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INTEGRATING THE RISK FACTOR WITHIN THE VALUE ENGINEERING EQUATION IN ARCHITECTURAL PROJECTS

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ABSTRACT

Both Value Engineering (VE) and Risk Management (RM) are effective tools for architectural project management. Eventually, the value engineering outputs provide recommended VE proposals or alternatives for a specific material or system; based on its quality and cost, while risk management provides analysis for the impact of the project risks by identifying the probability and impact of each single expected risk that might affect the project. The integration of both tools is necessary to benefit from both outputs simultaneously. The previous integration approaches have provided an integration protocol and methodology, but they have missed the mathematical attitude. This research aims to fill this gap by suggesting an integral equation that considers the impact of the risk factor associated with each of the value engineering proposals. This risk factor will express the resultant of all expected risk impacts that will affect the VE proposals, if executed, into a newly developed equation. This equation will optimize the selection of the VE proposal based on the accomplished risk impacts in a mathematical approach. The research used structural equation modeling (SEM) as a scientific method to develop the new equation and to study the relationship between its variables.

KEYWORDS: Risk management, Value engineering equation, Risk factor, Structure equation modeling.

1. INTRODUCTION

The integration efforts between risk management (RM) and value engineering (VE) were developed identifying proper procedures to benefit from them. These efforts have missed the mathematical description or representation of the influenced interaction between them. This paper proposes an integrated equation to develop this interaction, to direct the relevant stakeholders to nominate the optimum VE proposal. The nominated proposal will consider the predicted risk impact factor on the project objectives, based on the relative weight of each objective.

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This equation will be applied to the architectural projects in the design and construction stages to compare and nominate the optimum VE proposal for whatever material selection, finishing material, engineering system, or even architectural design scenarios, and construction options during the project phases, respecting the intended objectives of each phase.

1.1 Research Intent

The research intends to create a numerical equation that benefits from the techniques used in VE such as; performance analysis, life cycle cost, and value index. The equation will also incorporate the tools used in quantitative analysis of risk management, such as; probability and impact matrix, expected monetary value, and decision tree analysis. The equation will be developed to calculate the risk factors associated with the proposed VE options. This risk factor expresses the overall risk grade of each VE proposal. The integration of this risk factor within the value engineering equation during the VE job plan will optimize the VE proposal selection and rearrange them based on their risk factor. The components of the new integration approach are as shown in Fig. 1.

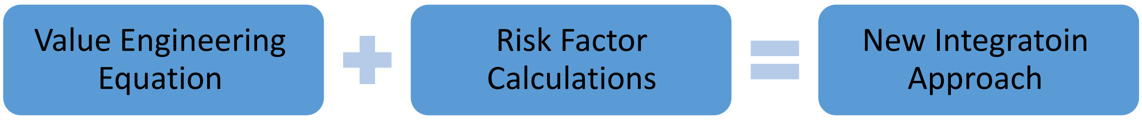

Fig. 1. Components of the new integration approach.

1.2 Research Problem

The integration approaches discussed in earlier studies have suggested integration protocols, and some sort of action plans or road map to integrate the two methodologies VE and RM [1]. The said integration was suggested to be applied during either condensed workshops or sequential stages. Other approaches recommended a protocol of application, without providing a tangible tool to distinguish between VE proposals based on the associated latent risks. This gap elaborates on the need for developing a mathematical integration approach to act as an advanced decision-making tool to be used during the VE and RM studies to promote the selection of the optimum VE proposal considering its associated risks [2].

1.3 Research Objectives and Methods

Based on the associated risk impact concluded in the risk factor for each VE proposal, this risk factor plays a significant role when it is well employed in the VE equation. The result will be an integrated equation to assist the decision-maker to select the best VE proposal which has the highest value, and safe impact on the project objectives (cost, time, and scope), while considering the related risk factor of each proposal. This process is important to develop the equation and support it with the necessary pragmatism.

To develop or create such an equation, the research depends on a scientific methodology to deploy its procedures and processes to build the equation structure. This scientific approach has to be followed in order to make the integration equation applicable, dependable, and trustable.

The scientific approach for developing equations belongs to mathematical science, specifically the linear equation [3]. The normal statistical methods such as linear regression mainly create direct impacts of uncorrelated variables. While indirect effects are hard to model and the presence of correlations between explanatory variables may lead to biased coefficient estimates and incorrect model interpretation [4]. To overcome this problem, the research depended on structural equation modeling (SEM) to develop the integration equation between VE and RM parameters or variables.

2. STRUCTURAL EQUATION MODELING (SEM)

Structural Equation Modelling (SEM) is an extension of linear regression that enables the modeling of complex relationships between interrelated and correlated variables [5]. The SEM uses several kinds of models to show relationships between practical variables with the same simple aim of providing a quantitative assessment of a theoretical model assumed by the researcher [3]. The SEM consists of 5 steps that should be followed to obtain the model equation as shown in Fig. 2. A brief description of each step that the researcher should follow to reach the desired equation will be presented below.

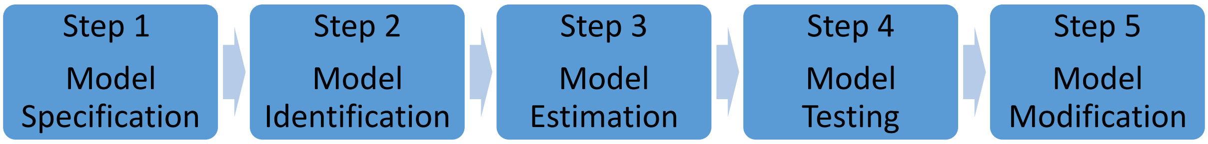

Fig. 2 Steps of the Structural Equation Modelling (SEM).

2.1 Step 1: Equation Model Specification

In the equation model specification step, the obtainable related theoretical concepts, researches, and evidences that are concerned with the VE and RM parameters or variables should be considered. These include the relation between value and cost, value and risk, and performance and cost, to develop a hypothetical model equation. This is followed by listing and describe the relationship between those variables and how they influence each other. [5]

2.2 Step 2: Equation Model Identification.

In this step, the following question should be asked: based on the theoretical concepts, how can a set of parameters be used to express this theoretical concept? Each variable in the model equation should be identified as either a free parameter, a fixed parameter, or a constrained parameter [4]. The free parameter is unknown and therefore needs to be assessed. The fixed parameter is a parameter that is not free, but is fixed to a specified value, typically either (0) or (1). The constrained parameter is a parameter that is unknown but is constrained to be equal to one or more parameters [6].

2.3 Step 3: Equation Model Estimation

In this step the different methods for estimating the parameters mentioned in step (2) should be explained. The estimation includes listing the tools and techniques that are expected to be used to find or calculate each parameter in the model equation independently [5].

2.4 Step 4: Equation Model Testing

In this step, the examination of how well the theoretical concepts fit the estimated equation model should be carried out, by assuming hypothetical data and running the model [6].

2.5 Step 5: Equation Model Modification

In this step, the model equation results are checked to determine the consistency with the theoretical concepts. If the results are not consistent, an analysis of what parameters to include or exclude from the model should be carried out and steps 1 to 4 are repeated again until the best-fit parameter configurations are achieved [5].

3. APPLYING (SEM) TO DEVELOP THE PROPOSED INTEGRATION EQUATION

The following section illustrates how the research has deployed the SEM steps to develop the intended integration equation.

3.1 Model Specification

3.1.1. The equation model variables.

It was debated that the best value for money can be attained by improving the project requirements or by decreasing the overall cost of achieving them [7]. The deployment of the risk assessment at the early stages of a project ensures that the potential risks are understood, and the project targets are well-identified [8]. The proposed integration equation for VE and RM should consider the associated risks of every single proposal of the VE proposals. The equation variables are shown in Fig. 3.

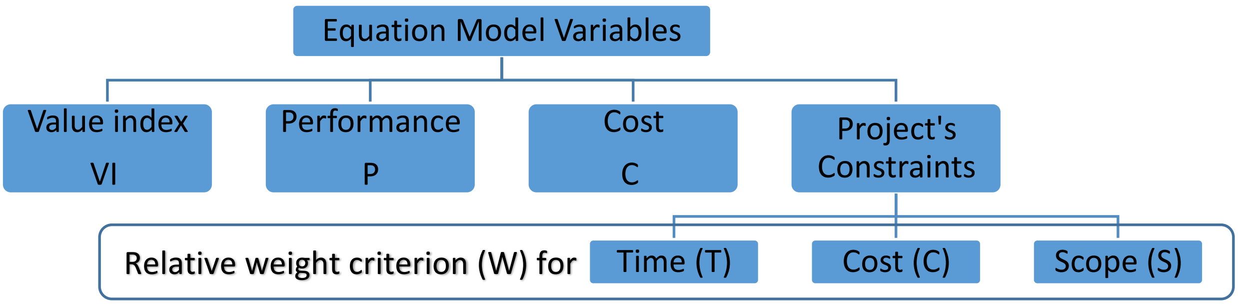

Fig. 3 Integration equation model variables.

The Value Index criterion (VI) expresses the total value of the proposal from the quality and cost points of view. It is the result of dividing the performance of the proposal by its life cycle cost [9]. The Performance criterion (P) implies the desired function required to be performed by the VE proposal. This criterion is referred to as the (Function) which is the overall properties and the functions achieved by each proposal [9]. Cost criterion (C) is the sum of all initial, production, construction, annual operations, maintenance, and energy costs of the VE proposal, in addition to the salvage costs [8].

Risk factor criterion (R) represents the overall risk exposure expected to occur when the VE proposal is implemented. This risk factor (R) is simply calculated by multiplying the risk`s probability of occurrence (P) by the risk's impact when it occurs (I) (either positively or negatively) [1].

Project's constraints criterion: The project manager, with the participation of all relevant stakeholders, identify the main constraints of the project at the early stage of the risk assessment workshop. The constraints may be (time T, cost C, scope S) or any other constraints. This identification will limit and direct the project management team to focus on the probability and impact of the risk factor based on the most important objectives for the project as per its urgency and nature.

Relative weight criterion (W): The relative weight of each one of the project's constraints represents the weight of importance of these constraints compared to the overall project objectives. This weight reflects the importance and the significance level of each constraint [10]. A common consensus should be reached at the beginning of the project to agree on a method to assess this weight, although this weight could be reassessed periodically to reflect the current or desired status of each constraint.

3.1.2. The hypothesized relationship between variables

The relation between the equation's variables is logically explained as the relationship between value (V) and performance (P). It is clear that when the performance of a specific system or a component increases, its value will increase as well. This is because the performance functions and options associated with this system will be more reliable and dependable to achieve its intended purpose [7]. On the other hand, the system or item may have extra functions and options that are not necessarily required by the client nor mean any added value to the end-user. This is what is called unnecessary functions or gold patting. Generally, the value (V) of a system or component is directly proportional to its performance (P).

The relationship between value (V) and cost (C) is obvious. The increase in the system's overall life cycle cost (LCC) reveals that this system is not a sustainable option and paradox with the client's investment perspective. It is the project manager's responsibility to monitor and control the project's budget and consider the impact of any increase in each system's cost, either initial cost or operation costs. The value of an item increases when its performance and functional application are higher than or equal to the afforded and paid expenses [8]. Hence, the value (V) of a system or component is inversely proportional to its cost (C).

The relationship between value (V) and risk (R): Risky options are not valuable options, this is why the value engineering proposals should not be separated from its relevant or associated risks. The project manager should analyze the value of any VE proposal in light of its relevant risks. This will lead to recognizing that the relation between value and risk is an inverse relation. Normally the value (V) of a system or component is inversely proportional to its risk (R) [11].

The previous review and hypothesized analysis show that the relationship between each element and component of the value equation affect each other by different means. This emphasizes that the project manager should be aware of the sensitivity of each VE proposal and evaluate properly the impact of each and consider its advantages, disadvantages, and hidden risks.

3.2 Model Identification

Model identification is the second step as per the (SEM) procedures. In this step, each potential parameter in the model must be specified as either a free parameter, fixed-parameter, or constrained parameter [6], as shown in Fig. 4.

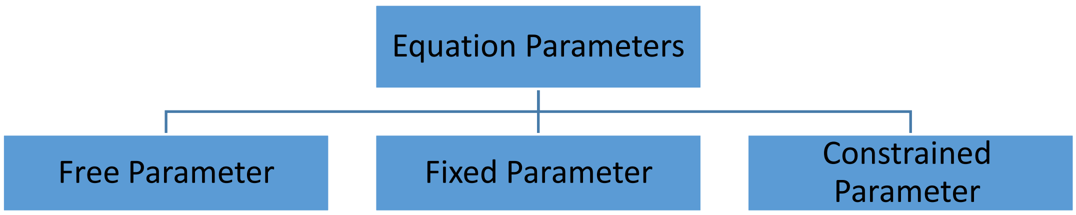

Fig. 4 Types of the SEM equation parameters.

3.2.1. Equation parameters

The free parameter: The value index with consideration of the risk factor is referred to as (ViRf) which is the unknown free parameter. The developed equation aims to find this factor throughout the equation itself.

The fixed parameter: There is an inversely proportional relationship between the value index (V) of any system or component and its cost (C) [9]. The model equation should thus have a fixed parameter to express this inverse relationship. This relationship is aligned with the logical senses that exist in the traditional VE equation [9]. The risk factor (Rf) is also inversely proportional to the value index. For example, for any VE proposal, the more risks it has, the lower its the value index.

In light of the above, it is clear that the fixed parameter in the proposed model equation is (1) since $V \alpha (1/C)$ [9, 12] gives the inverse proportion between the value and the cost. Also, there is a fixed parameter in the relation between the value and the risk factor (R), so that, the equation shall be $V \alpha (1/R)$. The fixed parameter in the proposed equation model is thus fixed at the specified value of (1), to be able to express the inverse proportion between the value, cost, and risk.

The constrained parameter: The first constrained parameter is the performance (P). This parameter is the sum of the overall evaluation and assessment of the exact needed requirements [1], specifications and necessary functions of the system in the VE proposal.

The second constrained parameter is the cost (C). As mentioned before, the cost should be calculated by the overall life cycle cost [7]. Yet, this decision should be identified early in the project to keep the consistency of the comparison results.

The third constrained parameter is the risk factor (R). It is the algebraic sum of the risk factors that shall affect the project in the future [11] as a result of using any of those VE proposals. The different parameters are shown in Fig. 5.

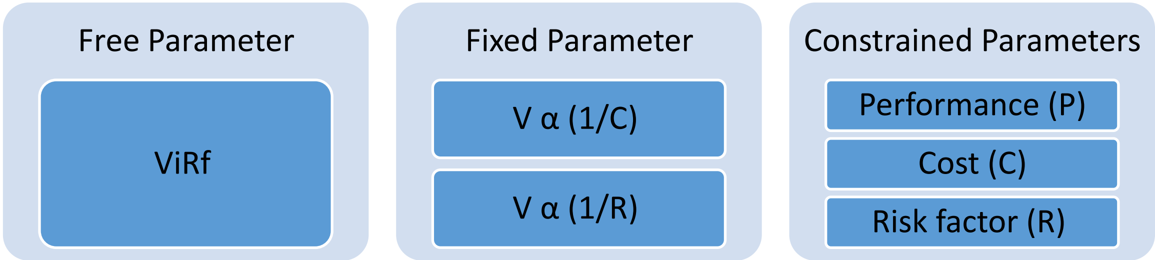

Fig. 5. Application of SEM to identify equation parameters.

3.2.2. The project triple constraints

Each project has a certain number of constraints and objectives as well as limitations that surround the project environment. The risk factor (R) proposed in this research will be limited only to 3 main constraints (quality, time, and cost) [13]. Those three constraints are the only limitation of this research. Yet it never means that those are the most important constraints because they vary from project to another according to each project case and situation.

3.2.3. The proposed formula for the equation

The (*ViRf*) is the VE index concerning the overall risk impact factors that are expected to face the project upon selecting and implementing any of the VE proposals. The risk impact is calculated based on the information available about the individual risks listed in the risk register and prepared earlier by the risk management team [2].

The proposed integration formula between VE and RM is given by Eq. (1).

$$Vi\,RF = \frac{Pi}{C} \times \frac{1}{\sum RF} \qquad (1)$$

Where

Vi RF : The VE index of each VE proposal, concerning the overall risk associated Risk Factors.

Pi : Performance index of each VE proposal.
C : Life cycle cost of each VE proposal.
∑RF : Total risk factors associated with each VE proposal. This risk factor will be calculated as shown in Eq. (2)

$$\sum RF = (RfS \times WS) + (RfC \times WC) + (RfT \times WT) \tag{2}$$

Where

∑RF : Total sum of all risk factors.
RfS : Risk factor of the scope deviation.
WS : Relative importance weight of the scope as a constraint.
RfC : Risk factor of the cost increase or decrease.
WC : Relative importance weight of the cost as a constraint.
RfT : Risk factor of the time changes.
WT : Relative importance weight of the scope as a constraint.

The risk factors RF for every single risk that would affect any of the project's constraints (scope, cost, and time) will be calculated by multiplying the probability of occurrence of every single risk with its impact [11], as shown in Eqs. (3-5).

$$RfC = (P)C \times (I)C \tag{3}$$

$$RfS = (P)S \times (I)S \tag{4}$$

$$RfT = (P)T \times (I)T \tag{5}$$

Where

RfS : Risk factor of scope constraint. In this equation, (P) is the Probability of scope deviation and (I) impact of this deviation.

RfC : Risk factor of cost constraint. In this equation, (P) is the Probability of increase in Cost and (I) impact of increase or decrease.

RfT : Risk factor of time constraint. In this equation, (P) is the Probability of delay in schedule and (I) impact of delay or crashing

Regarding the application of the relative importance index (RII) [14], each party of the project's stakeholders (client, consultant, contractor, end-user, etc.) will have 3 to 5 voices to vote. Each voice will give a rank out of 5 to the weight of each of the project's constraints, where (1) for not important at all, (2) for less important, (3) for important,

(4) for very important, (5) for extremely important. All votes will be calculated using the RII method to find the relative importance weight for each constraint to imply the overall perception for all relevant parties [15], as shown in Eq. (6)

$$RII = \frac{\Sigma \ W}{A \times N} \tag{6}$$

Where

RII	:	Relative importance index
W	:	Weight given to each factor by the respondents
A	:	Highest weight (i.e., 5 in this case)
N	:	Total number of stakeholders' respondents

The aim here is to find and calculate the impacts of the risk associated with the scope issues (RfS), by identifying the risks that might cause scope deviation or scope creep. Examples for the scope risks could be that the VE proposal will extend the scope of work by adding more activities that were not planned before [13], or the VE proposal will combine some of the planned activities to omit part of the scope avoiding its rework and complications (in this case it will be an opportunity and a positive risk). This kind of risk, and many more, are decomposed and listed then ranked in the risk register under the category of scope risks [11].

The risks associated with the Cost issues (Rf C) are sought. These may cause an increase or decrease in the budget and thus they might affect positively or negatively the estimated project budget if one of the VE proposals is implemented. Examples for the cost risks are:

- Increase in labors or transportation fees due to any scarcity of resources [16]
- Penalties in case of supply delayed due to shipping or transportation delay.

This kind of risks are decomposed and shown then ranked in the risk register under the category of cost risks [11]

The risks associated with the time or schedule issues (Rf T) are identified. They may lead to crashing or soothing in time schedule, and thus might affect positively or negatively the estimated project time schedule when one of the VE proposals is implemented. Examples for the time or schedule risks are:

- Delay in the insulation of curtain item depending on delay for its predecessor [10]
- Increase of delivery time for long-lead items due to late contracting with the supplier or incomplete purchase orders.

This kind of risk is decomposed and shown then ranked in the risk register under the category of time or schedule risks.

3.3 Model Estimation

In model estimation, the research will provide, review, and decide which estimation technique can be selected for estimating the parameters in the measurement model and structural model [5]. The scientific tools and the most common techniques that will be agreed on to be used during the project lifecycle will be indicated in the project management plan and agreed on by the project's upper management and the relevant stakeholders. Table 1 lists the tools and techniques that should be used to calculate and find the model parameters (cost, performance, risk factor, and relative weight).

Table 1. Tools and techniques to calculate each parameter in the equation.

Parameter	Tools And Techniques
The cost parameter (C)	Life Cycle Cost (LCC)
The performance parameter (P)	The weighted evaluation matrix [12]
The risk factor (R)	Risk probability and impact assessment. [2]
The relative weight (W)	Relative importance index (RII) [13]

3.4 Model Testing

Once the parameter estimates are obtained for a specified SEM model, how well the data fit the model should then be determined [4]. In other words, to which degree is the hypothetical model supported by the attained example statistics? There are many ways to think about model fit. One of them is to examine the fit of individual parameters in the model. The VE proposals will be tested against the proposed VE equation in this work in stages [6]:

Stage 1: The first process is the implementation of the traditional VE equation where VI =Performance/Cost [9] and ranking the VE proposals based on selecting the higher value index proposal.

Stage 2: the implementation of the risk factor impact associated with the triple constraints (scope, time, and cost). The implementation will use the probability and impact of every single risk in the risk register based on the actual project's data and exact conditions, and situations [8]. To unify the impact of all individual risks, this impact will be translated directly into a certain amount of money and calculated by either direct budget, percentage of the item's cost, or as mentioned in the contract agreement. All those risk impacts will be added together accumulatively to find the overall risk factor impact.

Stage 3: The integration of the relative weight of each one of the three constraints of the project [14]. This means that the relative importance index (RII) for each project constraint (scope, time, and cost) will be added to the proposed model equation to assess its impact on the rearrangement of the VE proposals.

3.5 Model Modifications

The final step in structural equation modeling is to consider the changes to the specified model that has poor model fit [3]. This typically occurs when it is determined that the specified model fit is not suitable [15]. To perform the model modifications in this research, the following terms and conditions will be adopted to assure the best model fitting and to present the model intent.

Firstly, the individual risks associated with each VE proposal should be picked, as possible, from the overall risk register for the project itself. Then, a certain number of the identified risks will be listed and set for each VE proposal. The project manager, the team, and stakeholders will assess the probability of occurrence for each risk per each VE proposal. The team will reach consensus and general approval about the probability of occurrence of each risk in case of using each VE proposal [9]. Each of the stakeholders will judge the probability of risks for each VE proposal based on his own experience and reference background. It will be much better if the team uses the RII method to reach this consensus neutrally and to estimate the average probability for each risk [15].

Secondly, the estimated probability is constant per each constraint (scope, time and, cost). This is to provide a stable judgment of the risks for each VE proposal. Then, a question will be asked regarding each risk for each VE proposal per each constraint (will this risk impacts this constraint?). If the answer is (YES), this means that this risk will have an impact, either negative or positive, on the project concerning the identified constraints (scope, time, and cost). The project manager with the team will then calculate and provide the relevant impact of this risk [11]. If the answer is (NO), this means that this risk has no impact on the identified constraint or it is an irrelevant risk. The project manager and the team will thus not pay an effort to calculate or find its relevant risk impact.

For example, the risk of delaying the delivery of one of the project materials [15] (for any proposal of the VE proposals) will affect the project time schedule. This will impact the time as a constraint, but will not increase nor decrease nor deviate the specified project's scope and will not impact the scope as a constraint.

Thirdly, when the project manager and the team assess the impact of each risk where it affects one or more constraints, the impact will be calculated and provided as a value of money [12]. This value represents the amount of money that will be lost (negative value) or gained (positive value) when applying this VE proposal. The negative value indicates that this risk is a threat that has a bad impact on the project and affects its objectives and constraints. The positive value indicates that this risk is an opportunity or a benefit that will be gained and achieved if this VE proposal is executed and implemented.

For example, when using one of the VE proposals, the construction time of this item will be reduced by about 5% of the baselined time schedule, in this case, the impact will be a positive value of a certain amount of money [15].

On the other hand, when using one of the VE proposals, for instance, there will be a need to perform pre-preparation works that require time, resources and cost. The impact here will be assessed as a negative value of a certain amount of money, leading to budget increase [12]. This increase in budget is a threat that is associated with the execution and implementation of that VE proposal.

Fourthly, the multiplication of the risk probability by its impact will result in a risk score. The risk score presents the earned value, expressed in money [16] . The risk impact is calculated for each VE proposal regarding each risk concerning the project constraints (scope, time, and cost)

Fifthly, the algebraic sum of all individual risk scores per each constraint shows the amount of money that will impact the project, especially a certain constraint either scope, time or cost upon applying any of the VE proposals.

Sixthly, the algebraic sum of those risk scores is multiplied by the relative importance index RII (to find the impact of the overall risks per each constraint) [16] for each constraint to express the severity of those risks for the project.

Finally, the impact of the overall risks per each constraint is added together to represent the whole risk impacts that are expected to affect the project [11] along with the 3 main defined constraints in the case of executing any of the proposed VE alternatives.

The whole risk impacts monetary values of each VE proposal may have one of two values, either negative or positive value, expressed in an amount of money. The negative value shows that this VE proposal will be associated with some sort of threat risk that will impact the project's budget by an amount of money [7]. The same for the positive value, yet the positive value shows an opportunity to have a profit to be added to the project budget. Here the project manager will arrange those VE proposals from the lowest value to the highest value (even negative or positive) ascendingly.

4 CONCLUSION

The successful integration of both VE and RM supports the decision-makers to look beyond the first result of the VE study [17] since it lacks the associated risks. The RM approach compensates for this lack by adding the third dimension to the VE process. This dimension is concerned with the accomplished risk factors that are expected to occur when executing any of the VE options or recommendations. The risk factor depends on the probability and impact of every single risk that may encounter the project if this VE option is nominated.

This paper used the structural equation model (SEM) [4] to develop an equation to integrate the compiled risk factors that might occur when executing any of the VE proposals. The developed equation has deployed the variables of the traditional value engineering equation (value, function, and cost) for each VE proposal, and has added the risk impact factor for the expected risks that might occur when implementing these proposals. The risk impact factor benefited from the risk analysis variables (probability and impact) to imply that each VE proposal might have latent risks, and analytical calculations should be used to express those risks, respecting the project constraints. Each project is limited with certain constraints and restrictions [7], for example, time, scope, and budget. Each constraint has a relative importance weight on the counter of the others. The risk factor impact on the project should be measured based on this weight. The research suggested the relative importance index (RII) to give the chance to the key stakeholders participating in the project to express the importance of each constraint [10] from his point of view, then to reach a consensus about the overall importance of those constraints.

The integration equation will give a comprehensive vision to the decision-maker about the drawbacks of selecting any of the VE proposals in light of its associated risks knowing the overall impact on the project's constraints.

DECLARATION OF CONFLICT OF INTERESTS

The authors have declared no conflict of interests.

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تكامل إدارة المخاطر ومعادلة هندسة القيمة لتعزيز اختيار البديل الأمثل للمشروعات المعمارية

يهدف البحث إلى اقتراح معادلة تكامل بين منهج هندسة القيمة ومنهج إدارة المخاطر كأدوات إدارة المشروعات المعمارية التي يتم توظيفهما لتحقيق أهداف المشروع تأخذ بعين الاعتبار تأثير عامل المخاطرة المرتبط بكل مقترح من مقترحات هندسة القيمة و تعتمد على توظيف محصلة مجموع المخاطر المتوقعة لأي من هذه المقترحات والتي قد يؤثر على محددات المشروع الأساسية مثل النطاق والتكلفة والوقت، بناء على الوزن النسبي لأهمية تلك المحددات، هذا و تعد المعادلة أداة تقويم تهدف إلى تعزيز اختيار المقترح الأمثل من بين مقترحات هندسة القيمة بعد دراسة تأثير عامل المخاطرة لكل مقترح.