Key performance indicators of value management in the Sri Lankan construction industry

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Abstract

Value management (VM) enhances the value of construction projects. However, presently there is no tool available to measure the performance of VM. Hence, this research was aimed to investigate the key performance indicators (KPIs) of VM in the construction industry in Sri Lanka. The scope was limited to probing only the KPIs of VM in the pre-construction stage. The research used a mixed research approach consisting of 10 semi-structured interviews and a questionnaire survey conducted among 70 professionals. Findings were analyzed using content analysis and mean weighted rating. Elemental design stage was found to be the most appropriate stage for VM implementation. The most appropriate VM technique for each construction stage and the five best KPIs for that stage along with the 10 most significant KPIs for cost, time and quality were identified. The research recommends considering these KPIs when implementing VM techniques in different stages of construction.

Introduction

Construction works involve building of new structures and activities related to land preparation for new constructions or land subdivision for sale (C¸elik et al. 2017). Construction projects have to be strategically managed by recognizing and realizing their values and using proper construction management methods and tools (Ford et al. 2002). According to Emmitt et al. (2005) and Martinsuo and Killen (2014), the final objective of all construction projects will be to achieve value. In the light of this, construction organizations often get tempted to employ different value creating logics with different cost and value drivers (Bygballe and Jahre 2009). Value management (VM) when employed in construction projects seeks to achieve a balance between cost, time and quality (Rangelova and Traykova 2014). On the other hand, Kelly et al. (2004) have considered VM as a process, which enhances the value for money starting at the concept phase and ending at the operation and use phase. According to Salem-Mhamdia and Ghadhab (2012), VM is a structured, systematic and analytical process that seeks to achieve value for money by providing all necessary functions at the lowest total cost consistent with the required levels of quality and performance. The need for VM arises when it is necessary to address the factors that contribute to poor value in projects so that more value for money could be obtained by enhancing project performance and removing unnecessary costs (Shen and Yu 2016). According to Oke and Aigbavboa (2017), VM has been introduced to obtain best function at the lowest possible overall cost. Enhancing value for money is the main purpose of VM as identified from various definitions. It is accomplished by delivering all necessary functions at the lowest life cycle cost while ensuring quality and performance of the product or the resource.

Mainstream literature confirms the inadequacy of the presently available tools and techniques to measure the success of projects and raises concerns about the value and effectiveness of project management (Mir and Pinnington 2014). Measuring the performance of construction projects is essential to identify the effectiveness of VM in improving construction project performance and cost effectiveness (Al-gahtani et al. 2015). The need for measuring construction project performance has led to the development and implementation of various key performance indicators (KPIs) (Haponava and Al-Jibouri 2009). A rigorous measurement of the performance of VM studies can improve the implementation of VM and enhance the confidence of clients about their investment in VM (Lin et al. 2011). The mainstream literature offers several studies that have been conducted on measuring performance of VM in construction projects. Some of these studies done by Lin and Shen (2007, 2010), Lin et al. (2011) and Al-gahtani et al. (2015) are on the use of KPIs in the construction industry for performance measurement of VM. However, these studies are focused more towards developed countries with little relevance to developing countries. The construction industry of a developed country is different from that of a developing country just as much a developed economy will be different from a developing economy. Thus, there is a need to conduct a study on VM in the developing countries as well. In Sri Lanka, which is still a developing country, VM is being implemented in an ad hoc manner (Perera et al. 2006). Karunasena and Gamage (2017) have also asserted that there is no pre-defined method to apply VM in the Sri Lankan construction industry. Therefore, the focus of this study was to identify the KPIs that will measure the performance of VM in the Sri Lankan construction industry. The findings of this study will be useful for enhancing VM practices in other developing countries as well.

Gidado (2004) considered the pre-contract phase of a project as having a majority of problems and that only good pre-construction planning can lead to the successful delivery of a project. Potts and Ankrah (2013) have highlighted the importance of using VM in this pre-contract phase of a project. According to Male (1998), VM brings into focus the overriding importance of an

early and comprehensive project briefing which has to involve all project stakeholders. The scope of the research was therefore confined to the pre-contract phase of construction projects. The research problem can be stated as 'What are the KPIs of VM in the construction industry in Sri Lanka?' The research objectives were to (1) determine the most suitable stage for VM in the pre-contract phase of construction, (2) identify the VM technique most suitable for each stage of construction, (3) identify the KPIs most suitable for each technique and (4) identify the KPIs significant to PM indicators (time, cost and quality).

Literature review

Value management process

VM provides opportunities to maximize the functional value and reduce the life cycle cost of a project by removing its unnecessary costs and ensuring that its quality, reliability and performance achieve value for money (Dell 'Isola 1997; Potts and Ankrah 2013; Shen and Yu 2016; Oke and Aigbavboa 2017). A systematic VM will offer a job plan, which can provide guidance to effectively address the issues that can arise throughout a building's life cycle (Jaapar et al. 2012; Shen and Yu 2012, 2016). This job plan commonly known as the value engineering (VE) job plan has been discussed in many forms varying from five to eight phases (Chhabra and Tripathi 2014). The three major stages of a VM process according to SAVE (1998), Yan (2012) and Rad and Yamini (2016) are pre-VM workshop stage, VM workshop stage and post-VM workshop stage. The SAVE International's Standard Job Plan (SAVE 2007) consists of six phases identified as information gathering, function analysis, creativity, evaluation, development and presentation phases.

Value management techniques

VM techniques are often used in projects when the exact project goals have not been identified (Leung et al. 2002). The VM techniques identified by Lin and Shen (2007) are 'functional analysis system technique (FAST)', 'functional analysis', 'simple multi-attribute rating technique (SMART)', 'value drivers', 'creative techniques', 'value for money', 'target costing', 'cost/worth', 'value profiling' and 'weighting techniques'. VM techniques considered by Dallas (2008) are 'value drivers', 'value for money' and 'target costing'. The VM techniques identified by Coetzee (2009) are 'functional analysis', 'quality modelling', 'risk modelling', 'choosing by advantage (CBA)' and 'life cycle costing'. 'Functional analysis' was considered as a VM technique by Fernandes (2015) as well.

Value studies of a project can be carried out at any stage of the project starting from its inception through its development to construction. Shen and Yu (2016) asserted that a well-planned VM programme should yield a reduction of 10–25% in the life cycle cost and that the cost of using VM in the project is less than 1% of the life cycle cost. However, the earlier the application of VM, the higher will be the probability of acceptance of value proposals, since previous studies reveal that higher the cost of application, lower is the probability of acceptance of proposals (Ilayaraja and Eqyaabal 2015). As identified by Locke (1994), inception, concept design, scheme design, elemental design and procurement stages are the stages in the pre-contract phase of a construction project in which VM can be applied.

Inception is the stage that can improve the value of a project most, as it is during this stage that the commitment on the construction and the costs and funding is made (Coetzee 2009). Furthermore, Abdulaziz (as cited in Abdullah and Arabiyyat 2016) identified three different design stages where VM could be applied. The first stage is the planning stage at which the functions and requirements of the project are established. The second stage is when 15–3% of the design has been completed and in the third stage 80–85% of the design has been completed. Kelly and Male (1993) also opined that the best time to apply VM is when approximately 35% of the design has been completed. Corrections or objections to the design or any other element done during briefing and design stages and once the construction has commenced, there will be less opportunities to alter the costs which even if altered will be expensive (Rangelova and Traykova 2014). Because of these reasons, the implementation of VM techniques at the later stages will provide less benefits and will also cause interruption to the construction process (Coetzee 2009). Thus, it is clear that all of the techniques cannot be used in all the stages and that it is important to identify the most suitable technique for each stage to get the maximum outcomes at each such stage.

Past research on performance measurement of value management in construction projects

Performance measurement (PM) is defined as the process by which the success of past activities is quantified (Neely et al. 2002). Many terms such as performance measurement, performance evaluation, performance

measures, performance metrics, key performance indicators and critical successful factors have been used in developing PM (Ramly and Lin 2016). Continuous measurement of VM performance will benefit the construction projects as it will ensure the most efficient implementation of VM (Al-gahtani et al. 2015). By considering objective indicators and subjective indicators, which are used in measuring the process of VM, Male (1998) formulated a VM benchmarking methodology. It was further developed by Palmer et al. (1996). A framework for benchmarking the VM process has been introduced by Fong et al. (2001) in one of their studies. Shen and Liu (2003) have identified and ranked critical success factors of VM studies on construction projects. Lin and Shen (2006) have developed a performance measurement framework for VM studies with distinct features based on the time and resource limitations encountered in the VM studies undertaken in the construction industry. Even though the available literature offers value to construction industry, only a few studies have focused on measuring the performance of VM during each stage of a project by implementing PM.

According to Lin et al. (2011), KPIs can play a major role in measuring the performance of VM. Many European construction organizations are now using the KPIs developed by the construction best practice programme in the late 1990s (KPI Group 2000). In the studies done by Lin and Shen (2007, 2010), Lin et al. (2011) and Al-gahtani et al. (2015), 27 KPIs for measuring VM performance in the construction process as a whole have been identified. The traditional practice, which is employed to evaluate the construction project performance is based on the factors – cost, quality and time – which form the so called 'iron triangle' (Ramly and Lin 2016; Koops et al. 2017). Measurements on how well the VM techniques are reaching certain standards and achieving project objectives depend on the KPIs. Therefore, identifying the KPIs suitable for each technique is essential for project success. However, there is very little research available on the KPIs related to these PM indicators in construction with respect to the stages in which different VM techniques are implemented.

Research methodology

Kothari (2004) identified research methodology as a dynamic process that can solve research problems. According to Zou et al. (2014), mixed method contains several different research methods, inductive as well as deductive, and it encourages iteration between theory and practice. Johnson and Onwuegbuzie (2004), Neuman (2011) and Teddlie and Tashakkori (2003) have stated that the mixed method also takes into account the weaknesses and the problems of mono methods to improve the validity and reliability of results of a research and enrich the comprehension of the studied phenomenon and emergence of new dimensions. Mixed method was therefore identified as the most suitable approach for this study, which has as its research problem the identification of the KPIs that can be used to measure VM performance in construction projects.

Table 1. Profiles of the participants of the semi structured interviews.

Interviewee code	Interviewee designation	Experience (years) (private/state)	Organization category (consultant/contractor)	Organization type
A	Chairman	20–25	Consultant	Private
B	Chief Quantity Surveyor	20–25	Consultant	Private
C	Managing Director	20–25	Consultant	Government
D	Assistant General Manager	20–25	Consultant	Government
E	Chairman	25–30	Consultant	Private
F	Chief Quantity Surveyor	20–25	Consultant and Contractor	Government
G	Chief Quantity Surveyor	20–25	Contractor	Private
H	Chief Quantity Surveyor	20–25	Contractor	Private
I	General Manager	25–30	Contractor	Private
J	Chief Quantity Surveyor	30–35	Contractor	Private

A literature synthesis was first undertaken to get an understanding about VM and how its performance can be measured. Tharuk (1992) explained that expert opinions and views that are difficult to be obtained directly from experts can be collected through semi structured interviews, which is a form of qualitative approach. Therefore, the qualitative approach consisting of semistructured interviews was used in this study as a preliminary survey to find out from experts, the applicability to Sri Lanka of the literature findings on VM techniques and the VM process, construction project stage most suitable for using VM and the KPIs most suitable to measure VM performance. Because of the dearth of subject experts in the country, only 10 experts could be identified for the semi structured interviews. The construction industry experience of all the experts,

who participated in these interviews was reported as above 20 years. Data gathered from the semi-structured interviews were analyzed using NVivo 11 code based content analysis software and interview findings were used to develop the questionnaire used in the subsequent survey.

According to Creswell (2003), data collection in quantitative research can be done using a questionnaire survey, which can find out about the attitudes of survey participants on a particular subject to statistically analyze the data gathered. Generally, a sample size between 30 and 500 at a 5% confidence level will be adequate for many researches (Borg and Gall 1979; Altunı¸sık et al. 2004). The questionnaire survey was conducted by distributing a detailed questionnaire among 150 professionals practicing in the Sri Lankan construction industry. Through this, the most suitable stage of construction at which VM could be used, the VM technique most suitable for each stage of construction, the KPIs most suitable for each technique and the KPIs significant to the PM indicators were determined.

Roszkowska (2013) described mean weighted rating (MWR) as a data analysis technique which is convenient and simple to understand by decision makers and useful to rank a set of factors to identify the most significant factor among them. Ekanayake and Perera (2016) have used MWR to evaluate the data they have collected in their respective researches to find out the criticality of the relevant issues along with the importance of different solutions possible. They have used the following formula to compute MWR:

$$MWR = \frac{\sum V_i F_i}{N} \quad (1)$$

where MWR ¼ mean weighted rating for an attribute; F_i ¼ frequency of responses in the range of 1–5, V_i ¼ rating of each KPI and N¼ total number of responses.

In this study too, MWR was used to analyze the data collected from the questionnaire survey. Cronbach's Alpha measures the consistency among different items in a scale (Nunnally and Bernstein 1994; Gliem and Gliem 2003; Mohsen and Reg 2011). Santos et al. (1998) have stated that Cronbach's Alpha is a measure of how well each individual item in a scale correlates with the sum of the remaining items. Since Alpha was above 0.7 for the data set collected in this study, the data collected was considered as reliable (Cronbach 1951).

Research findings

Findings of the preliminary survey conducted through semi-structured interviews

The profiles of the semi-structured interview participants are present in Table 1.

The stages of the pre-contract phase of a construction project life cycle in which VM can be employed were identified as inception, concept design, scheme design, elemental design and procurement stages. Seven (7) important VM techniques that were identified from the studies of Lin and Shen (2007), Dallas (2008), Coetzee (2009) and Fernandes (2015) were validated using the semi-structured interviews. The VM techniques identified were FAST, 'functional analysis', 'SMART methodology', 'value drivers', 'creative techniques', 'value for money' and 'target costing'. Even though 'SMART methodology' is not practiced in Sri Lanka, the experts believed that all seven techniques are suitable for Sri Lanka.

Twenty-seven (27) KPIs were identified from the studies of Lin and Shen (2007, 2010), Lin et al. (2011) and Al-gahtani et al. (2015). All interviewees agreed with these KPIs. They however wanted to add five more KPIs: 'saving construction time period', 'reducing construction cost', 'response of the participants', 'use of different construction methods' and 'use of different materials'. All 32 KPIs were used to develop the subsequent questionnaire.

Table 2. Profiles of the respondents of the questionnaire survey.

Work experience	Designation	Profession	
		Chartered Engineers	Chartered Quantity Surveyors
5–10 years	Quantity Surveyor, Engineer	10	12
11–15 years	Senior Quantity Surveyor, Senior Engineer	8	10
16–20 years	Chief Quantity Surveyor, Chief Engineer	6	7
21–25 years	Contracts Manager	–	3
>25 years	Director, Managing Director	9	5
		33	37

Profiles of the questionnaire respondents

Out of the 150 prospective participants, who were requested to take part in the questionnaire survey, 70 answered the questionnaire giving a response rate of 46.7%. The profiles of the respondents are presented in Table 2.

From the questionnaire survey, the most suitable stage of the pre-contract phase of construction during which VM could be used was identified and the KPI's were ranked against the VM techniques for the different stages. The VM techniques were also ranked against the VM usage in different stages of construction projects. Subsequently, KPIs were ranked against the PM indicators: time, cost and quality.

Most suitable VM techniques and five most significant KPIs of each stage of construction

The construction project phase most suitable for VM implementation is the pre-contract phase. The suitability of the stages of this phase in the descending order of their degree of suitability are elemental design stage, procurement stage, scheme design stage, concept design stage and inception stage with MWRs of 2.21, 1.99, 1.75, 1.50 and 1.37, respectively. The most suitable VM technique and the five most suitable KPIs that were identified for each stage are present in Table 3. 'FAST', 'functional analysis', 'target costing' and 'value for money techniques' are found to be the four techniques that have the four highest MWRs.

'Target costing' has the highest MWR and is therefore the best technique that can be used during the inception stage. This can be mainly because of the need to have cost margins to sustain the profitability of projects and the need to implement actions to gain the expected functionality without creating adversarial or confrontational circumstances. The highest ranked KPI for 'target costing' is 'clear objectives'. It is also the highest ranked KPI for the VM techniques, 'value for money', 'value drivers', 'functional analysis' and 'creative techniques'. It is during the inception stage that the strategic brief is prepared based on the client's requirements. Therefore, 'clear objectives' will be highly effective for the success of a construction project from its outset. The rankings of the VM techniques and the KPIs of the concept design stage are given in Table 4.

'Functional analysis' is ranked as the best VM technique that can be used during the concept design stage. The concept of a project is designed using client's requirements. Therefore, developing the conceptual design based on the initial project brief requires the analysis of functions in respect of several project strategies. Hence, 'identifying and clarifying the client's requirement' will be the best KPI of the functional analysis technique. It is also the highest ranked KPI for 'FAST' and 'SMART methodology' in which all functions have to be satisfied to fall in line with the concept of the client. During this stage, the performance of VM can be measured based on the requirements that have been fulfilled and the clarifications provided by the client. Any additional alternative that can be considered will help to increase the value of the project. Table 5 gives the rankings of the techniques and the KPIs of the scheme design stage.

'FAST' has been ranked as the best VM technique for the scheme design stage. During this stage which involves the crucial development of a design, the analysis of the functions will generate design alternatives and enhance the value of the project. In order to conduct a critical analysis of the functions, the background information collected will play a vital role. Thus, 'background information collected' has become the highest ranked KPI for 'FAST'. It is also the highest ranked KPI for 'SMART methodology' as well, indicating that it has a high impact on alternatives possible for functional improvement. The rankings of the techniques and the KPIs of the elemental design stage are present in Table 6.

The 'value for money technique' in the elemental design stage has the highest MWR. Since, the elemental design stage is the final stage of the project design, it is primarily focussed on giving additional value to

Table 3. VM techniques and KPIs in the inception stage.

Technique	Ranking	MWR	KPIs	MWR	Ranking
Target costing	1	4.00	Clear objectives	2.22	1
			Deliberating the alternatives	2.20	2
			Reduced construction cost	2.16	3
			Proposed changes to project investment	2.12	4
			Support received from stakeholders	2.10	5
FAST	2	3.76	Client's participation	1.66	1
			Clear objectives	1.64	2
			Support received from stakeholders	1.62	3
			Clarified client's objectives	1.60	4
			Disciplines of the participants	1.58	5
Value for money	3	3.16	Clear objectives	2.26	1
			Proposed changes to project investment	2.24	2
			Deliberating the alternatives	2.20	3
			Proposed changes to life-cycle cost	2.18	4
			Reduced construction cost	2.10	5
Value drivers	4	2.60	Clear objectives	2.00	1
			Client's support	1.98	2
			Participants' response	1.94	3
			Proposed changes to project investment	1.92	4
			Reduced construction cost	1.86	5
SMART methodology	5	2.46	Client's support	2.18	1
			Clear objectives	2.16	2
			Participants' response	2.12	3
			Proposed changes to project investment	2.08	4
			Reduced construction cost	2.06	5
Functional analysis	6	2.42	Clear objectives	2.48	1
			Client's support	2.46	2
			Primary functions/processes identified	2.44	3
			Deliberating the alternatives	2.40	4
			Participants' satisfaction	2.34	5
Creative techniques	7	2.06	Clear objectives	2.30	1
			Client's support	2.28	2
			Primary functions/processes identified	2.24	3
			Participants' response	2.22	4
			Acceptability of the techniques used in each phase	2.16	5

Creative techniques: Evaluate the ideas generated by creating common evaluation criteria. Functional analysis system technique (FAST): Links functions logically and allows to use a common language. Functional analysis: Analyses the functions of the constituent parts of a project.
Simple multi-attribute rating technique (SMART): Uses the concept of a value tree to link functions and

clients′ money by using the alternatives generated during the preceding stage. Therefore, ‘return on investment (ROI)′ of VM has become the highest ranked KPI for ‘value for money′. The highest ranked KPIs for each VM technique used in the elemental design stage differ from one another. ‘Reduced construction cost′ is however ranked highest for the two VM techniques, ‘target costing′ and ‘value drivers′, since construction cost reduction is perceived as an objective of VM in the construction industry of Sri Lanka. The rankings of the techniques and the KPIs of the procurement stage are present in Table 7.

It is evident from the values obtained for MWR that ‘value for money′ is the best VM technique that can be used at the elemental design stage as well as at the procurement stage. Providing best value for client′s money is considered as vital when awarding a contract to a party. ‘Support received from stakeholders′ has therefore become the highest ranked KPI of the procurement stage. Once the design phase has been completed and before construction is commenced, the participation of the relevant stakeholders will become important during the pre-contract phase. It is also found to be the major KPI of ‘creative techniques′ because stakeholders provide creative ideas to the project.

Top five KPIs significant to the PM indicators

Time, cost and quality are the three main PM indicators considered when evaluating the performance of a construction project. Respondents were asked to identify the 10 KPIs, which are most significant to each PM indicator. The top five KPIs among them were

Table 4. VM techniques and the KPIs in the concept design stage.

Technique	Ranking	MWR	KPIs	MWR	Ranking
Functional analysis	1	3.86	Identifying and clarifying client's requirements	2.16	1
			Client's support	2.14	2
			Primary functions/processes identified	2.12	3
			Client's satisfaction	2.08	4
			Support received from stakeholders	2.06	5
FAST	2	3.80	Identifying and clarifying client's requirements	1.80	1
			Client's participation	1.78	2
			Client's support	1.76	3
			Client's satisfaction	1.72	4
			Improving project quality	1.70	5
Target costing	3	3.78	Proposed changes to life-cycle cost	1.96	1
			ROI of VM study, i.e. proposed savings/cost of VM	1.94	2
			Deliberating the alternatives	1.90	3
			Reduced construction cost	1.88	4
			Participants' satisfaction	1.86	5
SMART methodology	4	2.98	Identifying and clarifying client's requirements	2.16	1
			Client's participation	2.14	2
			Client's support	2.12	3
			Client's satisfaction	2.08	4
			Support received from stakeholders	2.06	5
Value for money	5	2.74	Proposed changes to life-cycle cost	1.90	1
			Proposed changes to project investment	1.88	2
			Reduced construction cost	1.86	3
			Saving construction time period	1.80	4
			Improving project quality	1.78	5
Value drivers	6	2.40	Deliberating the alternatives	1.72	1
			ROI of VM study, i.e. proposed savings/cost of VM	1.70	2
			Primary functions/processes identified	1.68	3
			Reduced construction cost	1.64	4
			Qualification of the facilitator	1.60	5
Creative techniques	7	2.28	Deliberating the alternatives	2.66	1
			Primary functions/processes identified	2.64	2
			Proposed changes to life-cycle cost	2.60	3
			Client's satisfaction	2.58	4
			Support received from stakeholders	2.50	5

See footnote of Table 3.

selected for ranking. In Table 8, the rankings of the KPIs are presented.

'Saving construction time period' is the highest ranked KPI of the PM indicator time, probably because the prevention of time overruns can create a significant effect on successful performance of the project. One of the benefits that can be obtained through VM is time saving. 'Proposed changes to project investment' and 'reduced construction cost' are the next two most highly ranked KPIs, which can have an effect on construction duration and which will be useful in avoiding liquidated damages due to construction delays.

With regard to the cost of a project, 'reduced construction cost' is found to be the highest ranked KPI that can be employed for the measurement of the performance of VM. In Sri Lanka, VM is popular as a cost cutting or cost saving exercise. Hence, 'reduced construction cost' which results from VM implementation will indicate cost savings. The 'proposed changes to project investment' can enhance the cost saving potential and the prevention of time overruns will help to avoid cost overruns.

Quality can be measured using mainly the KPI, 'client's satisfaction' because the ultimate goal of a construction project will be to meet the client's requirements. In order to do so, it is necessary to seek clarifications of client's objectives. Hence, the extent to which client's objectives can be clarified and the identification of the client's requirements will also affect project performance. By employing VM in construction projects, it is expected to reduce costs, prevent time overruns and improve the quality of the projects.

Discussion

The significance of this research can be ascertained by revisiting the literature findings and analyzing the research findings. Male (1998) emphasized the application of VM at the early stages of a project and Potts and Ankrah (2013) have pointed out the importance of the use of VM in the pre-contract phase of a project. Although according to Coetzee (2009), the inception stage in the pre-contract phase is the best stage in which VM could be implemented in a project, this research indicates that it is the elemental design stage, which is the best stage to employ VM in Sri Lankan construction projects and that the

Table 5. VM techniques and the KPIs in the scheme design stage.

Technique	Ranking	MWR	KPIs	MWR	Ranking
FAST	1	3.56	Background information collected	2.32	1
			Identifying and clarifying the client's requirements	2.30	2
			Having a good, clearly defined agenda and a workshop preparation checklist	2.28	3
			Reduced construction cost	2.24	4
			Support received from stakeholders	2.20	5
Value for money	2	3.42	Primary functions/processes identified	2.02	1
			ROI of VM study, i.e. proposed savings/cost of VM	2.00	2
			Proposed changes to life-cycle cost	1.98	3
			Reduced construction cost	1.94	4
			Proposed changes to project investment	1.9	5
Functional analysis	3	3.10	Reduced construction cost	2.02	1
			Deliberating the alternatives	2.00	2
			Identifying and clarifying the client's requirements	1.98	3
			Saving the construction time period	1.94	4
			Clear objectives	1.90	5
Target costing	4	3.04	ROI of VM study, i.e. proposed savings/cost of VM	1.88	1
			Reduced construction cost	1.86	2
			Primary functions/processes identified	1.84	3
			Participants' satisfaction	1.80	4
			Proposed changes to life-cycle cost	1.78	5
Value drivers	5	2.92	Deliberating the alternatives	2.04	1
			Background information collected	2.02	2
			Identifying and clarifying the client's requirements	2.00	3
			Reduced construction cost	1.96	4
			Qualification of the facilitator	1.94	5
SMART methodology	6	2.72	Background information collected	1.88	1
			Identifying and clarifying the client's requirements	1.86	2
			Having a good clearly defined agenda and a workshop preparation checklist	1.84	3
			Reduced construction cost	1.82	4
			Participants response	1.78	5
Creative techniques	7	2.66	Deliberating the alternatives	2.68	1
			Having a good clearly defined agenda and a workshop preparation checklist	2.66	2
			Reduced construction cost	2.60	3
			Primary functions/processes identified	2.58	4
			Client's objectives clarified	2.56	5

See footnote of Table 3.

implementation of VM in the inception stage should be considered last. This research confirms the opinion of Kelly and Male (1993), which expresses that the best time to apply VM is when approximately 35% of the design has been completed. Hence, both the findings of this research and the literature confirm that VM has to be applied during the early stages of a project.

Past researchers like Lin and Shen (2007), Dallas (2008), Coetzee (2009) and Fernandes (2015) have discussed in general various VM techniques. According to the findings of this research, 'FAST', 'functional Analysis', 'creative techniques', 'value for money', 'target costing' and 'value drivers' are the VM techniques most suitable for Sri Lanka. However, none of the past researchers have ranked the VM techniques for each stage of the pre-contract phase of a project to find out the VM technique that best suits each stage. In this context, this research adds value to Sri Lankan construction projects by identifying the VM technique most suitable for each stage of the pre-contract phase of a project.

Lin and Shen (2007, 2010) and Lin et al. (2011) have identified KPIs suitable for VM in the construction industry in Hong Kong, while Al-gahtani et al. (2015) have investigated the KPIs of VM in the construction industry in Saudi Arabia. While substantiating the findings of the above research studies mentioned, this research has made it possible to identify five more KPIs that are applicable to Sri Lanka. By using an approach different from those taken by the past researchers, the KPIs most suitable for each VM technique were ranked for the inception, concept design, scheme design, elemental design and procurement stages of a project to customize them to the Sri Lankan construction industry. In the past, PM of VM only aimed to improve functions and cost savings of a project (Koops et al. 2017). The PM framework introduced by Kelly and Male (1993) and further developed by Palmer et al. (1996) measures the VM performance only in relation to cost reduction. However, this research has ranked KPIs of VM against all three PM indicators, cost, time and quality. Hence, this research presents significant findings pertaining to the measurement of performance of VM in Sri Lankan construction projects.

Conclusions and recommendations

VM seeks to achieve all functions required by a construction project at the lowest possible cost while

Table 6. VM techniques and the KPIs in the elemental design stage.

Technique	Ranking	MWR	KPIs	MWR	Ranking
Value for money	1	4.04	ROI of VM study, i.e. proposed savings/cost of VM	1.80	1
			Client's objectives clarified	1.78	2
			Deliberating the alternatives	1.76	3
			Reduced construction cost	1.70	4
			Proposed changes to project investment	1.68	5
Target costing	2	3.98	Reduced construction cost	2.08	1
			Proposed changes to project investment	2.06	2
			Deliberating the alternatives	2.04	3
			Participants' satisfaction	2.00	4
			Proposed changes to life-cycle cost	1.98	5
Functional analysis	3	3.86	Identifying and clarifying the client's requirements	2.82	1
			Background information collected	2.80	2
			ROI of VM study, i.e. proposed savings/cost of VM	2.76	3
			Reduced construction cost	2.74	4
			Support received from stakeholders	2.70	5
FAST	4	3.46	Primary functions/processes identified	2.28	1
			Client's objectives clarified	2.26	2
			Identifying and clarifying the client's requirements	2.20	3
			Reduced construction cost	2.18	4
			Support received from stakeholders	2.16	5
Value drivers	5	2.90	Reduced construction cost	2.04	1
			Proposed changes to project investment	2.00	2
			ROI of VM study, i.e. proposed savings/cost of VM	1.96	3
			Proposed changes to life-cycle cost	1.90	4
			Qualification of the facilitator	1.88	5
SMART methodology	6	2.84	Client's objectives clarified	2.00	1
			Primary functions/processes identified	1.98	2
			Identifying and clarifying the client's requirements	1.94	3
			Having a good , clearly defined agenda and a workshop preparation checklist	1.90	4
			Reduced construction cost	1.88	5
Creative techniques	7	2.78	Support received from stakeholders	2.28	1
			Background information collected	2.26	2
			Client's objectives clarified	2.24	3
			Having a good clearly defined agenda and a workshop preparation checklist	2.20	4
			Reduced construction cost	2.18	5

See footnote of Table 3.

complying with the stipulated levels of quality and performance. VM, which has started to gain popularity in the construction industry in Sri Lanka is presently practiced in the country in an ad hoc manner. Elemental design stage was identified as the most suitable stage in which VM can be implemented in the pre-contract phase of construction project spanning from inception to procurement stages.

The VM technique most suitable for each stage of the project was also identified. 'target costing', 'functional analysis', 'FAST' and 'value for money' were found to be the VM technique most suitable for the inception stage, concept design stage, scheme design stage, elemental design stage and procurement stage, respectively.

KPIs most suitable for the VM techniques at each stage of the project were first identified and the five KPIs among them that best measure the performance of different VM techniques were ranked for the inception, concept design, scheme design, elemental design and procurement stages. Some of the highest ranked KPIs were 'support received from stakeholders', 'reduced construction cost', 'background information collected', and 'ROI of VM study'. The most suitable KPIs identified in this study are similar to those identified in studies related to Hong Kong and Saudi Arabia. Therefore, findings of this study can be used as a first step for research studies in other countries.

The top ranked KPIs for measuring the PM indicators – cost, time and quality of a project are 'saving the construction time period', 'reduced construction cost' and 'client's satisfaction', respectively.

It is recommended that these research findings be made use in the systematic implementation of VM in construction projects, particularly in the pre contract phase. The VM technique most suitable for each project stage should be identified based on its ranking. It is also recommended to conduct VM workshops before the construction phase of a project commences as design phases can play a vital role in the effective implementation of VM.

Limitations of the study

The current study examined only five KPIs that are most suitable for each VM technique and the KPIs related to PM indicators were ranked only for the

Table 7. VM techniques and the KPIs in the procurement stage.

Technique	Ranking	MWR	KPIs	MWR	Ranking
Value for money	1	4.04	Support received from stakeholders	1.80	1
			Deliberating the alternatives	1.78	2
			Reduced construction cost	1.76	3
			ROI of VM study, i.e. proposed savings/cost of VM	1.72	4
			Acceptability of the techniques used in each phase	1.70	5
Target costing	2	3.98	Reduced construction cost	1.60	1
			Proposed change to project investment	1.58	2
			Support received from stakeholders	1.54	3
			ROI of VM study, i.e. proposed savings/cost of VM	1.52	4
			Acceptability of the techniques used in each phase	1.50	5
Functional analysis	3	3.86	Reduced construction cost	3.02	1
			Proposed change to project investment	3.00	2
			Deliberating the alternatives	2.98	3
			ROI of VM study, i.e. proposed savings/cost of VM	2.94	4
			Saving the construction time period	2.50	5
FAST	4	3.46	Background information collected	3.14	1
			Identifying and clarifying the client's requirements	3.12	2
			Improving the project quality	3.08	3
			ROI of VM study, i.e. proposed savings/cost of VM	3.06	4
			Reduced construction cost	2.98	5
SMART methodology	5	2.90	Background information collected	2.98	1
			Identifying and clarifying the client's requirements	2.96	2
			Improving the project quality	2.92	3
			ROI of VM study, i.e. proposed savings/cost of VM	2.90	4
			Reduced construction cost	2.84	5
Value drivers	6	2.84	ROI of VM study, i.e. proposed savings/cost of VM	2.22	1
			Identifying and clarifying the client's requirements	2.20	2
			Client's objectives clarified	2.16	3
			Background information collected	2.14	4
			Participants' satisfaction	2.10	5
Creative techniques	7	2.78	Support received from stakeholders	1.78	1
			Proposed change to project investment	1.76	2
			Participants response	1.74	3
			ROI of VM study, i.e. proposed savings/cost of VM	1.70	4
			Improving the project quality	1.66	5

See footnote of Table 3.

stages in the pre-contract phase of construction projects ranging from inception to procurement. These can be considered as the limitations of the study. Another limitation is the limited number of experts in VM available in Sri Lanka and the limited number of questionnaire survey respondents which was due to the absence of VM applications in the construction industry of Sri Lanka. Hence, the results of the study have to be considered in the light of these constraints.

Table 8. Rankings of the five most suitable KPIs related to PM indicators.

PM indicator	KPIs	MWR value	Rank
Time	Saving construction time period	1.78	1
	Proposed changes to project investment	1.76	2
	Reduced construction cost	1.74	3
	ROI of VM study, i.e. proposed savings/cost of VM	1.70	4
	Acceptability of the techniques used in each phase	1.68	5
Cost	Reduced construction cost	2.18	1
	Proposed changes to project investment	2.16	2
	Saving construction time period	2.14	3
	Acceptability of the techniques used in each phase	2.10	4
	Proposed changes to life-cycle cost	2.08	5
Quality	Client's satisfaction	1.76	1
	Client's objectives clarified	1.74	2
	Identifying and clarifying the client's requirements	1.70	3
	Deliberating the alternatives	1.68	4
	Client's support	1.66	5

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