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Application of Value Engineering Concept to MEP Works in Sri Lankan Construction Industry: A Case Study

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Abstract
Mechanical, electrical and plumbing (MEP) systems are the life-blood of a building, which enhance functionality. However, the value of MEP works constitutes a large portion of construction cost. Due to increasing complex MEP systems and high cost, clients demand value for their money, while enhancing functionality. Value engineering (VE) is renowned as an approach for improving quality and functionality, while ensuring value for money. Therefore, this research investigates the application of VE to MEP works in Sri Lankan construction industry. A qualitative approach was adopted and three building projects, which have employed VE were selected for data collection through unstructured interviews, document review and observations. Subsequently, data were analysed using content analysis. The study revealed that the application of VE to MEP works has potential saving opportunities such as improvements in capacities, locations and material in MEP works. The challenges encountered include difficulty in identifying the possible scope for VE, poor attitude of people and lack of information. Most of the difficulties can be overcome if a formal value study process and a team with a trained facilitator is employed. The study recommends the use of VE to be more systematic and the awareness of the concept should be improved.

Keywords
Value Engineering; Mechanical, Electrical and Plumbing Works; Sri Lankan Construction Industry

1. Introduction

Construction is a large, multifaceted and dynamic industry with processes for building new structures and engineering projects (Çelik *et al.,* 2017). In construction projects, primary needs and functions for the activities in the constructed product are provided by the mechanical, electrical and plumbing (MEP) systems (Chen *et al.,* 2012). Kuo *et al*. (2011) indicated that MEP systems typically include air-conditioning, water supply, gas pipes, sanitary lines, telecommunication systems and security networks. Moreover, MEP systems are positioned in limited space, restricted by the design, construction and maintenance criteria provided for them (Clemente & Cachadinha, 2013). As per Khanzode (2010), the complexity of these systems has increased over the years with the rise in material costs and decline in skilled labour component required for MEP installation, even though owners are demanding projects to be completed faster at lesser cost. Khanzode *et al.* (2008) identified that cost of MEP and fire protection systems can escalate up to 50% of total project cost and it was also proved by Bosché *et al.* (2014) stating that a significant amount of construction cost is constituted by MEP works. Therefore, an extensive role of the construction sector is played by MEP works, in terms of cost and function and thereby for the value enhancement. Since quick delivery of projects is anticipated by the proprietors at a lesser cost, better strategies are constantly sought by the project teams to address these difficulties (Khanzode, 2010). In light of this, Ciocan and Onutu (2017) pointed out that the development of competitive construction firms towards a meaningful, durable and economic environment is enabled by value engineering (VE). Amongst various definitions for VE, Shu *et al.* (2010) defined VE as ‘‘the systematic application of recognized techniques which identify the function of a product or service, establish a monetary value for that function, and provide the necessary function reliability at the lowest overall cost”. Kalani *et al.* (2017) concluded that researchers have probed in to VE and its application in engineering subcategories. Regardless of the heightened application of VE in the construction industry, Zhang *et a.,* (2009) argued that the construction industry is practising VE in the same fashion as it was 50 years ago. Karunasena and Gamage (2017) substantiated this claim by explaining that VE concept and its applications are not well embraced by the construction sector of majority of developing countries. According to Nguyen and Luu (2016), 5–10% cost savings from construction projects are achieved through VE studies. Given the fact that a substantial portion of construction cost is compounded by MEP works, application of VE to MEP works would influence the value of a construction project to a great extent. This research therefore aims to investigate the application of VE concept to MEP works in building construction projects in Sri Lanka.

2. Literature Review

2.1 Significance of MEP works in construction projects

MEP systems perform core tasks in the architectural engineering by performing the most critical role in construction segment, of providing a comfortable, safe living environment (Guo *et al.,* 2013). According to Wong *et al.* (2016), MEP installations are proved to be vital to any construction project when considering the number of workers and companies involved, hence, takes an imperative part in the construction industry. Mechanical drawings, mechanical drafting and design services, and the knowledge of electrical and plumbing equipment are important to MEP systems (Baig *et al.,* 2015). MEP and related systems contribute to the construction costs in large portion (Palomera-arias, 2015) and vary with the facility type and its unique system requirements (Riley *et al*., 2005). MEP systems can contribute up to 50% of project value in technically challenging projects like those focused on high technology, healthcare and biotech industries (Khanzode *et al.,* 2008; Clemente and Cachadinha, 2013). In fact, Khanzode (2010) identified the percentage from project cost for MEP work may vary from 40% to 60% in modern day high technology driven projects, playing an important role on project performance and success. Pérez-Lombard *et al.* (2008) highlighted the high contribution of energy consumption in buildings by MEP works and Palomera-arias (2015) pointed out the high operational and maintenance cost of the work due to MEP systems. Bosché *et al.* (2014) contended that compared to structural works, tracking MEP components is challenging. This is primarily as a result of increased complexity in configurations and less flexibility of installation compared to structural components. Modelling tools in the MEP works are rarely implemented by contractors due to the high costs and limited time (Guo *et al.,* 2013). Therefore, it is evident that with the increment of demand for upgraded living in contemporary buildings, the MEP systems of building projects have become more complex and challengeable (Chen *et al.,* 2012). If the time, cost and quality of construction works and services are properly managed, the success of construction works can be achieved (Haddadi *et al.,* 2016).

2.2 Application of value engineering to construction industry

Despite the availability of various techniques, the cost and time objectives are not fulfilled by many construction projects (Olawale & Sun, 2010). Hence, a new methodology named value engineering (VE) has been introduced to the construction industry to increase efficiency and client satisfaction as client requirements have become more onerous (Austin & Thomson, 1999). However, since its introduction, VE has been well employed in construction industry, as it enables realisation of life cycle cost and cost effectiveness of projects, although its effectiveness as a management technique does not seem to be fully understood by construction industry (Omigbodun, 2001; Naderpajouh & Afshar, 2008; Kemmochi & Koizumi, 2012). After VE entered the construction industry, approaches have been developed by the combined effort of academic research and practitioners in order to fit the unique characteristics of the industry (Khaled & Pandey, 2016). Apart from VE applications to structural components, the application of VE job plan to mechanical works is described by Patel *et al.* (2014) by explaining the use of as-built status of pipes, conduit and ductwork critical for control and earned value measurement. Although the potential of application of VE has already been demonstrated for the construction industry, lack of proper investigation into its applicability to reduce cost and enhance functionality of MEP systems s evident.

VE has been effectively implemented in many developed countries, and the concept has become more relevant to developing country like Sri Lanka with one reason being the absence of proper cost control techniques such as cost planning in Sri Lankan construction industry (Perera *et al.,* 2003). Moreover, application of VE in Sri Lankan construction industry lacks systematic approaches (Karunasena & Gamage, 2017). The Authors further revealed that life cycle cost of a project is not considered before application of VE techniques and Sri Lankan contractors are forced to mainly focus on reducing cost through VE while time and quality is given relatively less consideration. Although there are few examples on the application of VE to structural components, there is lack of a study on the application of VE to MEP works in Sri Lankan construction industry. Hence, the study aims to investigate the application of VE to MEP works in Sri Lankan construction industry.

3. Research Methodology

This research administered a qualitative approach, as qualitative methods contribute to conduct in-depth investigation (Fellows and Liu 2008; Yin, 2011). Due to lack of application of the VE concept in construction projects in Sri Lankan construction industry, drawing a large sample of respondents for the data collection was constrained. Since the case study approach enables in-depth examination (Yin 2009), it was considered that case study approach would supplement and extend the in-depth investigation for this research. Multiple case study design was selected in order to obtain better results through cross-case analysis. Yin (2011) explained that criteria for selecting a case depend on the convenience, judgement, time and cost constraints. In this research, three (03) building projects, which have applied VE concept to MEP works were selected considering all the aforementioned factors. The following selected cases were procured under design and build method:

- a university building,
- an office building, and
- a mixed development project.

Yin (2009) pointed out several data collection techniques to be included in case studies research such as interviews, observations and document reviewing. Punch (2005) highlighted interview method as one of the most commonly used data collection method when the research embodies a qualitative approach. Employing un-structured interview method is preferred in qualitative approach since the respondents are given the opportunity to answer independently with a limited control imposed by the researcher (Dawson, 2007). Accordingly, un-structured interviews were conducted for collecting data focusing on selected respondents, who involved in the VE study of the MEP works. Moreover, observations and document reviews were undertaken to capture data. The contract documents of the projects, VE proposals, drawings, specifications and standard documents related to MEP works were the documents reviewed during the study. The locations of each case were visited by the researcher and the current situation of the cases was observed in terms of quality and functionality. The key details about the projects and the respondents are summarised in Table 1.

Table 1: Profile of the Cases and Respondents

Details of the Case	Details of the Respondent
Project A	
• Project A is a university for 2,000 students, built, with a gross floor area of 65,000m^2 • Project cost is LKR 10.5 billion and cost of MEP works is LKR 2.8 billion • Total project duration is 30 months	• A1: Chief Engineer-MEP Designs with 21 years of work experience • A2 : Electrical Engineer-Designs with 8 years of work experience • A3: Mechanical and electrical engineer with 6 years of work experience
Project B	
• Project B is a demolition of existing building and to develop a new office building (MEP works), with a gross floor area of 8,900 m^2 • Project cost is LKR 425 million and cost of MEP works is LKR 141 million • Total project duration is 12 months	• B1: Chief Engineer-MEP Designs with 5 years of work experience • B2 : Electrical Engineer-Designs with 4 years of work experience • B3: Mechanical and electrical engineer with 5 years of work experience
Project C	
• Project C is a mixed development project with a gross floor area of 92,903 m^2 • Project cost is LKR 15.2 billion and cost of MEP works is LKR 5.07 billion • Total project duration is 39 months	• C1: Manager-MEP with 22 years of work experience • C2 : Electrical Engineer with 12 years of work experience • C3: Mechanical engineer with 8 years of work experience

For qualitative researches, content analysis provides subjective interpretation of texts through a systematic coding and pattern (Hsieh & Shannon 2005). The research findings were analised using manual content analysis.

4. Research Findings

4.1 Value engineering applications in the MEP works

In all three (03) cases, VE activities were initiated by the contractor by considering the requirements of clients to reduce the cost and enhance the value of the project. Cost reduction, high possibility of improvement and ability of choosing a variety of options were the major reasons for undertaking VE exercise for MEP works. According to A1, *"since the project is an educational institute and the society's attention is towards the project and reducing costs was a major concern"*. Possible usage of developing technologies related to MEP works was another driver. Respondents also claimed that VE was the best method to reduce the project cost without affecting the functional requirements or without compromising the quality. B2 explained; *"it was identified that the best way to reduce the cost without impacting the functional requirements was to do VE to MEP works"*. The total number of active members in Case A, Case B and Case C are five (05), six (06) and seven (07) respectively, and each team was consisting of a team leader, designers, cost estimators and other specialists. Team leaders of both Case A and Case B were the chief MEP Engineer. In Case C, the team leader was the project manager. In Case A and Case C, VE workshops were conducted in the construction stage and pre-construction stage respectively whereas, Case C has conducted two workshops in pre-construction and construction stages. The duration of workshops has lasted from one (01) to ten (10) days.

In Case A, after the appointment of VE team, they first have taken a comprehensive understanding about the project in order to identify high cost areas. The evaluation criteria adopted was based on initial cost, operational cost, maintenance cost, maintainability and reliability. In Case B, before VE workshop has begun, the team has got together and collected all the required information. They have recalculated all load calculations related to MEP works and identified the areas of improvement. In each identified area the major functions were analysed to identify primary and secondary functions. The evaluation criteria was based on initial cost, maintenance cost, maintainability, availability, efficiency and durability. The initial preparation of VE activities were similar in Case C also, however, the VE workshop activities seemed more organised and formal in Case C compared to other two cases. They have prepared reports for each VE proposal with cost comparison and, supporting documents such as relevant drawings and specifications. The evaluation criteria were based on life cycle cost, maintainability, availability, durability and aesthetics. Decisions taken at the VE workshops related to MEP works are summarised in Table 2.

Table 2: Decisions Taken at the VE Workshop related to MEP Works

Before VE Workshop	Decisions Taken at VE Workshop
Project A	
1. Dual stack water distribution system with one line for carrying drinking water the other for carrying treated water	1. To use a single stack water distribution system.
2. Each building was having 2 overhead tanks	2. To have one OH tank in the main building thereby removing all the booster pumps
3. Use uPVC as pipe material	3. Use various pipe materials according to the requirement
4. 3,500kVA electricity requirement from Ceylon Electricity Board and 1,800kVA backup power system	4. 3,000kVA CEB connection and full backup power system.
5. Central air conditioning (A/C) system with three high capacity chillers at one location	5. Three optimum capacity chillers at three locations and use of VRF systems accordingly
Project B	
1. A single direct line to deliver water to the overhead tank	1. Use of a break tank at the middle floor of the building and making pump sizes reduced
2. Use of PPR for pipe material according to the initial pressure requirement of the OH tank	2. Use of uPVC for pipe material due to the reduction of pressure requirement
3. Pumping stations in the sewer system	3. Use of gravity disposal system
4. Copper (CU) cables for electrical wiring	4. Aluminium (Al) cables for wiring
5. Split A/C system	5. Central A/C system
6. Staircase pressurisation duct inside mezzanary duct	6. Staircase pressurisation only with duct
7. Galvanized iron (GI) ducts to be used in air conditioning system	7. Pre-insulated ducts to be used in air conditioning system
Project C	
1. Ductile iron pipes in basement floor	1. Use of PVC pipes with catch pits instead of joints
2. Two metering systems for commercial tenants and apartments	2. Single metering system for both types
3. Separate earthening lines coming from each floor to the earth	3. Use of combined earthening cable from the seventh floor to ground floor
4. Cu tapes as down conductors	4. Mild Steel (MS) rods, Structural rebar
5. GI conduits	5. To use a combination of GI and PVC Conduits
6. Separate systems for fire horse and wet riser system	6. Using a combined system for both the systems
7. Ducted system for apartment kitchen hood	7. Separated kitchen hood extractor in each place
8. Single zone hotel water supply system	8. Three-zone system

Before VE Workshop	Decisions Taken at VE Workshop
9. 80m^3 sewage holding tank	9. Direct disposal of sewage

In all three cases, VE study has not incurred much additional cost. However, the respondents highlighted about the unanticipated time consumption in the VE workshops. Despite the challenges, VE solutions have generated about 6%, 15% and 10-12% of cost saving from the total project costs of Cases A, B and C respectively.

4.2 Challenges in implementing value engineering to MEP Works

Implementing VE in MEP works was constrained due to many challenges as pointed out by the respondents. Most significant challenge was the difficulty in understanding the possible scope for VE. Difficulty in obtaining client's requirements was another significant challenge. A1 confirmed that "*even though we have identified some possible VE options at the pre-study phase where there were areas with high cost consumption, the client did not want the design to be changed from that aspect"*. Among the other challenges, difficulty in collecting all drawings and proper specifications was also highlighted. Difficulty in generating alternative ideas without compromising the quality was challengeable. B2 explained; *"sometimes they see that the original design is costly, but they cannot think about a way to reduce the cost without compromising the quality"*. Selecting the most impacting factor to be considered on evaluating alternatives was difficult. Moreover, if VE is proposed with cost increments it is very difficult to get approvals. Difficulty in keeping track of the implementation process was also pointed out. As explained by A2, *"after we complete the design, the project is not in our hands"*. Attitudes of the client and consultants are still not favouring VE concept restrains the creative execution of VE since they are not convinced of the true benefits of VE. Less awareness about VE and MEP works was a major challenge. C3 claimed; *"knowledgeable personals for both MEP works and VE are very rare in construction industry which is a huge barrier to the application of VE to MEP works"*. Lack of proper guideline and standard procedure for VE process in Sri Lanka is another barrier. Limited availability of resources also restrains the full potential of VE implementation. B1 explained; "*4-inch pipe and 6-inch pipe sizes are in Sri Lanka. But if the requirement is slightly more than 4 inches it cannot be gone with 4 inches but 6 inches is more than the requirement"*. Moreover, once the architect finishes the entire design, there is less opportunity for applying VE. Outdated standards in MEP works are challengeable. A3 pointed out; *"the standard values given in standards of various government authorities are outdated"*. The respondents have tried their best to overcome the aforementioned challenges to a great extent throughout the VE application process.

4.3 Strategies to optimise application of VE to MEP works

The strategies adopted by the respondents to overcome the challenges encountered are specific to the situation and can sometimes be generalised. Difficulty of understanding the possible scope was solved by informing the client and consultants frequently about the possible areas of VE. Since obtaining the exact requirement of the client is not possible, the team members sought client's approval when a possible application of VE is identified and by arranging meetings with the client. At the times when conducting meetings was not possible, verbal communication through telephone or electronic media were done. In order to get approvals, the proposals were incorporated with technical details and by arranging site visits and explaining using past project details. For the unavailability of the drawings, the teams had to contact consultant and request that information. When possible, alternative solutions cannot be made, the waste and non-value adding functions related to functions were removed to improve the designs. Preparing presentations in an understandable way to the client was the solution provided to overcome the lack of awareness about VE. Among the other strategies proposed, employing a VE facilitator to conduct a proper VE workshop was encouraged. Respondents were of the view that, this facilitator should be a person, who is aware of both MEP and VE concept. Changing the procurement process was suggested because implementation of VE during the concept design stage was well endorsed by the respondents. Hence it can facilitate the architect to formulate designs with the MEP design team. Beyond the project level, strategies such as creating formal education opportunities on VE and thus developing awareness and positive attitudes towards VE and updating outdated MEP related national standards was proposed. Moreover, the importance of introducing a standardised guideline for VE application in MEP works was also highlighted.

6. Conclusions and Recommendations

It can be inferred that the adoption of VE in the construction industry is still not developed to exploit the maximum benefits. Evidently, VE is applied in MEP projects in an ad-hoc manner and a formal process of VE workshop is not incorporated. Nevertheless, with the current level of applicability of VE to construction projects, major value improvements have been attained, primarily because all the MEP sections carry various opportunities for value improvement as identified through the case studies. Improving reliability of works is devised as the value achieving strategy used in all the MEP sections. The application of VE to MEP works has not only resulted in improving the value of construction by reducing cost and improving quality but also has reached to an optimum life cycle. VE teams encounter difficulties in adopting VE to MEP works majorly due to the absence of a proper VE team and a formal VE process in Sri Lankan context. But with the time and budgetary constraints and lack of assistance from regulatory bodies these situations are difficult to be overcome. Finally, it can be concluded that the Sri Lankan construction industry has proven the use of VE concept to MEP works to improve value for money regardless of the facts that the use of VE have to be developed more systematic and the awareness of the concept should be improved in order to get optimum use of the concept.

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