VALUE ENGINEERING DECISION MAKING MODEL USING SMART

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Abstract –

Value Engineering (VE) has a great potential to enhance project delivery. It has become a standard practice for many government agencies, private engineering firms and contractors since its first adoption. Decision makers judge the alternatives performance under selected criteria and simultaneously weighing the relative importance of the criteria in order to reach a global judgment. Multi-Criteria Decision Analysis (MCDA) has been widely used over the last several decades to reduce assessment subjectivity. One of MCDA methods is Simple Multi-Attribute Rating Technique (SMART). This paper presents a model that improves VE utilization through applying SMART to determine the optimum alternatives. A spreadsheet application was developed to automate the process of criteria and alternatives weighing and assessment. The proposed model has been applied to a case study project to show its capabilities and usage. The case study is a laboratory building in Doha, Qatar. It is a part of new Liquid Natural Gas (LNG) Support Campus. The structural slab system of the building was selected to be under VE study. The VE team selected four alternatives for the structural slab with nine performance criteria for evaluation. An in-depth structural analysis was conducted for all building structural elements such as columns and foundations to support the analysis process. The proposed model is expected to facilitate and support project managers in taking timely informed decisions.

Keywords –

Value Engineering, Simple Multi Attribute Rating technique (SMART), Criteria and Decision Making.

1 Introduction

Value Engineering (VE) was born out of necessity after world war II as a consequence of wartime shortages when, alternative materials were used in innovative designs that offered improved performance at lower cost. This led to research into means of achieving the function of the components by an alternative technique [14] and [17]. As the application of VE expanded, there was also a change in context, from review of existing parts to improving conceptual designs [26], [5] and [9] VE study is mainly divided into 3 main stages, which are pre-study stage, job plan stage and post study stage. The value methodology is a systematic process that follows the Job Plan. A value methodology is applied by a multidisciplinary team to enhance the value of a project through the analysis of performance criteria [4], and [21]. VE provides organizations with a definitive tool to enhance the value of product, project or process. Design/construction contractors have used this technique [19]. Generally, VE intends to find alternatives, which provide the same function at the minimum cost. Consequently, VE has been mainly considered as a cost saving tool with an objective vision of value [20]. However, many owners fail to implement VE because of a lack of experience, accountability, or motivation. Often VE is applied late in a project as a backup to cut costs, and the process can be difficult as it interrupts the flow of work, causes delays, requires extra design resources, and may result in the loss of critical design features [13] and [25].

Decision-making is the analysis of identified alternatives based on the values and preferences of the decision maker. While planning, it not only required to identify as many of these alternatives as possible but also to select the one that best fits with stakeholders' goals, objectives and requirements [1], [10], [11] and [3]. Multi-Criteria Decision Analysis (MCDA) is one of the techniques used by decision makers to evaluate criteria and alternatives. MCDA techniques have been an active part of the field of operation research for at least four decades [22] and [7]. Edwards and Barron [8] defined SMART as the method of rating alternatives and weighting criteria as a method, which is a simpler form of Multi Attribute Utility Theory (MAUT). SMART technique is based on a linear additive model, which calculates the overall value of a given alternative as the total sum of the performance score of each criterion multiplied with the weight of this criterion [16], [15] and [12] Major advantages of SMART are that it is simple to use and it actually allows for any type of weight assignment techniques (i.e., relative, absolute, etc.). It requires less effort by decision makers. It also handles data well under each criterion [23], [18] and [24]. SMART's common applications are in environmental, construction, transportation, logistics, military, manufacturing and assembly problems [6] and [2].

The purpose of this paper is to develop a decision-making model based on applying SMART methodology to assess criteria and alternatives in a quick simple process. Value engineering helps in developing better understanding and appreciation of the project scope of work and in reducing unnecessary cost without impacting the required functions of project components being considered. The model developed in this research can be of help to value engineering team members, design professionals and owners and stakeholders.

2 Proposed Methodology

The developed model provides users with an automated and comprehensive methodology and computational platform. It considers a wide range of criteria for evaluation and selection of the best alternatives that satisfy the owners' requirements. SMART calculations have been implemented to help VE team in assessing and ranking various alternatives of project items using multi-attributed criteria. Pre-study activities are conducted as a first step to get a clear view of the stakeholder's requirements, and to establish pre-defined priorities for the VE study. The main purpose of this phase is to achieve a basic level of understanding for the VE team members. After finishing pre-study stage, job plan stage is initiated, which is composed of six major sequential phases. Information phase starts by data collection to define the status of the project and the target of VE study. Function analysis follows information phase to define the main performance criteria. Restating and combining criteria, or omitting less important criteria is vital to focus on value-oriented functions. If the weight for a particular criterion is quite low, that criteria should not be addressed. There is no specific number of criteria appropriate for decisions. User should rank the importance of the changes in the criteria from the worst levels to the best levels. Ratio estimates of the relative importance of each attribute relative to the one ranked lowest in importance should be developed by user to be able to evaluate criteria efficiently.

User assigns points to the least important attribute. The relative importance of the other attributes is then evaluated by giving them points based on relative importance. The points given by the decision maker are normalized to get the weights. After calculating criteria weights, user defines several alternatives to attain the same functions. In SMART, ratings of alternatives are assigned directly, in the natural scales of the criteria. In order to keep the weighting of the criteria and the rating of the alternatives as discrete as possible, the various scales of criteria need to be converted into a common scale, which is done mathematically by the decision-maker by means of a value function. Simplest and most widely used form of a value function method is the additive model, which in the simplest cases can be applied using a linear scale (e.g. going from 0 to 100). Finally, after approving alternatives weights and ranking, development and presentation phases are conducted. Final VE report is prepared to assure final approval from customer. Implementation and follow up activities follow as last activities for post study stage, as shown in Figures 1.

After criteria definition, decision makers are asked to rank the importance of criteria from lowest to highest then relative importance scores are inserted by decision makers. For simplicity 0 - 100 scale is used where a score of 100 indicates extremely high importance and zero indicates virtually no importance. This scale is used to put score for each criterion based on the relative importance. Normalization process occurs to allow normalization of the relative importance into weights summing to one. During creative phase, alternatives are defined and decision makers are asked to rate alternatives against criteria. For example, when assessing the criterion "cost" for the choice between different alternatives, a natural scale would be a range between the most expensive and the cheapest alternative. Linear scale is used during this step based on each criteria property to calculate the final score for each alternative and to reach to a final global judgment and ranking for the chosen alternatives as described in equation 1.

$$Xa = \Sigma\ (Wj^{*}\ rij) \qquad (1)$$

Where Xa is alternative score, Wj normalized weight calculated for each criterion and rij performance of each alternative against criterion. The alternative with highest score will be the best alternative and ranking will be based on that score. All the equations, algorithms and reports had been implemented in Microsoft Excel spreadsheet to facilitate the calculation and reporting process. The whole process is described in figure 2.

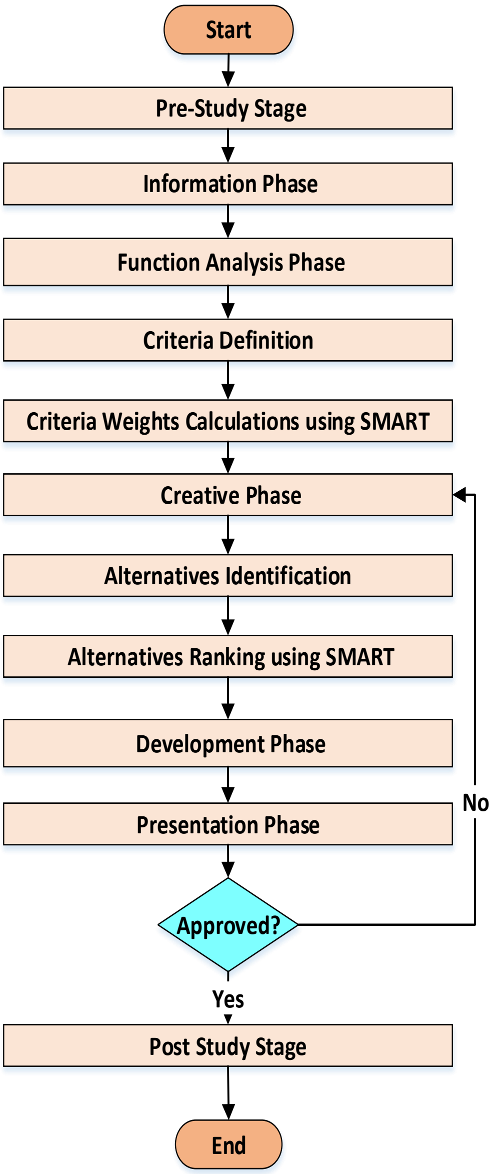


Figure 1. Proposed methodology

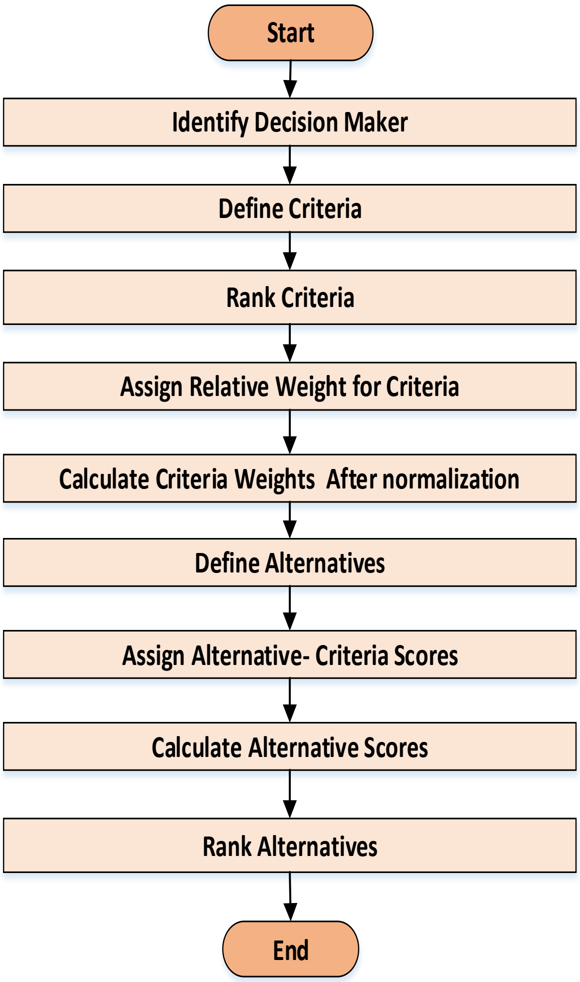


Figure 2. SMART process

3 Model Verification

The proposed model had been verified through applying it to real case study, which is phase 2 of new Liquid Natural Gas (LNG) Support Campus at Mesaieed lies 45 km south of Doha, Qatar. The new LNG Support Campus is being developed on a 1000 m2 area, located at south west of Masaieed Industrial City along Sea Line Road. The project is composed of various buildings. Laboratory building had been chosen to be the case study. Laboratory building (LNG16) is designed to reflect an image of hygiene and cleanness, which accommodates labs at the ground floor while the offices and staff facilities are at the first floor. The building facades match the overall theme of the LNG Support Campus. The building consists of two stories offices with span ranging from 3.0 to 8.0 m and floor height around 5.0 m. The final selected criteria for the case study are nine criteria, which are cost, time, appearance, serviceability to services and utilities requirements, material availability, durability, fire resistance, flexibility for future modifications and possibility of future expansion. Criteria weights are calculated based on the value team input. Table 1 is showing the resulted criteria weights. All results had been verified to ensure the correct SMART formulas are used on the spreadsheet as discussed before. Cost was ranked first criteria with 32%, time with 19% then appearance with 16%.

Table 1- Laboratory building criteria weights

Criteria	Ranking	Score	Weight %
Cost	1	100	32%
Time	2	60	19%
Appearance	3	50	16%
Serviceability to services and utilities requirement	4	30	10%
Material availability	5	30	10%
Durability	6	15	5%
Fire resistance	7	15	5%
Flexibility for modifications	8	10	3%
Possibility of future expansion	9	5	2%

After defining the criteria and final weights, VE team members had defined four alternatives for the structural slab system, which are flat slab, post tension, hollow block slab and hollow core slab, as shown in Figure 3. 3D model was created for each alternative to facilitate structural analysis as shown in figure 3. Most of the criteria were evaluated qualitatively by the VE team except for the cost and time. To calculate the estimated construction duration and cost for each alternative, a detailed quantity take off would be necessary. So, an in depth structural analysis was conducted for each alternative to calculate the concrete and steel reinforcement quantities for the structural elements of each alternative. The structural model for each alternative was only conducted for typical three bays in X direction and three bays of Y direction as a representing for the whole laboratory building. Figure 4 demonstrates the developed structural models for each alternative. ETABS and RAM structural software programs were used to get the serviceability deflection, straining actions, the amount of steel reinforcement and concrete dimensions. Figure (5- a) shows the vertical bending moment for the marginal floor beams in the flat slab alternative. While Figure (5-b) represents the ultimate bending moments for typical post tensioned slab alternative. Figure (5-c) presents the shear force diagram in Y direction for typical floor beams in the hollow block slab alternative. Whereas, figure (5-d) depicts restraint reactions for hollow core slab. 3D BIM model had been developed for each alternative after the final design creation to estimate time and cost, as shown in Figure 6. Quantities were calculated using each alternative 3D BIM model as shown in table 2 then cost rates and production rates were used to convert these quantities to time and cost parameters.

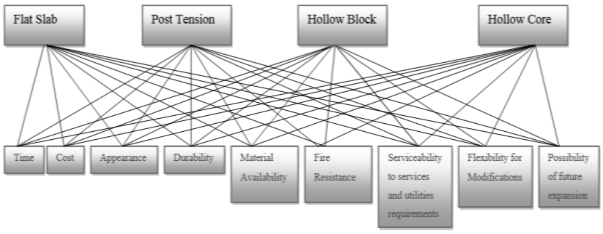
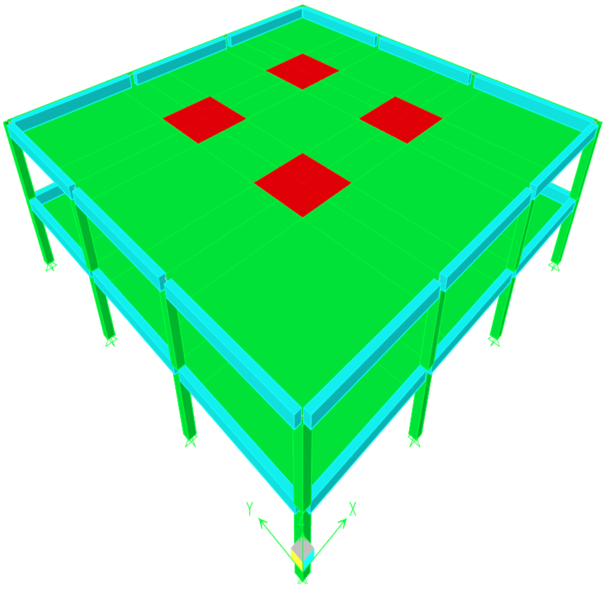
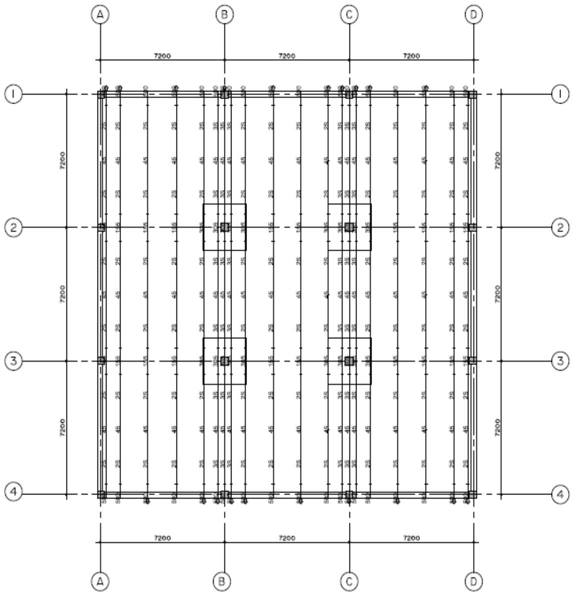


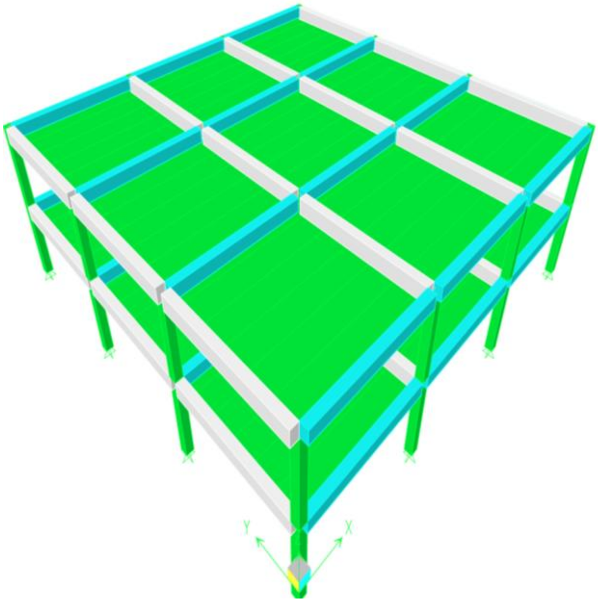
Figure 3. Laboratory building alternatives - Criteria scores structure



(a) Flat slab

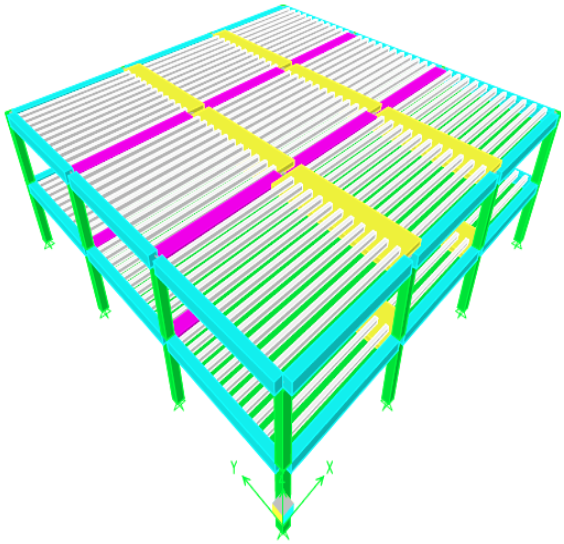


(b) Post tensioned slab

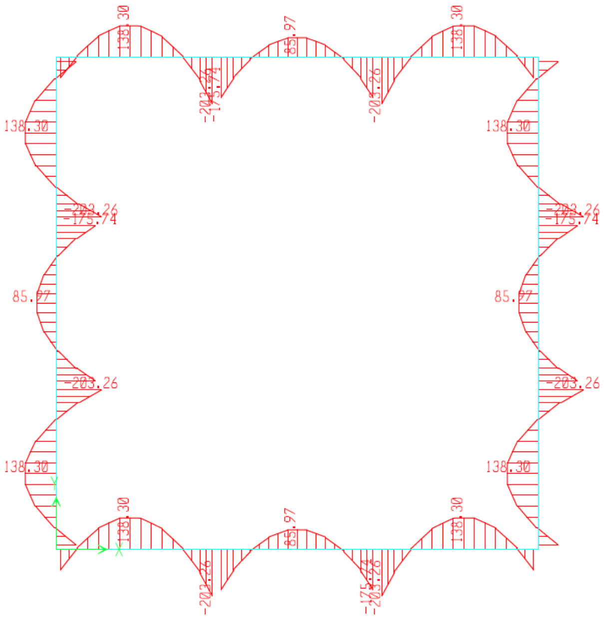


(d)- Hollow core slab

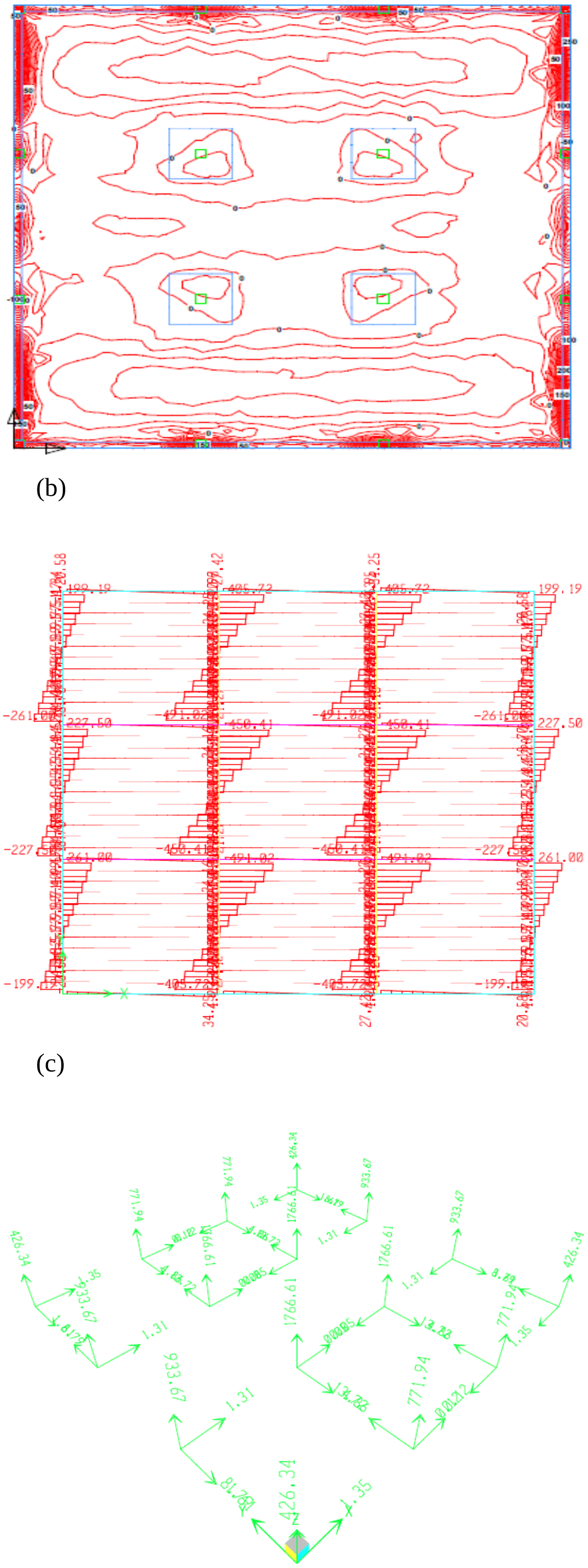
Figure 4. Laboratory building alternatives developed structural models



(c)- Hollow block slab



(a)



(b)

(c)

(d)

Figure 5. Laboratory Building design sample

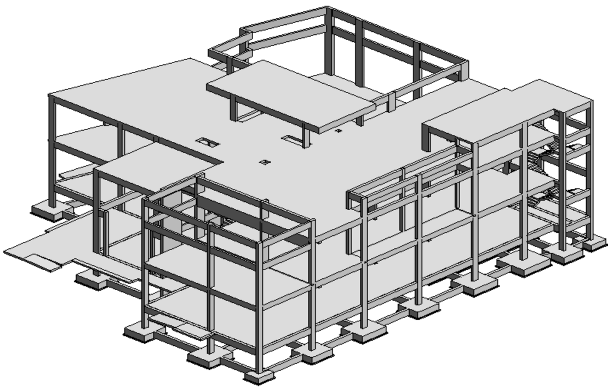


Figure 6. Laboratory building developed 3D model

Table 2 - Laboratory building alternatives quantities

Criteria	Flat slab m3	Post Tension m3	Hollow Block m3	Hollow Core m3
PC Foundation	37.53	35.56	26.84	26.84
RC Footing	616.08	545.89	522.65	522.65
RC Tie Beam	77.9	81.74	82.33	82.33
RC SOG	288.82	288.82	289.11	289.11
RC Beams	101.44	106.67	112.48	122.09
RC Slab	692.06	592.81	75.44	115.07
RC Stairs	14.97	14.97	15.11	15.11
RC Columns	125.77	136.64	132.4	132.07
RC Walls	52.17	53.43	47.8	47.8
Hollow Block Slab	NA	NA	282.6	NA
Hollow Core slab	NA	NA	NA	411.28

Alternatives cost and time are calculated to be used as the main input for alternative - criteria evaluation. The results were shown in Figure 7 for cost in Qatari Riyal (QR) and time in days. VE team members had evaluated remaining criteria for each alternative to calculate the total score for alternative. After assessing all alternatives flat slab had been ranked first as the best alternative for the laboratory with score 90.5 then post tension with score 85.8 then hollow block with score 82.7 then hollow core slabs with 67.8, which was compatible with the chosen system for the building as shown in table 3.

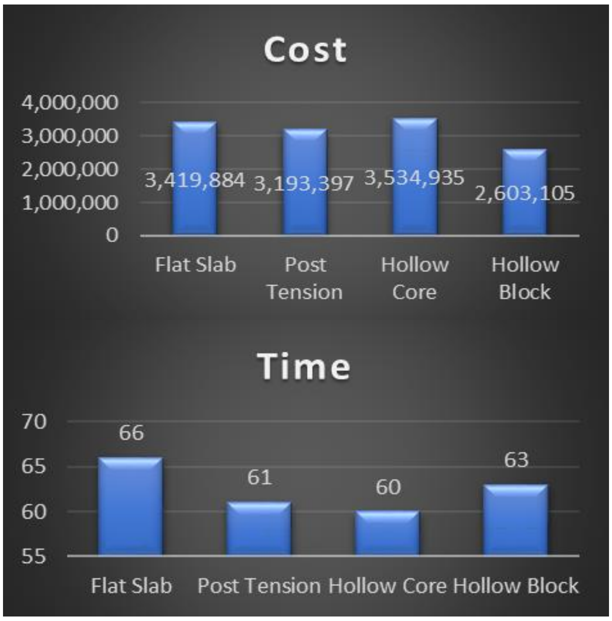


Figure 7- Laboratory building alternatives cost and time

Table 3- Laboratory building alternatives ranking

Criteria	Flat Slab	Post Tension	Hollow Block	Hollow Core
Cost	76	82	74	40
Time	90	98	95	100
Appearance	100	80	80	60
Serviceability to services and utilities requirement	100	70	70	50
Material availability	100	100	100	100
Durability	100	100	100	100
Fire resistance	100	100	100	100
Flexibility for modifications	100	35	35	35
Possibility of future expansion	100	100	100	100
Total Score	90.5	85.8	82.7	67.8

4 Conclusion

Value Engineering (VE) is a powerful tool to achieve essential functions of projects through choosing the optimum alternative based on project specific criteria. This paper presents a model for applying VE using Simple Multi Attribute Technique (SMART) in construction projects. It provides a preliminary work plan for making the decisions during value engineering study and assists the project team to decide which of the options to choose. SMART applications throughout the excel sheets shown in the paper gives user the opportunity to study the impact of modifying criteria or alternatives scores in easy manner. SMART gives the user the optimum solution in simple Process and it allows different weight techniques usage during the scoring process. SMART formulas were implemented in excel spread sheet and verified manually. Additionally, real project is used to validate the use of the model and verify its processes. Nine criteria were chosen to assess alternatives. Four alternatives for the structural slab system were the base for value engineering study, which are flat slab, post tension, hollow block slab and hollow core slab. Algorithms and alternatives ranking reports are developed upon inserting user inputs. The established model, methods and support VE application in easy manner. The developed model enables value engineering team to determine the optimum solution for project implementation methodology.

References

[1] Baker, D., Bridges, D., Hunter, R., Johnson, G., Krupa, J., Murphy, J., and Sorenson, K. Guidebook to Decision- Making Methods, *WSRC-IM-2002-00002*, Department of Energy, USA, 2002.

[2] Barfod, M. B., & Leleur, S. Multi-criteria decision analysis for use in transport decision making. (2 ed.) DTU Lyngby: *Technical University of Denmark*, Transport, 2014.

[3] Chen, Y., Kilgour, D.M., and Hipel, K.W. Screening in multiple criteria decision analysis. *Decision Support Systems*, 45: 278-290, 2008.

[4] Davis, E. Finding Value in the Value Engineering Process. *Journal of Cost Engineering*, 46(12):24-27, 2004.

[5] Dell Isola, A.J. Better Utilizing Value Engineering in Project Delivery. *AACE International Transactions*, PM.1417, 2013.

[6] Demirel, T., Demirel, C. and Kahraman, C. Fuzzy analytic hierarchy process and its application. *In fuzzy multi-criteria decision making: theory and applications with recent developments*.16: 85-117, 2008.

[7] Dey, P.K. Project Risk Management: A Combined Analytic Hierarchy Process and Decision Tree Approach. *Journal of Cost Engineering*, 41(10):13-26, 2002.

[8] Edwards, W., and Barron, F. H. SMARTs and SMARTER; Improved Simple Methods for Multi attribute Utility Measurement. *Organizational Behavior and Human Decision Processes*, 60(1):306-325, 1994.

[9] Garrido, J.S. Conceptualizing Value for Construction: Experience from Social Housing Projects in Chile. *PhD Thesis*, Loughborough University Institutional Repository, Loughborough, England, 2013.

[10] János, F. Introduction to Decision Making Methods. *Report*, Laboratory of Operations Research and Decision Systems, Computer and Automation Institute, Hungarian Academy of Sciences, 2006.

[11] Jose, F., Salvator, G. and Matthais, E. Multiple Criteria Decision Analysis: State of the Art Survey. *Report*, Kluwer Academic Publishers, Boston/Dordrecht/London, 2005.

[12] Kasie, M. Combining Simple Multiple Attribute Rating Technique and Analytical Hierarchy Process for Designing Multi-Criteria Performance Measurement Framework. *Global Journal of Researches in Engineering Industrial Engineering*, 13 (1), 2013.

[13] Mansour, F and Hulshizer, A. The Antidote to Value Engineering Phobia. *AACE International Transactions*, VE&C.02, 1997.

[14] Miles, L.D. *Techniques of Value Analysis and Engineering*. 2nd ed., McGraw-Hill, New York, USA, 1972.

[15] Mustajoki, J., Raimo, P. and Ahti, S. Decision support by interval smart/swing incorporating imprecision in the smart and swing methods. *Decision Sciences*, 36(2):317–339, 2005.

[16] Olson D.L., Comparison of three multicriteria methods to predict known outcomes. *European Journal of Operational Research*, 130: 576-587, 2001.

[17] Parker, D.E. *Value Engineering Theory* .3rd ed., the Value Foundation, www.valuefoundation.org, 1997.

[18] Pöyhönen, M., and Hämäläinen, R. P. On the Convergence of Multi-Attribute Weighting Methods. European *Journal of Operational Research*, 129(3): 106-122, 2001.

[19] Rains, J. Value Methodology Standard. *Joint Cost Management Societies Proceedings*, SAVE.01, 1999.

[20] Raj, H. VE Is Not a "Group Cost Cutting". *AACE International Transactions*, CSC.17, 2001.

[21] SAVE, Society of American Value Engineers International. Value Methodology Standard and Body of Knowledge, *Report*, 2007.

[22] Stewart, T. J. A Critical Survey on the Status of Multiple Criteria Decision Making Theory and Practice. International Journal of Management Science, 20(1): 569-586, 1992.

[23] Stuart, G. Beyond value engineering: SMART value management for building projects. *International Journal of Project Management,* 12(1).:49-65, 1994.

[24] Velasquez, M., and Patrick, T. An Analysis of Multi-Criteria Decision Making Methods. *International Journal of Operations Research*, 10(2):56-66, 2013.

[25] Wandahl, S. Value in Building. *PhD Thesis*, Aalborg University, Denmark, 2003.

[26] Younker, D.L. *Value Engineering Analysis and Methodology*. Marcel Dekker, Ltd., New York, USA, 2003.