

Strengthening the Evaluation Phase by Improving Consistency during Value Engineering Workshops

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Abstract

Value engineering is a well-defined and robust methodology based on a six-step job plan, each step focusing on achieving certain targets that will either be used in the following step, or contribute to the overall study purpose. The methodology, however, leaves the use of tools in each of the steps open, which is why value engineering/analysis has been thriving and has stood the test of time.

The paper does not propose any changes to the methodology; rather, it presents a new tool that could be used to enhance the evaluation phase in case value engineering is used to optimize the project design and identify/select the highest value option (design alternative). Thus, this enhancement would not be suitable for a workshop that aims to identify creative ideas for a project or process.

Evaluation consistency could be critical during a value engineering workshop when the objective is to identify a preferred option to be pursued. In case of civil engineering applications, for instance, the task of improving consistency at this point can often be best addressed by using systematic methodologies, such as the Analytic Hierarchy Process (AHP). AHP offers a useful methodology for supporting decision making since it is simple to understand and it fits a workshop context. What is more, this can translate into effective “buy-in” on the part of the workshop participants because it can be smoothly integrated with expert input.

This paper describes a methodology for improving the evaluation phase through integration of the AHP model and expert input. By resorting to the present methodology one can quickly resolve all the inconsistencies, in part through the expert advice. As a result, the transparency of this approach allows improving the evaluation phase and the overall value engineering program enabling the participants to better justify the options that are selected as having the highest value.

Introduction

The use of the Analytic Hierarchy Process (AHP) during the evaluation phase has been subject to scrutiny. AHP stands for a logical evaluation methodology that derives ratio scales for comparisons and is useful for determining the best option among alternatives while consistency is being preserved. Although previous studies have used variations of AHP for checking the evaluation criteria consistency, the method utility has mainly been understood in terms of decision support. Yet, as these studies also indicate, there are many different methods of undertaking the evaluation phase of value analysis.

AHP's true merit for the value engineering process lies in its ability to be merged with expert opinion. Consistency measures that translate into real confidence for participants are those that account for the knowledge of the experts, rather than relying solely upon mathematical input. Furthermore, this approach allows the evaluation phase to unfold as it is supposed to: in a manner that is both defensible and executed with confidence. The proposed methodology, the background of which is presented in this paper, therefore, benefits from the robust framework of AHP and yet can be presented in a simplified manner that does not require a complex mathematical effort. By integrating it in a workshop format, input can be gained from the participants with minimal effort. Thus, it is clear that this input is itself responsible for rendering the decision criteria consistent.

This research paper presents a literature review of various evaluation methodologies, discusses the advantages of using the Analytic Hierarchy Process and its implementation, introduces consistency concepts and stresses their importance in the evaluation process, offers suggestions on how to improve consistency, and describes the proposed AHP-based methodology in a workshop setting.

Literature Review

D.H. Stafford presented six evaluation methodologies in his paper titled "The Judgment Phase: More than One Way to Skin a Cat (Stafford, 1990, 65-77)." The paper described various evaluation methodologies without favoring one over the other. Instead, it allowed the practitioner to select what they think is the best way to evaluate. These methods are: 1) dictator; 2) benevolent dictator; 3) weighted matrix; 4) consensus; 5) voting; and 6) voting with discussion. Each of the above six evaluation methodologies has its own advantages and disadvantages. Stafford does not make any recommendations regarding the methodology; instead, the facilitator must decide on the style that best suits the project.

Nevertheless, except for "dictator" methodologies, some kind of a criteria weighting process will be necessary. Bert Frattini presented a criteria weighting and analysis matrix supported with a case study for mining application (Frattini, 1980, 29-33). The paper identified the criteria and described them in terms of their individual meanings. Criteria weights were then evaluated using a pairwise comparison matrix. The weight was presented on a scale from 0 to 10, the options were scored, the total scores were tallied, and the highest scoring option was selected. A more complex weighting process appears in Yuh-Huei Chang and Ching-Song Liou's paper that presented a methodology for incorporating risk analysis and value engineering in a real case project for Taipei transit (Chang and Liou, 2005).

Manoj Kulshrestha and V.B. Deshpande present a multi-criteria decision support system for value management that integrates variations of AHP and fuzzy-set methodology (Kulshrestha and Deshpande, 2002). The AHP was found to be suitable and effective, especially when the attributes can be decomposed hierarchically in terms of goal, attributes, sub-attributes, etc. Although the authors briefly introduced the consistency ratio, they did not discuss how to improve that ratio.

H.R. Sandberg presented an elaborate five-step evaluation process that was used in civil engineering projects (Sandberg, 1983, 35-43). These five steps include: 1) choose evaluation criteria from the functions determined during the function analysis phase; 2) rank these criteria in order of importance (the ranking is done as a pairwise comparison using 0 and 1); 3) assign weights of importance to the criteria using a scale of 1 to 10 (the highest ranked criterion was assigned 10 points, and the lowest was assigned a weight of 4); 4) rate each alternative in terms of how well it fulfills each criterion on a scale of 1 to 4; and 5) calculate the acceptance index for each alternative. In the paper, the consistency concept was mentioned during step two. In case of illogical reasoning, the score of the criterion can be revised

manually at this stage. When more than one criterion has the same ranking, this can be a sign of inconsistency.

S.S. Venkataramanan presented four different methods to evaluate the criteria weights. These methods are: 1) “straight hunch”; 2) “which criterion is more important”; 3) “which criterion is more important and how much more important”; and 4) “which criterion is more important and how much more important, out of the determined minimum (Venkataramanan, 1987, 71-76).”

These different methodologies prompt an important question: how can the evaluation phase most successfully take place? Answering this question is very difficult, if not impossible, due to the fact that each study is unique. Because of the different types of facilitators, participants, study scope, and objectives, as well as the owner’s desired outcome, it is impossible to compare various studies and identify the best methodology.

Methodologies for Improving Consistency

Value engineering methodology is a well-established and proven methodology with room for innovation in terms of various techniques and tools used to fulfill the work plan. It is crucial to follow the work plan as each step fulfills an important task. The information phase establishes a study objectives, shares the knowledge between participants, and confirms the scope and study objective. During the function analysis phase, a team identifies what the project will do and what function will be attained. The creativity phase allows the group to generate ideas in a creative environment. The evaluation phase is a step, in which participants critique and judge these ideas. Finally, the development and presentation phase summarizes the study findings.

Therefore, each step of this process is crucial, the evaluation phase being of utmost importance among them. Even with the best and most sophisticated presentation tools, the most detailed function analysis, and the most creative efforts of experts during the creativity phase, the process could fail to select the best alternative or idea if the evaluation phase has not been done properly or logically. For this reason, each step must be carefully fulfilled and the tools used during value engineering must constantly be improved.

When value engineering is conducted for civil engineering projects, the workshop objective is usually related to identifying creative ideas with a view to improving the project performance or functions, or reducing the overall cost by identifying different methodologies for delivering the same function (not as a cost-cutting exercise); the workshop can also be aimed at selecting the highest value option/alternative from a set of options.

Since each evaluation methodology has its own merit and concepts, the methodology characteristics and attributes should be considered to make sure that the method being used fits the purpose of the workshop objective. Below are some of the methodology characteristics:

- 1- Simplicity: The evaluation methodology should be simple and easy to use for a multidisciplinary team.
- 2- Steadiness: If used by the same team under the same conditions, the methodology should yield the similar results.
- 3- Consistency: Consistency relates to logic. It is very easy to conduct a pairwise comparison between two criteria at a time, but the challenge is to be consistent when comparing four or more criteria.

Proposed Methodology and Example

The proposed methodology rests on a hybrid approach combining both a mathematical methodology and expert input simulation. The overall methodology could be described as detailed below:

- 1- The methodology depends on a value engineering workshop objective and whether this evaluation methodology is required.
- 2- Identity evaluation criteria: evaluation criteria.

- 3- Conduct Analytic Hierarchy Process (AHP).
- 4- If the consistency ratio is more than 0.1, discuss with the workshop participants if they want to check for logical mistakes. In some cases the participants might not choose to change the evaluation if the relative weight of the criteria matches their expectations.
- 5- If the participants decide to address logical mistakes (inconsistency), identify the causes of inconsistency, or use a model that could calculate the causes of inconsistency.
- 6- Use simulation methodology to identify what changes to evaluation are required in order to achieve a result without logical mistakes.
- 7- Discuss with workshop participants and decide on how to proceed.

Since the mathematical procedure is overly complex and calculation would be time-consuming to conduct in a workshop setting as the iterations are based on the number of inconsistent elements identified, Step 4 has been simplified specifically for the proposed methodology. It employs user input to conduct simulation for various comparison intensities for the identified elements. As shown in Figure 1, if participants are comparing two criteria, A and B (A on the row side and B on the column side), the number of possible comparison intensities is 17 (i.e., 2, 3, 4, 5, 6, 7, 8, 9, 1, $1/2$, $1/3$, $1/4$, $1/5$, $1/6$, $1/7$, $1/8$ and $1/9$). In this case, numbers 2 to 9 indicate that A is greater than B, $1/2$ to $1/9$ indicate that B is greater than A, and 1 is for the case when the team thinks A and B have the same level of importance.

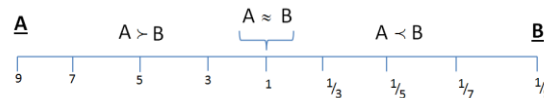


Figure 1. Pairwise Comparison between Two Criteria

A degree of freedom must be proposed for each of the identified elements. This is done by workshop participants by asking for their opinion about the elements in the pairwise comparison, resulting in one of the following situations:

- 1- None (no degree of freedom): The team members do not want to change pairwise comparison for that element.
- 2- Direction Only: The team members think that the current comparison is correct in terms of logic, but intensity is wrong. As shown in Figure 2.

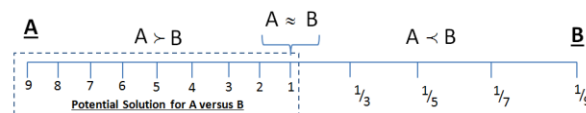


Figure 2. Degree of Freedom - Direction Only

- 3- Direction and Magnitude: The team members are unsure which criterion should be more important and would accept change in logic and intensity, as shown in Figure 3.

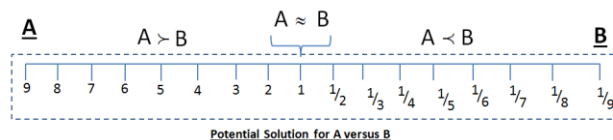


Figure 3. Degree of Freedom - Direction & Magnitude

Once this step has been completed, the various combinations are evaluated and then shown to the participants so that they could select the new logic and intensity. For the purpose of simplification, the process was integrated in a computer program that could be used in the workshop settings. This program was developed to be further used in many workshops. Several screenshots are shown in Figure 5 to Figure 8 in order to illustrate how the process would work. Assuming there are four criteria, A, B, C and D on a logical scale, as shown in Figure 4, where $A > D > B > C$ are known, then:

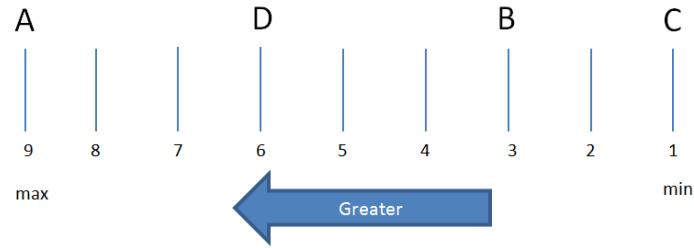


Figure 4. Four Criteria on Scale

AHP can be conducted in such a way that intensity is represented as a difference between each criterion, which is a good assumption (for example, A is greater than D by 3 [$9-6=3$]). The resulting weight and consistency ratio is shown in Figure 5 where consistency = 0.02. This should be expected, as that which is more important is already known.

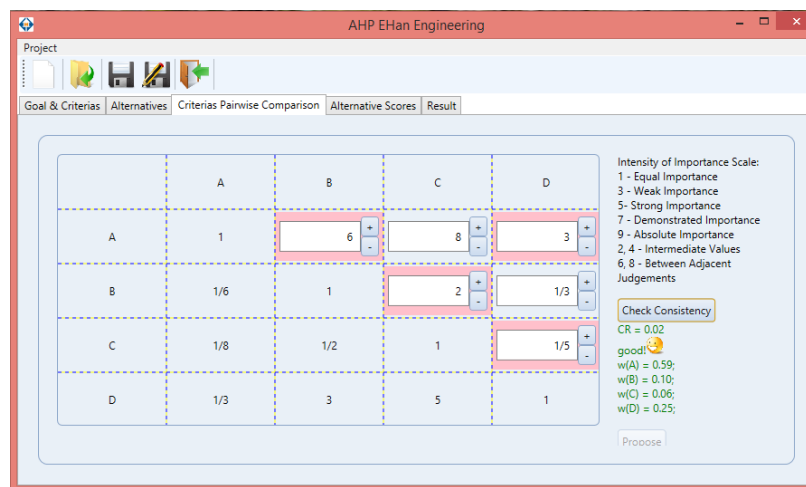


Figure 5. AHP Calculation for Illustration

Assuming that the team made a logical mistake in comparing criteria D and C by changing 1/5 to 7, the resulting C.R. will be 0.615, which is greater than 0.1 and indicates that there is a logical mistake (see Figure 6)

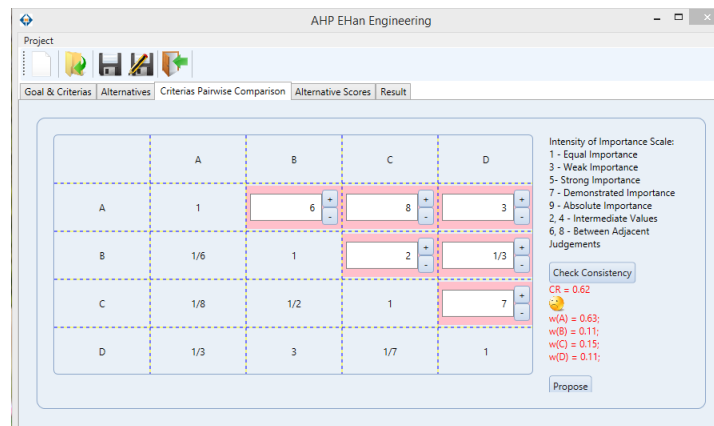


Figure 6. AHP Calculation for Above Example, Containing a Logical Error

To resolve the issue it is necessary to identify the inconsistent element by constructing an induced matrix. This is done by calculating the deviation from zero, as shown in this case in Figure 7. The value engineering team contributes to setting the degree of freedom for these two elements, as shown in Figure 7 (A:C - Direction only; C:D - Direction and Magnitude).

Original:

	A	B	C	D
A	1	6	8	3
B	1/6	1	2	1/3
C	1/8	1/2	1	7
D	1/3	3	1/7	1

Degree of Freedom:

	A	B	C	D
A	1	None	Direction Only	None
B	None	1	None	None
C	None	None	1	Direction & Magnitude
D	None	None	None	1

Intensity of Importance Scale:
 1 - Equal Importance
 3 - Weak Importance
 5 - Strong Importance
 7 - Demonstrated Importance
 9 - Absolute Importance
 2, 4 - Intermediate Values
 6, 8 - Between Adjacent Judgements

Check Consistency
 CR = 0.62
 w(A) = 0.63;
 w(B) = 0.11;
 w(C) = 0.15;
 w(D) = 0.11;

Figure 7. Identify the Inconsistent Elements

Later on, the simulation is run (136 combinations for this case, 8 (direction only) *17 (direction and magnitude)) to establish the most consistent scenarios based on the participants' input. In this case, the most consistent situation is when C & D is (1/4) with a resulting consistency ratio = 0.015.

CR = 0.015

	A	B	C	D
A	1	6	8	3
B	1/6	1	2	1/3
C	1/8	1/2	1	1/4
D	1/3	3	4	1

CR = 0.017

	A	B	C	D
A	1	6	9	3
B	1/6	1	2	1/3
C	1/9	1/2	1	1/3
D	1/3	3	3	1

CR = 0.017

	A	B	C	D
A	1	6	9	3
B	1/6	1	2	1/3
C	1/9	1/2	1	1/3
D	1/3	3	3	1

Intensity of Importance Scale:
 1 - Equal Importance
 3 - Weak Importance
 5 - Strong Importance
 7 - Demonstrated Importance
 9 - Absolute Importance
 2, 4 - Intermediate Values
 6, 8 - Between Adjacent Judgements

Check Consistency
 CR = 0.62
 w(A) = 0.63;
 w(B) = 0.11;
 w(C) = 0.15;
 w(D) = 0.11;

Figure 8. Simulation Results

Based on the achieved results, the team could agree to implement the proposed scenario or adjust it if needed.

Thus, this example was shown to illustrate the simplicity of the process and the way it supports the interaction between the facilitator and participants. This process has been used in several projects and the participants have accepted the results. As it turned out, the participants appreciate that they are the ones introducing new adjustments in the pairwise comparison and determining the final comparison matrix.

Another major advantage of this methodology is that the process retains the majority of the original input data given by the participants for the pairwise comparison, as well as the adjusted figures, which were also introduced with input from the participants.

As indicated earlier, this tool is only effective if the workshop objective is to optimize a design, and the additional time required to conduct this methodology is no more than 20 to 30 minutes. It is crucial for the facilitator to have the mathematical model (software) to conduct this analysis as the methodology should be used only in the proper format and when needed.

Conclusion

Value engineering phases are equally important and advancements in any of these phases would result in an improvement in the overall methodology, translating into higher value of the project achieved by adding more functionality or reducing the life cycle cost of the project. As it has been shown above, the evaluation phase is critical, and value engineering facilitators have invested a huge amount of effort to improve its methodology. In principle, the phase should either screen various options by incorporating the owner's criteria and selecting the highest value option to be pursued, or reduce the number of creative ideas to a manageable number of improvements to a program, facility, system or service.

The level of sophistication of the evaluation phase tools is one of the issues that have to be resolved by the value engineering facilitator and will depend on both the problem at hand and the overall objective of the study. In this paper, the Analytic Hierarchy Process (AHP), which is already in use by many practitioners, was discussed in light of the challenging issues that accompany the quality of analysis and consistency ratio of the evaluation phase.

It is important to conduct a fair and logical evaluation. Evaluations could be done simply, as in the "dictator" methodology; in a straightforward way, such as with pairwise comparisons using an Excel sheet with a 1 to 3 scale, or more complexly, as with the AHP plus a measurement to account for how consistent the team was during the assignment of the weight. The proposed methodology combines a mathematical approach to identify where inconsistencies could have occurred and a simulation of various alternatives in order to propose a consistent solution that is based on expert input.

To sum up, the present methodology can be easily applicable in a workshop setting and would produce consistent weights to select an option with confidence. The process also promotes confidence for the value engineering team by assuring that the weights were derived in a consistent manner. In addition to that, the methodology could be used to enhance the evaluation phase in some cases, and this enhancement proved to get higher buy-in from both the owner and participants.

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