.7	20.7	3.36	12	25	12	2
Rework relative to structural works	8.0	10.2	12.5	26.1	21.6	21.6	3.35	13	7	13	24
Rework relative to finishing works	9.2	9.2	14.9	24.1	21.8	20.7	3.33	14	12	10	21
Strikes	3.5	16.3	18.6	15.1	15.1	31.4	3.28	15	10	14	27
Waiting for equipment	2.3	5.7	27.3	21.6	23.9	19.3	3.24	16	15	16	20
Low employee morale	1.1	11.5	10.3	35.6	27.6	13.8	3.22	17	12	25	15
Unreliable/defective equipment	1.1	11.4	19.3	26.1	26.1	15.9	3.16	18	19	18	19
Waiting for specialist to arrive	3.4	13.8	17.2	27.6	17.2	20.7	3.14	19	19	19	18
Defective materials on site	3.4	11.4	21.6	25.0	19.3	19.3	3.14	20	17	17	28
Idleness on site	2.3	9.2	21.8	31.0	19.5	16.1	3.12	21	22	22	11
Unnecessary work	4.6	4.6	27.6	27.6	24.1	11.5	3.11	22	24	21	13
Inappropriate positioning of cranes	20.7	17.2	6.9	21.8	23.0	10.3	3.03	23	30	22	10

(*continued*)

Table IX.

NVAA	Unsure	Minor 1	Response (%) ... 2	3	4	Major 5	MS	Overall	Ranking by group Clients	Consultants	Contractors
Waiting for labour to arrive	3.4	13.6	25.0	20.5	23.9	13.6	2.99	24	18	24	32
Waiting for work space/platform	6.8	12.5	21.6	27.3	19.3	12.5	2.98	25	22	31	23
Poor ergonomics and injuries	15.9	15.9	15.9	19.3	21.6	11.4	2.96	26	29	27	22
Rework relative to formwork	9.1	11.4	25.0	26.1	13.6	14.8	2.95	27	21	20	34
Loss of materials on site	1.1	9.1	28.4	33.0	19.3	9.1	2.91	28	34	28	26
Waiting for inspections	1.1	10.2	30.7	29.5	14.8	13.6	2.91	29	25	36	13
Poor equipment movement	5.7	12.6	20.7	31.0	24.1	5.7	2.89	30	27	32	30
Rework relative to electrical works	17.2	10.3	25.3	24.1	12.6	10.3	2.85	31	31	26	35
Rework relative to services	10.3	9.2	27.6	32.2	10.3	10.3	2.83	32	33	29	31
Rework relative to mechanical works	17.2	8.0	26.4	29.9	9.2	9.2	2.82	33	28	30	37
Poor vehicle/truck movement	8.0	10.2	22.7	35.2	21.6	2.3	2.81	34	36	33	28
Unnecessary material handling	4.5	14.8	25.0	34.1	15.9	5.7	2.71	35	35	34	36
Needless repetitive handling of tools	18.2	12.5	20.5	34.1	12.5	2.3	2.65	36	37	35	32
Waste of raw materials on site	2.3	19.3	27.3	30.7	11.4	9.1	2.63	37	38	38	25
Deterioration of materials on site	3.4	22.7	21.6	33.0	13.6	5.7	2.56	38	32	37	39
Excess materials on site	4.5	14.8	47.7	23.9	5.7	3.4	2.32	39	39	40	38
Excessive inspection of materials	8.0	34.1	15.9	25.0	14.8	2.3	2.30	40	40	39	40

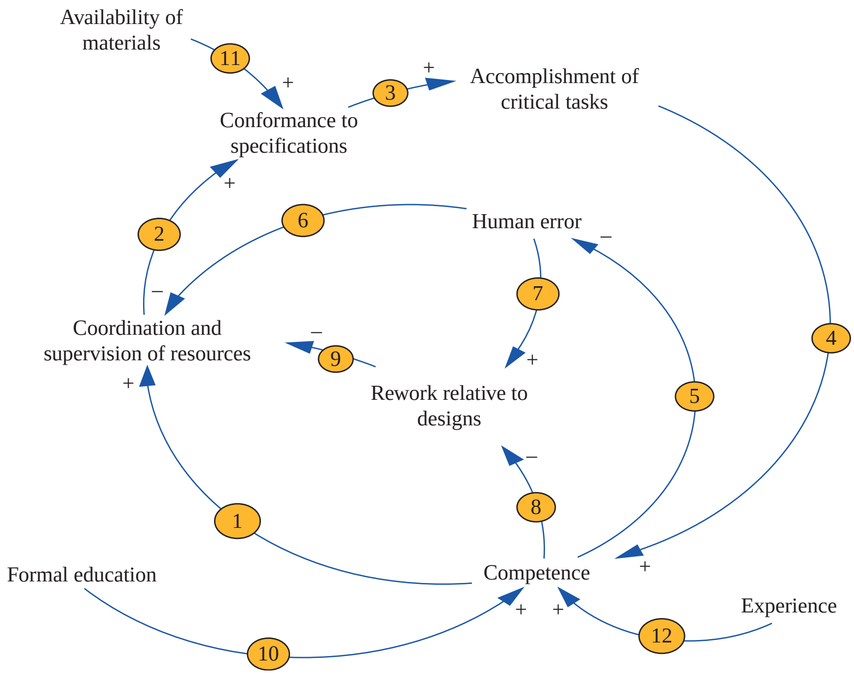

Figure 3.
Dynamics of NVAAs in South African construction

results (Love *et al.*, 2008). The availability of required materials may also either improve or decrease conformance to specifications achieved on construction sites (11 in Figure 3). The accomplishment of critical tasks do not only speed up the progress of project implementation, but it may also add to the experiential knowledge of project stakeholders involved in the project as it can form aspects of an informal training. Accomplishment of critical tasks may thus invariably increase the competence of reflective individuals within the project team (4 in Figure 3). Although documented reports suggest that the combination of formal education and experiential training determines the competence of individuals, a South Africa study suggests that this combination only holds true when both education and training are appropriate (van Wyk, 2008; 10 and 12 in Figure 3). In the event that formal education and experiential training fell short of required expectations, rework related to design may occur or avoidable human error may become unavoidable (5 and 8 in Figure 3).

It is important to also note that while human error may lead to increased rework/design changes, both human error and rework negatively influence efforts devoted to coordination and supervision of resources (6, 7 and 9 in Figure 3). In brief, this particular illustration (Figure 3) further highlights the dynamic structures at play in terms of construction project performance in South Africa. Thus, Figures 1-3 that are qualitative in nature are powerful tools to map the feedback structure of complex systems as they are not only deemed helpful in presenting the salient results of the empirical study, but also they are effective for capturing mental models. As an illustration, Figure 1 suggests that a range of issues may lead to the propagation of NVAAs; Figure 2 indicates that these NVAAs tend to have feedback processes that may reinforce their intensity and frequency in the construction process; and Figure 3 demonstrated the dynamics of NVAAs with respect to project performance through the accomplishment of stated project critical tasks (milestones).

The quantitative survey findings, though limited by the response rate of 25.4 per cent, nevertheless corroborate previous NVAAs related research findings. The NVAAs, their causes, and impact that are deemed to be major support the findings of Alwi *et al.* (2002a, b), Koskela (1992), Alancon (1997) and the South African CIDB (2011). The findings suggest that the lack of required competencies and shortage of skills necessary for supervision constitute a problem in South African construction as earlier mentioned through the work done by Lawless (2005, 2007); repetitive revisions and changes as well as other design related problems such as delay in design approval marginalises the construction process (Love *et al.*, 2008); and time overruns, cost overruns, and variation/claims eventuate as notable consequences of anomalies in construction (Ndihokubwayo and Haupt, 2008; Han, 2008; Love *et al.*, 2008).

4. Conclusions and recommendations

NVAAs are fundamental tasks to be weeded out of construction as they exhibit persistent ability to engender poor performance. Every construction task consists of VAAs, VSAs and NVAAs. Of these three types of activities, the literature suggests that the reduction of VSAs and the elimination of NVAAs could lead to performance improvement. This can be done through redesigning and/or restructuring how construction tasks are carried out. New ways/work processes could therefore benefit from the evaluation of existing processes through their identification and analysis.

Using the South African infrastructure sector as a case study, NVAAs and their causes that could significantly contribute to poor performance were identified. The explanations that were provided suggest that unless these NVAAs are addressed, they tend to proliferate in construction. Notable NVAAs such as lack of required competencies have to be addressed in South Africa. Perhaps, the elimination of major causes of NVAAs such as lack of appropriately skilled workers provides a way forward. The findings of the study emphasise the need to implement lean construction principles in South Africa in order to address certain consequences of NVAAs.

The implications of the findings for the management of construction projects in South Africa are threefold. First, public sector clients should promote objective assignment of construction project management responsibilities to appropriately skilled and/or competent in-house experts. Given that employers (mostly public sector) were deemed to have contributed to project failure in South Africa (Valentin and Vorster, 2012), it is imperative that those vested with project delivery responsibilities are experts or specialist in their chosen field. It is important to emphasise this advice as a recent South African study contends that in order to improve the performance of existing municipal infrastructure, and also ensure favourable delivery of new ones, critical intelligence (soft and hard skills) should be found among public sector clients (Emuze and Smallwood, 2011). According to the study, public sector clients must recruit qualified built environment/engineering graduates into responsible government positions that have decision-making authorities so that the appointees cannot be easily overruled based on political considerations. In other words, critical technical positions should not be made subservient to political positions in matters of technical nature (Macleod, 2007).

Second, consultants should avoid the use of fresh graduates without the requisite "know-how" to sign-off jobs on construction sites as instead of being viewed as experts, their input may be considered immature or not practicable by site management professionals. This recommendation is necessary in order to address design and information related NVAAs and their causes. Third, contractors should place emphasis on both academic and professional development of their existing employees, and also ensure that new recruits are armed with appropriate built environment qualifications so that they are sure of their suitability for challenging roles in the industry. Since Valentin and Vorster (2012) observed that project failures due to factors under the control of contractors are low in frequency in comparison to other members of the project team, but high in intensity with severe direct consequences; and the fact that NVAAs have the propensity to propagate into other activities when they are not adequately addressed, it is vital for contractors to improve the competencies of their site management employees in South Africa.

However, because of the limitations of qualitative models, a quantitative model shall be developed in a future research endeavour. The dynamics explained in Figure 3 will be expanded further to develop a simulation model for analysing the effects that competence has on the accomplishment of critical tasks. The "stock and flow" diagram to be developed shall endeavour to detail salient parameters that contribute to the process of assigning critical tasks to competent specialist within the South African construction industry context. Attempts shall be made to derive estimates for the model parameters from site experiences of researchers, and subsequently, validation of the estimates shall be done through a focus group that will be made up of principal construction industry stakeholders. Thereafter, it is envisaged that the simulation model will be applied to selected projects in South Africa so as to assess its usefulness for the management of construction projects.

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Corresponding author
Fidelis Emuze can be contacted at: fidomy@gmail.com

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