DEVELOPMENT OF A ROAD QUALITY ASSURANCE MEASUREMENT TOOL IN CONSTRUCTION PROJECTS

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ABSTRACT

This paper aims to explore South African construction project deliveries' to local communities built by small and medium enterprise (SME) contractor. The objective was to explore construction project delivery practice within the construction sector with the intention of developing a road quality assurance measurement tool specifically for construction organisations. A questionnaire was administered to 160 randomly-selected project/construction managers, architects, quantity surveyors, client/managers and South African local government administrators. Quantitative methods of data analysis were used to analyse data gathered from the self-administered questionnaires from South African road construction projects. This paper concludes by showing that the SME construction project lacks strategic planning and poor quality of construction project delivery. Inadequate development and quality control has been identified as a key source of inadequacy. The findings suggest that the SME construction organisations would benefit from adopting a program of product quality for the construction of long-term relationships with local authorities and communities. Developing road quality assurance process of SME construction organisations also helps to community flexibility and overall continuous process improvement. Conversely, at present, little research has been conducted on how SME construction organisations deal with the poor quality of road projects.

Keywords: Implementation, quality assurance, design, effectiveness, SME road construction organisation

INTRODUCTION

In today's global competitive environment, the construction industry has been criticised for its poor performance in relation to other industries. The industry's customers demand improved road quality products and innovations in project management techniques and tools. The occurrence of accidents in construction still remains at a high level mostly owing to a misalignment of management commitment and subordinate actions [26]. The construction industry furthermore has the highest work-related injury rates globally [20]. South Africa has

the misfortune that very few cities have the capacities to build infrastructure themselves [24]. As a result, many of the businesses processes and practices used to support construction organisations are being challenged. In a construction project, customer satisfaction is one of the key dimensions used for measuring the efficiency of a project. Consequently, these organisations depend on constructors to deliver infrastructure within the budget, quality and time [4].The inadequate pool of experienced engineers appropriate for managing positions, the steep learning curve and time frame necessary to prepare alumni with managing capabilities remain a significant barrier to implementing quality construction in South Africa (25].

Quality assurance processes assure improvements in design of products, products, processes, services, concurrent engineering, experimental design, design team formation and management [26]. In every construction project, customer satisfaction is a key dimension used for measuring the efficiency of a project. Quality of service plays a major role in the construction industry and is a major factor of competitiveness. Some researchers have examined the implementation of QA processes related to the road construction industry and its positive impact on the performance of an organisation [6; 25]. Quality of service plays a major role in the construction industry and is a major factor of competitiveness. A review of the literature specifies that numerous institutes have proposed that quality cannot be seen as an expensive process, an expensive product, or time-consuming but as necessary to improve competitive abilities in the marketplace [1]. Quality can be defined as meeting the customer's necessities as well as providing people who are performing many organisational purposes with a common language for improvement ([5]. Conversely, the meaning of quality for construction projects is different from that of manufacturing or services industries as the product is not repetitive but a unique piece of work with specific requirements [6].

Ofori [28] states that the construction industry is viewed by the South African government as a national asset that should be established and sustained. Previous studies on construction industry matters and SMEs contractor development around the world were reviewed. It was found the construction industry accounted for about 10 % of the world economy, and that approximately 70 % of construction investment was accounted for in the United States of America, Western Europe and Japan [25; 27]. Studies reviewed revealed that the concept of total quality is widely known, however the development of road quality assurance measurement tools in construction projects and process implementation had not been researched. Quality assurance is critically-required for construction sites, remains a concept held by senior managers and is not fully disseminated to their subordinates, and management requirements cannot be fully implemented during the execution of the project [15; 29]. There is a need to focus on quality road construction projects. In this paper, discussion of SME contractor's performance impeding factors on construction projects has centred mainly on some of the studies conducted in the developed countries. The objective of this article is to examine and measure the quality of road construction projects built by SME organisations. This is because SMEs play a substantial role in South Africa in dealing with the challenges of poverty and job creation in developing countries [22; 25]. In view of the arguments above, measuring productivity was chosen as the theoretical point of departure for this study and the basis for development of the road assurance quality measurement tool as discussed below.

RESEARCH QUESTIONS

i. What methods must be implemented to ensure that contractor QA processes are optimised in terms of planning, project control techniques and be linked with the road construction projects?
ii. What factors facilitate the success of process implementation of QA in the road construction projects?
iii. How can implementation of QA processes be established?

LITERATURE REVIEW

Quality control in construction projects

There is a global increase in demand for improvement of road infrastructure in developing countries to improve the socioeconomic conditions experienced by citizen. Quality control in construction projects can be viewed as a method that monitors specific project outcomes to determine if they conform to specifications and identify ways to eliminate the causes of bad results [9]. The rationale behind quality control is that it involves a monitoring action, but is also concerned with finding and eliminating causes of quality problems so that the necessities of the customer are determinedly met [12]. From a construction project perspective, the quality control includes observing or measuring actual performance remedial actions to determine whether there are deviations [11]. Quality control conveys with it a general framework for quality management, and is essentially the actions and systems applied to attain and sustain the quality of a product or service [8; 27]. The quality control activities should describe but not necessarily be limited to describe and implement a measurement system and measure the selected parameters, for instance, weight and temperature [11]. Juran and Gryna [17] state that quality controllers should be experts in the fields of project and statistical quality control, sampling and probability, and must be able to measure quality outputs. Often these control processes include the monitoring of actual project results to evaluate compliance with standards of quality and to eradicate poor performance, developments and products [9; 19; 26]. The quality of construction depends mostly upon the control of construction which is the key concern of the contractor [30].

Quality engineering

Juran and Gryna [17] state that quality engineering relates the specific necessities of the plant and organisations to the existing quality technology-including both hardware equipment and planning and control activities to put in place of the quality systems framework for the organisation. Foster [12] defines quality engineering technology as the body of technical knowledge for formulating policy and for analysing and planning product quality in order to implement and support that quality system which will yield full customer satisfaction at the lowest cost. Quality engineering technology provides the technical areas to deal with utilisation of quality information equipment, the type of information data required, and how should it be scrutinised [13; 26]. Because of this, Cooke and Williams [9] improved the approach to determine quality engineering. Instead of pursuing the characteristics of

computing productivity, they clarified the implication of quality-by exposure to quality videos, workshops, and seminars and the decisive need to respond to the tasks of competitiveness.

Costs of quality in construction developments

Costs of quality in the rural roads construction developments may be viewed as the total costs incurred by investment in preventing non-conformance to requirements, evaluating the product or service for conformance to requirements and failing to meet requirements [27]. Within the construction context, costs of quality comprise all the outlays incurred in performing quality to project activities [23]. Quality cost studies are conducted to comprehend what the existing cost of quality is at best as well as providing an educated estimate of the costs and not an accurate measure [21]. Nyakala [25] agrees with these points that balance should be found among the total cost of prevention and evaluation and the total cost of failures. Application of a road quality assurance measurement tool by SME construction organisations not only reduces negative costs of operation, design development, and construction and improves staff performance, customer satisfaction and confidence in the organisation's products/services

The costs of quality is thus an integral part of business planning. Although many more quality costs exist, the summary of quality costs provides a valuable classification of key targets for improvement of construction organisations (2; 21; 23]. The reasoning behind quality costs is that all SME contractors implementing strategic appraisal and prevention audits will reduce quality costs [20]. The final objective is to ensure a proactive process necessitating commitment from all members of the road construction organisation [4]. This paper discusses the importance of the quality concepts of project management, construction projects including total quality management and road infrastructures built by SME contractors. Since construction projects involve the importance of quality training, management need to allow persons to get assistance required to be successful individually and collectively as teams. This study provides a holistic approach to the construction projects' implementation and measures, and contributes to the theory of project success and continuous quality improvement.

Road quality assurance measurement tool

The proposed measurement model provides confidence among all concerned that construction quality-related activities can be performed effectively. It embraces the project construction design, project planning and control techniques, commitment and support, organisational structure, process implementation, and an effective communication system required to implement QA as illustrated in Figure 1. The adequacy of the road construction system, and the quality of products, identification, evaluation and developments are measured by their compliance to specified methods for achieving the anticipated quality result. Writing about South African SMEs contractors, Nyakala *et al* [25] states that development and control costs need to have robust management and likewise identify critical aspects causing quality of work failure, involve and evaluate the processes affecting the development of QA and also assist government to realise some of its broader socioeconomic aims to empower previously disadvantaged individuals as depicted in Figure 1.

Figure 1: Road quality assurance measurement tool

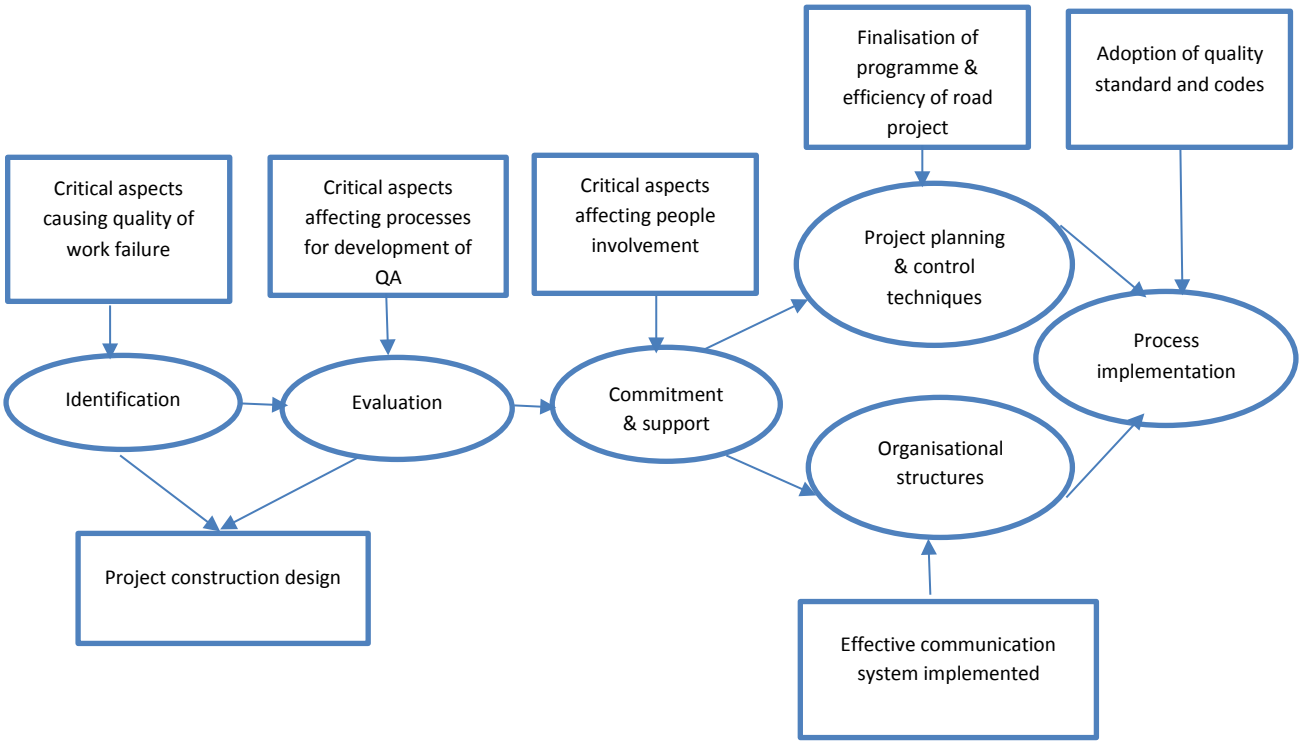

Figure 1: Road quality assurance measurement tool, source: Authors (2017)

The road construction QA processes model is a product of the construction industry. The proposed framework is also aimed at providing the basis for a structural and logical approach. The need for a road construction QA model increases with the size of projects. Road quality assurance measurement tool concentrates on factors contributing to quality/work processes effectiveness, development of QA, skill acquisition processes, project planning and control techniques, project construction design, implementation processes, quality standards, organisational structures and people involvement. Construction industry designers' need to strictly monitor and guide SME road construction managers and/ or owners, especially in the implementation process of road quality standards and strategies.

Project and quality management tools must also be in place to enable practical implementation of standards. In construction project management studies, there thus emerges awareness of the need to measure the importance that stakeholders assign to various success factors. Measures provide construction organisations with a technical base for continuous improvement, efficient use of money, time and other resources. Management must agree on the meaning of the QA processes, its implications and the direction to take. Application of a QA process leads to a reduction in the cost of the operation, design development and construction. It results in an improvement of staff performance, customer satisfaction and confidence in the road construction design and the standards have important economic and social effects. They are useful to construction and business associations for all kinds, to management, to other conformity assessment bodies, to contractors, to governing bodies, and customers of products and services in both the public and private sectors, and to cities in general in their role as customers and users.

Measuring productivity of construction project

Customer satisfaction and employment in project management are indicated in this study in line with the findings by Ofori [28]; Mofokeng and Thwala [22], where measuring of the construction project to continuously improve productivity was established. This refers to comprehensive and effective quality control as key determinants for successful quality management system implementation. This has also been advocated by various researchers [6; 26]. Total Quality management (TQM) is perceived as new by members of the building industry within the context of developing countries [30] in terms of measuring productivity in construction working procedures. TQM is regarded as a philosophy needed for construction projects owing to various principles such as customer satisfaction, employee involvement and continuous improvement in road improvement quality.

Likewise, application of TQM in project management practices within the construction industry in developing countries could be approached through productivity measurement [7]. Besides, this gives practitioners and investigators a powerful tool to quantify and evaluate their impact on the process of controlling action [16; 17]. When it comes to measuring productivity for road quality in the construction context, application of TQM is largely beneficial because as it brings sustainable business growth, global competitiveness. It establishes the right organisation for managing the delivery of infrastructure regarding cost standards, time and quality [6].

METHODOLOGY

Questionnaire

A questionnaire was administered in accordance with the methodology adopted by most previous research studies into quality of work in construction projects. The majority of these have used descriptive statistics and quantitative methodologies on survey data collected by questionnaire [3; 7; 24]. Based on a comprehensive review of the critical success aspects mentioned in the literature on quality assurance process implementation, a structured questionnaire was developed precisely for this study [14]. The draft survey was then subjected to a face-to-face pilot test involving interviews with four project/construction practitioners who had expertise in managing quality in construction projects as well as four practised empirical academics. The final questionnaire consisted of two parts. Section A contained questions in relation to businesses' profiles, whilst section B concentrated on rating the importance of activities related to Section A. Descriptive statistics such as frequencies, percentages, means and standard deviations were calculated, whilst the Pearson correlation was used to measure the strength of the relationships together with factor analysis. The QA processes assessment model contained a number of factors each consisting of items. Rating of the items using a five point Likert scale to allow the construction project organisation to examine and rate itself against these particular factors or criteria. In addition to this, Likert scale items were summated for each of the subscales of the questionnaire.

Sample

A questionnaire was distributed to 250 randomly-selected construction/project managers, architects, quantity surveyors, managers/clients and South African local government

administrators. The total sample of respondents was 160 resulting in a 64% response rate from the 250 questionnaires distributed. The Kaiser-Meyer-Olkin (KMO) and Bartlett's Test of Sphericity showed that sample was adequate [14]. It measures the index of the appropriateness of factor analysis for overall statistics including each variable related with factor analysis [10].

Data analysis

The statistical package SPSS version 22.0 was utilised for data processing. Descriptive statistics was used to examine the differences between the project participants' quality assurance measurements based upon the various economic sizes of the road construction projects. In accordance with previous studies [16; 18], Pearson correlation was used to measure the strength of the relationships together with confirmatory factor analysis.

RESULTS

Project evaluations provided by project consultants are pleased with the skills and expertise of designers, and they are very satisfied with the smoothness and flexibility of collaboration with designers [3]. Quality can be problem to small businesses, which lacks technical capability, inspiration and resources to attain the necessary implementation goals [9].The implementation of a continuous improvement programme and effective road quality assurance process will, however, contribute to the effort of in sizes of project-based organisations. The implementation of QA processes and efficiency of road construction contribute to the efficiency of road construction projects. This effort will improve the overall performance and competitiveness of the business. Table 1 shows the staff position occupied in the businesses.

Table 1: Staff position occupied in the business

	Frequency	Percent	Valid Percent	Cumulative Percent
Quantity Surveyor	18	11.3 15.0	11.3 15.0	11.3 26.3
Client/Manager	24	11.9 15.6	11.9 15.6	38.1 53.8
Project/Construction Manager	19	41.9	41.9	95.6
Architect/ QA Engineer	25	4.4	4.4	100.0
Government Official	67	100	100	
Project Administrator	7			
Total	160			

Table 1 shows the staff position frequency of the participants. Approximately 41.9 percent (n=67) of the respondents showed that they were occupied as government officials, 15.6 percent (n=25) were working as Architect/QA engineers and 15.0 percent (n=24) were working as Client/Manager, 11.9 percent (n=19) reported occupying as Project/Construction Managers whilst 11.3 (n=18) indicated that they were working as Quantity Surveyors in the road construction. The smallest number of the respondents (n=7; 4.4%) reported they were working as a Project Administrators. Knowledge of project management by members of a particular construction project delivery system whereby the purpose of construction project management (CM) is to control a project's time, cost and quality [7]. This is done by going through a bidding process with various contractors [5].The set of eight critical aspect criteria

was subsequently coded as C1-C8 and formed the basis for coding QA processes, namely, Quality of Implementation and Importance Rating Factors and Sub-factor-items. The Critical Aspect Criteria included C1-level of skill acquisition process, C2-project planning and control techniques, C3-project construction design, C4-process implementation, C5-financial management skills, C6-quality standards, C7-organisational structures, and C8-people involvement as illustrated in Table 2.

Table 2: Coding of Critical Success Factor-items

CODE	Factor Criteria	Number of Items Per Factor Criteria	Quality of implementation Factor-Item Code (ni-j)	Rating of Importance Factor-Item Code (ni-j)
C1	Level of skill acquisition process	5	C1.1.1- C1.5.1	C1.1.2-C1.5.2
C2	Project planning and control techniques	6	C2.1.1- C2.6.1	C2.1.2-C2.6.2
C3	Project construction design	4	C3.1.1- C3.4.1	C3.1.2-C3.4.2
C4	Process implementation	2	C4.1.1- C4.2.1	C4.1.2-C4.2.2
C5	Financial management skills	5	C5.1.1- C5.5.1	C5.1.2-C5.5.2
C6	Quality standards	5	C6.1.1- C6.5.1	C6.1.2-C6.5.2
C7	Organisational structures	4	C7.1.1- C7.4.1	C7.1.2-C7.4.2
C8	People involvement	4	C8.1.1- C8.4.1	C8.1.2-C8.4.2
	Total number of items	35		

Data generated in Table 3 shows the coding system for Critical Aspects, the number of Items per Critical Aspect as well as Quality of Implementation Factor-Items and Importance of Rating Factor-Items. In addition, it could be clarified that Quality of Implementation Factor-Items and Rating of Importance Factor-Items were numbered according to the number of Sub-factor items related to the Critical Factor-Items whereas Quality of Implementation Factor-Items ended with a digit 1 and Rating of Importance Factor-items ended with the digit code 2. All 35 Quality of Implementation Factors-Items and 35 Rating of Importance Factor-Items using SPSS were subjected to Cronbach's Alpha validity, reliability and correlation analysis. The results gathered illustrated that all Factor-Items (70) were accepted to be relevant, valid and reliable. Results Cronbach's Alpha are shown in Table 3.

Table 3: Cronbach's Alpha results

Internal Code	**Cronbach's Reliability and Validity Factor and Item Analysis Summary**	**Number of Items per factors (n-j)**	**Quality of Implementation – Cronbach's Alpha**	**Rating of importance-Cronbach's Alpha**
C1	Level of skill acquisition process	5	0.850	0.879
C2	Project planning and control techniques	6	0.872	0.879
C3	Project construction design	4	0.867	0.873
C4	Process implementation	2	0.773	0.774
C5	Financial management skills	5	0.778	0.790
C6	Quality standards	5	0.827	0.849

C7	Organisational structures	4	0.933	0.937
C8	People involvement	4	0.681	0.699
	Total number of items	**35**		

The result output for the 35 Quality of Implementation Factor-Items and Rating of Importance Factor-Items using SPSS illustrated that the Cronbach's Alpha value for Quality of Implementation Factor-items were α = 0.681$\Longrightarrow$ α =0.933, and for Rating of Importance Factor-Items were from α =0.699$\Longrightarrow$0.937. All 35 Quality of Implementation Factor-Items and Rating of Importance Factor-Item's Cronbach's Alpha were greater than $\alpha \geq 0.80$ illustrating a good internal consistency (rule of thumb alpha is that alpha should not exceed > 0.80) (Hair *et al*. [14] between factors-items in the scale. Quality of Implementation and Rating of Importance Factor-Items measured were according to the latent (or underlying) construct and showed an inter-correlation Cronbach's Alpha measurement of relevancy, reliability and validity. With respect to these Critical Aspects, an inclusive set of 35 Quality of Implementation Factor-items and 35 Rating of Importance Factor-items, in total 70 factor-items, were used in formulating the process of QA. Successful implementation of a QA encompasses suitable skill acquisition, effective planning and operations, review, process implementation as well as financial management skills at all levels of an organisation. This view is also supported by Thorpe *et al*. [29] who state that successful implementation of a road construction projects needs effective planning, processes and review, as well as continuous improvement of the system. A construction process planning is frequently of high detail resulting in high coordination effort and high throughput rates.

Table 4 illustrates the four (4) factors extracted (level of skill acquisition process, the planning and control techniques of the project, project construction design, process implementation), twenty-two (22) iterations required. In addition to this, four (4) factors were also extracted (financial management skills, quality standards, organisational structures, as well as involvement of people about quality assurance processes implementation. Pearson's chi-square test proves that SME construction organisations did not implement QA processes in the road construction projects. This result shows that there was no statistical difference between the percentages of the SME construction organisations implementing processes of quality assurance in the local municipalities in the road projects, which can be termed as a positive moderate correlation at the given levels whereby p<.000 for all eight scales measured. Table 4 indicates sufficient reliability on the eight (8) coefficients. This means there is a strong relationship between the variables used in SME-led projects related to road construction projects, since the Cronbach is 70 which is advantageous.

Table 4: Table KMO and the Bartlett's tests

Factor	**KMO measures of sampling adequacy**	**Bartlett's (Chi-square) test**	**df**	**Sig**
Level of skill acquisition process	.728	2207.910	105	0.000
The planning and control techniques of the project				
Project construction design				
Process Implementation				
Financial management skills	.929	9494.842	595	0.000
Quality standards				
Organisational structures				
Involvement of people				

Source: Field work, 2016

Table 4 shows a significant positive relationship exists, therefore, there is support for this study question. Concerns have surfaced the construction design impact using measurement model and for construction projects. Poor construction design may cause high accident rates and improper process implementation, in addition to damaging vehicles and roadway. This has had an impact on both business performance and project. The study also found a strong similarity in the most commonly used project management techniques by both groups for time/cost control and planning. A recent survey of South African cities and countries identified some interesting strategies for dealing with poor quality of construction design. Much of the data from the study covers practices and comprises matters such as a quality assurance processes application during construction process. It is apparent from the data that there is gap among the applications of quality standards, process implementation and developments of road quality measurement tools used by SME construction organisations. The usage of very high quality basic materials, the establishing of stylish construction, analysis and project techniques using up-to-date methodical attainments are significant in the construction project delivery. Co-operating efficiently within and external can have positive impacts on the development of dissimilar processes for enhancing road quality building even in extreme conditions, decreasing the whole life cycle costs of road re-engineering, and subsequently, minimal poor road projects. The study also found a strong similarity in the most commonly used project management techniques by both groups for time/cost control and planning. These aspects were the key complications facing road SME construction organisations to ensure successful application of tasks efficiently.

Implications

The SMEs in construction should take the opportunity to develop skills in different roles/areas so as to meet the expectations of all employees. Senior management should also strive to facilitate employees learning new skills. Quality review meetings should be established because they would assist the organisation to identify how far they are with implementing successful quality efficiency.

CONCLUSIONS

This study promotes an understanding of the development of a road construction quality measurement tool and the application of a QA system which could be uniformly accepted industry wide. By applying this developed model, one can measure the quality of completed as well as ongoing road projects which, in turn can be used for comparing finished projects and developing strategies for continuous improvements in construction projects. This study also promotes the importance and understanding of successful road construction quality efficiency and its implementation processes. It highlights the need to measure the importance that various projects' stakeholders allocate to various success factors in a construction project quality studies. Good investment in road construction projects yields substantial socioeconomic benefits in relation to improved regional growth, as it allows for the movement of goods and services between producers and markets [24]. The study empirically contributed to the body of knowledge within the construction industry for construction managers on the role of project and SME road contractors. Suggestions or recommendations of these impacts and difficulties were also discussed.

The developed measurement tool can be applied to different road projects and quality of road projects has been identified. It has been observed that developed measurement tool can be easily be applied to any road construction projects. Automaton and software applications can also be developed in Matlab and MS Excel for commercialisation of developed model. The paper presented a road construction quality measurement guide. Application of developed quality guide can be done in checking for quality different roads. The road construction quality guide has been developed for road project in South Africa, which can be generalised to ant construction project. The findings and results obtained from the study undertaken added valuable new perspectives to the QA processes implementation as a critical necessity to attain efficiency in a project-based organisation. The measurement tool developed measures for the current level of quality standards of the SME contractors by means of discrepancies analysis. It identified the aspects causing quality or work processes failure and analysed constructability provisions and depictions within numerous SME contractors' entities to implement QA processes in the construction industry. This tool also determined the effectiveness of road construction projects, and contributed to assisting SME contractors with implementing and measuring the prominence of quality control, costs of quality project management tools and techniques, and continuous improvement technique.

The results clearly indicated that policies and objectives were defined by the senior project management to ensure that resources were used effectively. Involvement of people, QA/QC training, planning and project control techniques also had a positive impact on quality of

implementation. The outcome of this study provides a standard for further study to identify the foremost indicators of quality road construction project consisting of both technical aspects and organisational. Developing a road quality assurance tool of the construction project delivery through a software which incorporates the technical and organisational aspects of industry exercise is a clear way forward.

Conflict of interest

The authors of this study certify that they have no conflict of interest in the subject matter or materials discussed in this study.

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