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New practical innovative tool for the value engineering ideation process with the oriented creativity matrix

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This study attempts to solve the challenges facing value engineering due to the shortage in the creativity stage via using an innovative tool during the ideation process to arrange the ideas' creation; this tool is the Oriented Creativity Matrix (OCM) to ensure communication and considering the designer concern during that process. This shortage could be either the inapplicability of the proposals generated from the creativity stage or the inability to discover workable proposals. Per the previous research, many implementation challenges were reported as roadblocks impeding the value engineering proposals. To encounter those challenges, the OCM method was set, including identifying the potential altering aspects by which the sub-alternatives are generated and then composed to configure the main alternatives. Generating alternatives via the pre-identified alteration aspects promotes the coverage of all potential alternatives and ensures their performance from the perspective of each of them. Furthermore, this procedure establishes clear ground rules for the participants in the creativity stage, unifying their efforts to propose sub-alternatives to resolve the problem from an ascertained perspective rather than wasting efforts to defend their pre-desired main alternatives without due consideration for each perspective. To specify the most affective alteration aspects, a questionnaire distributed to the value engineering (VE) specialist to ensure the completeness of the included aspects and track any further alteration aspects. Per the collected data via the questionnaire, the altering aspects of completeness were statistically proved, and the OCM method was designed and elaborated to facilitate its usage in the VE ideation process.

Keywords Oriented creativity matrix, Challenges, Implementation challenges

Abbreviations

VE	Value Engineering
VEP	Value Engineering Proposal
SAVE	Society of American Value Engineering
PPP	Public-Private Partnership
DBOM	Design-Build-Operate-Maintain
HKIVM	Hong Kong Institute of Value Management

Value Engineering (VE) is a systematic methodology aimed at achieving the best balance between function, cost, and performance throughout a project's life cycle[1–3]. It has been widely recognized as an effective tool for improving quality, reducing unnecessary costs, and enhancing decision-making in construction and infrastructure projects[4]. Despite its proven benefits, many recent studies on structural strengthening have primarily focused on material performance[5–7] and structural efficiency[8–11], while overlooking the integration of value engineering principles. This gap highlights the need to consider VE not only as a cost-saving tool but also as a comprehensive approach to ensure that strengthening solutions remain feasible, sustainable, and aligned with project objectives[12–15].

Value Engineering definition per Save International is '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 unction reliability at the lowest overall cost'[16]. Another VE definition was provided by the Hong

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Kong Institute of Value Management (HKIVM), where it was defined as 'a structured, systematic, flexible, team-oriented approach for assessing the relationship between function, cost and worth'. Mao et al.[17] defined value engineering as a process in which the team tries to understand specific system functions to realize their essentials at the lowest possible life cycle cost. Bader[18] conveyed the SAVE international definition for value engineering as SAVE International as "a prepared energy to analyze the functions of the machine, project, product, and services to identify the crucial functions with an optimum life cycle cost which are consistent with the required performance, reliability, quality, and safety.". A value system is defined as a corporation's value chain embedded in a more significant activities stream consisting of a Firm value chain, Supplier value chain, Other Business units value chain, and Buyer value chain[19].

Value engineering has become a recognized methodology with a comprehensive procedure to meet stakeholders' expectations in developed countries[20]. The same was mentioned by Bader[18], who stated that value engineering is deemed one of the most beneficial practices for aligning an organization to achieve its objective. Mao et al.[17] mentioned that the VE has been used widely as a definitive tool in many industries, including the construction industry. Moreover, Kissi et al.[20] stated that value engineering can promote finding solutions for deadline slippage, overbudgeting, and low quality, which are the biggest challenges facing construction projects in developing countries' public sector. Where the VE is usually conducted in the early design stage[17]. Per Kissi et al.[20], VE is one of the most significant economic development factors as it balances the cost with the product role. Al-Yami[19] confirmed that Value Engineering could be exercised within the brief stage to outline requirements and within the construction stage to realign the value systems for the client and contractor, demonstrating the constructability. Mao et al.[17] emphasized the same, stating that the VE should be considered during the construction stage, where the contractor's practical experience, innovative construction, and logistics plans will contribute to the time and cost saving and improve the quality of the deliverables. Additionally, Al-Yami[19] stated that value engineering becomes more efficient when it is conducted in the early stage of the project to structure the problem, helping the stakeholders to decide the best solution for the problem and contributing to identifying the need for investment and the risks might coincide that investment where go/no go decision is to be taken. A multidisciplinary team should apply value methodology to enhance the value via performance criteria analysis[16]. Kissi et al.[20] added that using value engineering in public projects with an elaborate methodology and sound approach for analyzing the project objectives and attributes focuses on alternative development and benefits regarding costs and quality[18]. discussed many benefits that could be leveraged by the implementation of value engineering, such as validating the approximate life cycle cost (LCC), improving quality, delivering visible projects, saving the project time, improving project value, saving costs, claims resolution, project effectiveness, communication enhancement, standing enhancement, and enhancing constructability. Kissi et al.[20] additionally mentioned that the VE provides extra benefits such as reducing risks, improving quality, understanding the customers' requirements, transferring knowledge, eliminating delays, boosting quality, and advancing the growth of the technology. Moreover, Geissdoerfer et al.[21] revealed that the value ideation process helps companies enhance their provided values from economic, social, and environmental perspectives by providing additional values to wider stakeholders' interests.

VE phases and stages

Three stages are incorporated in the value engineering (preworkshop, workshop, and postworkshop). Value engineering workshop sessions are the critical stage, and they include function analysis, creativity, and evaluation phases[17]. Value engineering, per SAVE International, has six phases: information, function analysis, creativity, evaluation development, and presentation phase[18].

Although value engineering has been recognized as a powerful methodology for optimizing cost, quality, and performance, its application in the creativity stage still suffers from significant limitations. Many proposals generated during brainstorming are either impractical or fail to address real project constraints[22–24], which reduces the efficiency of the entire process[25–29]. At the same time, a considerable body of research has investigated strengthening structures through different approaches—some focusing on extending service life[30–32], others on enhancing performance[33,34], and others on achieving maximum efficiency[35,36]. However, most of these studies overlooked the integration of value engineering principles, particularly during the ideation phase, which could ensure that strengthening solutions remain both effective and feasible[37,38]. To address this gap, the present research introduces the Oriented Creativity Matrix (OCM) as an innovative tool to guide the ideation process, unify participants' efforts, and generate more viable and applicable alternatives. By testing and validating the completeness of the altering aspects through expert feedback, this study aims to provide a structured framework that enhances the effectiveness of the creativity phase and strengthens the overall value engineering practice.

VEP implementation problem

Mao et al.[17] stated that although the Value of the project is improved by the outcomes of the Value Engineering exercise without compromising its designed functions, a new records poll showed that 43% of respondents considered it a marketing ploy.

Al-Yami[19] stated that a lack of experience, accountability, or motivation causes the owner's failure to implement VE. Where VE is often conducted late in the project as Costs Cut backup, difficulties might be encountered, such as workflow interruption, the need for extra design resources, and the probability of losing critical design features. Mao et al.[17], in his review of research to value methodology, mentioned some limitations in the conventional VE process. Those limitations that may hinder the achievement of the desired sustainability goals could be summarized in the following:

(1) Over-emphasis on cost.

(2) Determination of criteria in the pre-study and information phase.

(3) Using pair-wise comparison.
(4) Abstract allocation of weights to criteria.
(5) Rating or ranking the alternative by advantages and disadvantages.
(6) Absence of creativity promotion and improvement.

Mao et al.[17] stated that the conventional VE, especially the FAST technique, is considered a cost-worth technique that is typically first-cost-driven as the potential of project system improvement is measured by the cost/worth ratio.

Kissi et al.[20] conveyed that the statement of the VE situation within the developing country is prescribed as blurry. He also stated that the same situation may be faced within construction projects even in developed nations such as the UK, the USA, China, and Hong Kong. He dwelled on saying that although various VE implementation challenges were mentioned, the underlying factors of such challenges were not examined, especially those encountered in the developing area.

Bader[18] attributed the low implementation rate for value engineering proposals to the risks associated, such as the unavailability of resources and conflict of interest between the stakeholders. He investigated therein effeteness for 21 success factors for Value Engineering, culminated with identifying the following significant factors for Value Engineering rejection:

(1) More information is needed for VEP development.
(2) Need for more support from senior management.
(3) Shortage of the assigned team to follow up on implementing VEPs.
(4) Deficiency in required personnel to plan, execute, and track the implementation of the VEP.
(5) More time is needed to develop VEP to get decision-makers approval.
(6) Unauthorizing department representatives to make decisions in the implementation meeting.

Mao et al.[17]stated that brainstorming in the creativity stage in value engineering requires spending a substantial amount of time and effort creating many ideas. Most of those ideas will eventually be proven useless as they are irrelevant to the project, impacting the efficiency of the value engineering exercise.

Al-Yami[19] mentioned the cultural opposition between unequal institutions, which value engineering might face, and stated the need to get approval from that opposition. He also reported that some countries, such as the UK and Australia, have modified the value engineering approach radically to fit their situation and culture. Further, other countries like China and Japan modified the Value Engineering approach to fit their state and practice. However, the traditional United States Value Engineering approach must be contextualized in Saudi Arabia.

Mao et al.[17] stated that the value engineering creativity phase is crucial and relies on the brainstorming process where many ideas are generated to spend a substantial amount of effort. Time is spent treating those ideas while most are being proven useless.

Lis of direct influencing implementation challenges

In seeking to examine the challenges facing the value engineering proposal implementation, a study was conducted to reveal the challenges directly influencing the implantation of value engineering proposals. After defining the influencing areas within which the challenges are transforming to influencing the implementation of value engineering proposals in a direct manner, all reported challenges within the previous research were categorized and rearranged per their influencing areas. Then, the direct-influence challenges were further grouped under three implementation barriers over which the proposal should pass to be implemented. These three barriers are the proposal's viability, the support of decision-makers, and the implementation. By studying the influencing factors under these three barriers, 30 direct-influence challenges were revealed, as seen in Table 1.

VE creativity phase

As elaborated previously, the value engineering creativity phase starts with brainstorming (idea creation), which imposes avoiding judging any of the proposed ideas or attempting to evaluate them in seek of keeping the idea creation within a free-thinking atmosphere. However, many of these ideas have later been proven useless and have been dropped. Such a manner in treating the value problem is not only wasting the value team's time in treating useless proposals, but it causes a loss of the chance to discover beneficial proposals, which impacts the efficiency of the whole value engineering process.

Impact of the normal creativity procedure on the VE implement ability

As the proposal is initiated within the creativity stage, absence of the proposal continuous alignment with the implementation influencing factors will result in lack to the proposal applicability. Such alignment must be proved, presented and documented in a self- explanatory format to avoid future resistance from stakeholders due to the miscommunicating the VE team ideation perspectives with them.

This situation is triggering the challenges under the three barriers and increasing their likelihood to happen. For the proposal viability, it became obvious that such an uncontrollable procedure is to generate an unviable proposal. The impact will still exist for the decision makers' support, where the.

Attempts to enhance the VE Efficiency - TRIZ

In his trial to tackle the shortage of ideation in the creativity stage within value engineering job plans, Mao et al.[17]applied the theory of inventive solving problems (TRIZ) in VE's creativity phase. His research introduced (TRIZ) as a technology-dependent technique for ideation rather than being dependent on psychology in generating ideas as it is in the normal brainstorming process. Further, he recommended integrating this feature with the normal brainstorming process to enhance the generation of innovative ideas and avoid distracting the

Barrier	Challenge	Mohamed., 2019	Moa, 2017	Alssaleh, 2017	Montaser., 2017	Kissi, 2016	Woa, 2015	Berawi, 2014
Proposal Viability	Misalignment with VE Goals (Irrelevant Ideas)		✓	✓	✓		✓	
	Disagreement on the proposal's added value.	✓					✓	
	Contradiction with the project's objectives.	✓	✓	✓				
	Contradiction with client commitments.	✓		✓				
	Contradiction with project phasing plan.	✓						
	Contradiction with business plan.	✓		✓				
	Conflict with the site constraints or other design components. (Physical or Performance conflict)		✓					
	Conflict with other client's projects.			✓				✓
	Not meeting technical requirements (lack in function).	✓	✓	✓	✓		✓	
	Not meeting key Stakeholder's requirements.	✓		✓	✓			
	Misalignment with client policies and procedures.	✓		✓		✓		
	Misalignment with the regulations.		✓	✓				
	Lack of proposal constructability and required resources	✓	✓	✓	✓	✓		
	Misalignment with service providing availability.	✓			✓			
	Causing a Lack of maintainability	✓						
	This causes a lack of durability, reliability, and quality.		✓	✓	✓	✓	✓	
Decision Maker Support	Poor presentation to the Decision Maker (DM)			✓		✓		
	Untrusted Creation Process by DM			✓		✓		
	Unacceptable proposal risks	✓		✓		✓		
	Misalignment with decision maker's prioritization order (Expectations)	✓		✓	✓	✓		
	Not considering the decision maker's authority limitation.			✓		✓		
Implementation Follow up	Unclear direction & execution action plan (Lack of proposal traceability)			✓			✓	
	Unjustifiable technical viewpoint (Lack in the proposal description information)						✓	
	Conflict with the organization's overall directive	✓					✓	
	Exceeding the allocated implementation budget.		✓	✓		✓		
	Not consistent with dedicated development timeframe		✓	✓	✓	✓		
	Not consistent with the available design resources.				✓		✓	
	Incorrect assumptions during VE ideations.	✓						
	Triggering change resistance.	✓						
	Lack of consideration of full life cycle cost	✓	✓	✓		✓	✓	

Table 1. VE proposals implantation challenges.

creativity process. The research explained that (TRIZ) is a set of tools and techniques to analyze problems from various angles and find an inventive solution.

However, reviewing the procedure of the mentioned technique revealed a complicated procedure could not be applied by normal value team. Despite relative inapplicability of TRIZ, the concept that posed by it about standardizing the ideation still valid and attempted to be met by the proposed OCM technique in here.

Oriented creativity matrix (OCM)

OCM methodology

Oriented Creativity Matrix is an additional technique that intends to add some control to the brainstorming process within the Idea Creation phase by orienting the creativity toward certain sequential tracks to concentrate all mental power into a unified, focused partial problem to find the possible subsidiary solutions for those partial problems. These tracks are called altering aspects (where altering aspects are the aspects that could be alternated in the matter subject to the value engineering, such as (used material, geometrics, mechanism, etc.) for which the creativity could be oriented to generate sub-alternatives to be combined forming the main alternative later). Next to identifying the altering aspects, the process for reporting the original design proposed subsidiary solution is started, which is called the baseline here. The original study team should list the baseline subsidiary solutions and mention the subsidiary concept that drove them to set these subsidiary solutions. Then, proposing subsidiary solutions among each track is to be started by repeatedly altering the proposed subsidiary solutions in the baseline. By repeating that process for all creativity tracks, many subsidiary solutions (sub-alternatives) will be found. After that, the practitioners start composing the subsidiary solution with the compatible subsidiary solutions in the next track, including the subsidiary solutions in the baseline. Hence, it is not allowable during this composition phase to pass through any track to the next without finding a compatible subsidiary solution in that track. The composition phase is to be started horizontally from the first track on the left side toward the right side until the last track on the right side. Reaching the last right track, the selected subsidiary solution within each track will compose the first alternative, where all considerations in each track will then be considered. Repeating

this composition step covering all continuous horizontal lines will compose all possible workable alternatives. Integrating the relevant sub-alternatives considering the perception in each track (creativity approach) will create a comprehensive alternative studied from all perceptions with minimal implementation risk.

Figure 1 shows a descriptive diagram of the OCM solution and the creative approaches used in the construction project. These approaches or tracks could vary from one industry or project to another and be tailored per the situation requirements. For instance, the given example in Fig. 5 is for an infrastructure construction project.

The VE facilitator role is essential here, where he has to integrate all efforts to create the OCM matrix and lead the design team and the VE team while filling it. However, his required effort to manage the conflicts between the participating parties is much reduced due to the reduction of the conflicts themselves; this reduction in conflicts will happen due to unifying the target of all VE workshop participants to think about the possible subsidiary solution for a particular track rather than having unintegrated distracted efforts, and setting the solid ground for objective discussion rather than jumping to conclusion subjectively.

Further to the OCM benefit for ensuring the viability of the posted ideas by giving clear guidance for the creativity process, the OCM is easing the record for the proposed idea in a presentable way and releases big overburden from the evaluation phase where idea validation will be already done within the creativity phase. All these benefits contribute to solving or mitigating the challenges, as seen in Table 2.

Furthermore, applying such technique within the brainstorming process will increase the team's understanding of the project, promote team cooperation, integrate all efforts, record the discussion within the workshop, justify the VE recommendations in a presentable way, save the team's time and efforts during the brainstorming, and transferring the technical perceptions to the development team.

Benefits of OCM

As illustrated earlier, the OCM is providing a way of thinking rather than rigid steps for its implementation. Therefore, the included creativity aspects could be changed to adapt the studied situation and tailoring itself could be done using any of the group thinking tools.

Defining, considering, and working around the various considerations are recorded in a well-structured way, easing the process of tracing the ideation approach and visualizing the discussion between the VE team. This method significantly increases the reliability of the proposed alternative and maximizes their improvement through the cooperation between the workshop participants. Such cooperation is a result of eliminating the bias to specific ideas by countering the subjectivity through the subdividing of the altering process and reaggregating the sub-alternative into the main alternative.

The OCM was designed in light of the revealed value engineering proposals' implementation challenges. Thus, OCM is to be providing practical solution contributes in overcoming 26 challenges out of the revealed 30 value engineering proposals' implementation challenges. Table 2 is showing the contribution of the OCM in overcoming each of those challenges.

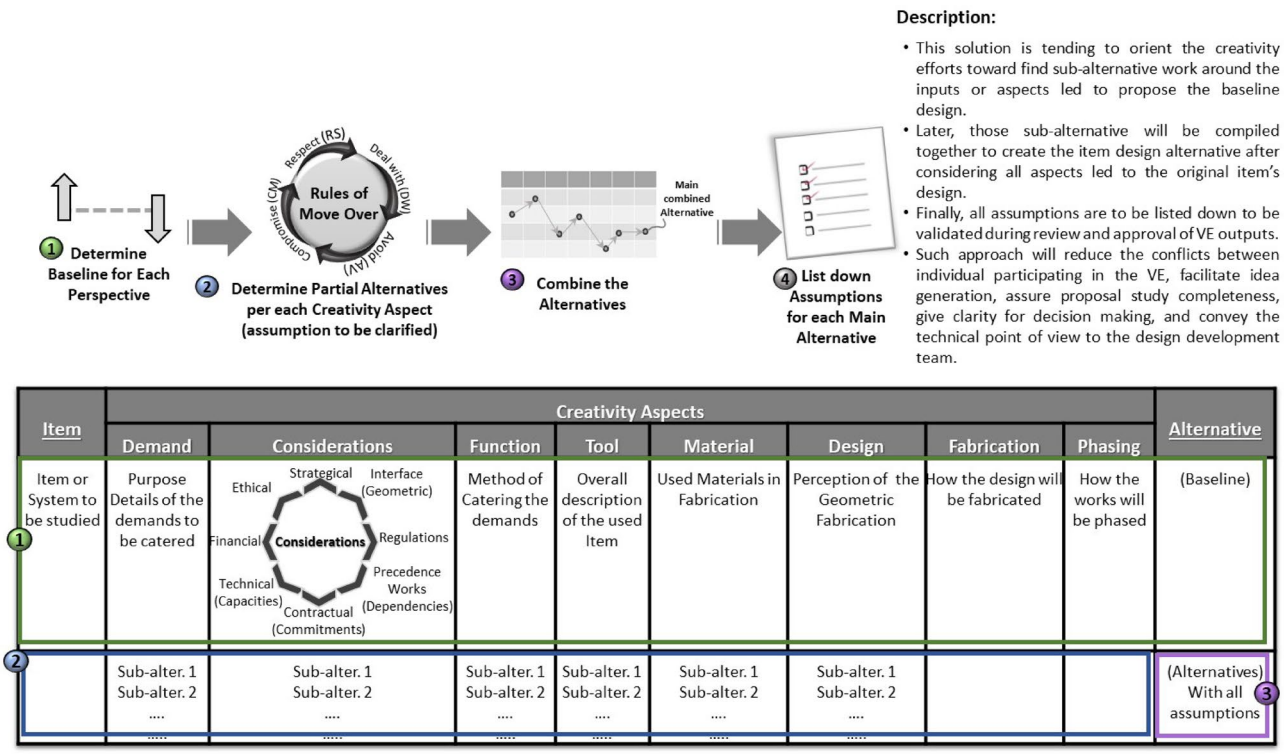

Fig. 1. OCM methodology scheme.

Barrier	Challenge	OCM's Contribution to solving the challenge
Proposal Viability	Misalignment with VE Goals (Irrelevant Ideas)	VE goals are to be considered as a strategical consideration during ideation per the OCM procedure.
	Disagreement on the proposal's added value.	OCM provides a holistic study of the alternative from all relevant perspectives
	Contradiction with the project's objectives.	The project's objectives are to be considered strategically during ideation per the OCM procedure.
	Contradiction with client commitments.	Client commitments are to be considered within the contractual considerations in OCM.
	Contradiction with project phasing plan.	A phrasing plan is one of the creative aspects that must be considered during ideation via OCM.
	Contradiction with business plan.	Business Plan constraints are to be considered as a strategic and financial consideration in the OCM ideation.
	Conflict with the site constraints or other design components. (Physical or Performance conflict)	Interface and geometric constraints are included in the OCM's consideration of the creativity aspect to be considered during ideation.
	Conflict with other client's projects.	This is to be translated into commitments and dependencies that are included in the OCM ideation.
	Not meeting technical requirements (lack in function).	Technical requirements are included in the technical consideration to be addressed during the OCM ideation.
	Not meeting key Stakeholder's requirements.	Commitments and regulations are included in the consideration of creativity in the OCM.
	Misalignment with client policies and procedures.	Client's procedures are to be translated into contractual and regulation consideration win the OCM
	Misalignment with the regulations.	This is to be covered by the regulations' constraints in the consideration of creativity.
	Lack of proposal constructability and required resources	The fabrication creativity aspect covers these perceptions
	Misalignment with service providing availability.	This will be covered by the design creativity aspect and the technical part, taking into consideration the creativity aspect.
	Causing a Lack of maintainability	This will be covered by the technical aspect, taking into consideration the creativity aspect.
	This causes a lack of durability, reliability, and quality.	All these points are to be covered by technical constraints in consideration of creativity.
Decision Maker Support	Poor presentation to the Decision Maker (DM)	As the OCM will provide a clear presentation recording all discussions and considerations
	Untrusted Creation Process by DM	OCM enable the decision maker to have a comprehensive understanding of the basis on which the ideation was tackled and the proposal alignment with the key perception.
	Unacceptable proposal risks	The breakdown of the proposals that to be provided by OCM will contribute in discovering and addressing the gap from which the risks could be generated.
	Misalignment with decision maker's prioritization order (Expectations)	-
	Not considering the decision maker's authority limitation.	-
Implementation Follow up	Unclear direction & execution action plan (Lack of proposal traceability)	-
	Unjustifiable technical viewpoint (Lack in the proposal description information)	OCM will be working as an effective communication document analyzed enough to capture all bases/viewpoints on which the alternative was proposed
	Conflict with the organization's overall directive	The directive is to be defined and considered by the strategical part while considering the creativity aspect.
	Exceeding the allocated implementation budget.	The financial and contractual constraints are to be defined and considered within the consideration creativity aspect.
	Not consistent with dedicated development timeframe	This is deemed one of the commitments that should be addressed by considering the creativity aspect during the ideation via the OCM.
	Not consistent with the available design resources.	-
	Incorrect assumptions during VE ideations.	As per the OCM procedure, all assumptions for the subalternities that configure the main alternatives should be recorded and validated.
	Triggering change resistance.	OCM is providing well-structured thinking procedure and justifications for the alteration process which will promote the engagement of the relevant stakeholders and providing sufficient answers for the counter arguments if any.
	Lack of consideration of full life cycle cost	-

Table 2. OCM contributions to overcome the VEP implementation challenges.

Quantitative analysis

To examine the OCM procedure quantitatively, a questionnaire was distributed to the specialists in value engineering to collect their feedback regarding the proposed methodology. Questionnaire surveying is suitable for collecting feedback from a wide sample of respondents as much as required to conduct the quantitative analysis for this purpose. However, the nature of the surveying doesn't allow the required open discussion with the respondents to discuss and elaborate on the proposed methodology; thus, surveying objectives were identified to fit the nature of the surveying and provide the required information. These objectives were:

1. Ensuring that all altering aspects in the provided list are covered, which validates the base of the OCM, which is countability for the altering aspects through which the VE idea could be generated. Assess the effectiveness of the listed altering aspects.
2. Assessing the effectiveness of the listed altering aspects.

Sq	Position	Certificates
1	Infrastructure Manager	PHD, LEED GA, VMA
2	Value Engineering Certified consultant	MBA, CVS
3	President at EHAN Engineering, Vice president at Save International	PhD, P. Eng., CVS
4	President of Value Engineering at YVE	CVS- Life, FSAVE

Table 3. Pilot survey participants.

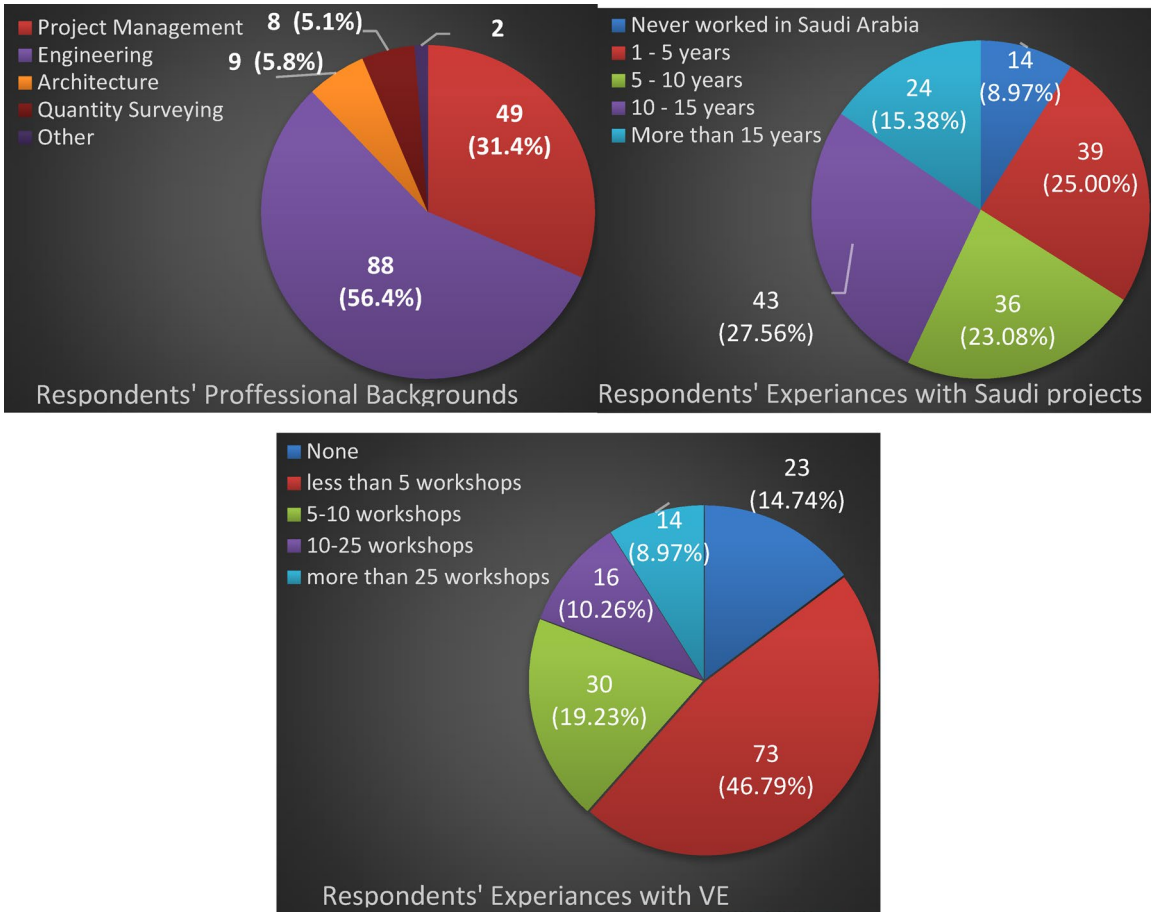

Fig. 2. Respondents' information.

Pilot survey

Prior to releasing the questionnaire, a pilot survey was conducted in the form of interviews with experts to discuss the draft of the questionnaire with experts in value engineering inside and outside Saudi Arabia. The collected feedback from those experts was helpful to refine the questionnaire and the research accordingly. Table 3 shows the information and qualifications of the experts interviewed.

Respondents information

The survey intended to collect the key characteristics of the respondents to ensure coverage of all respondents' categories. Those categories are grouped under three categorization criteria, which are (their experience with value engineering, professional background, and experience with Saudi projects).

The questionnaire was conducted online using Google Forms and distributed as a link to the respondents via various social platforms such as LinkedIn, WhatsApp, and Telegram. The feedback was received from 156 respondents. Figure 2 shows the respondents' categorization and the percentage of each category.

Altering Aspects Completeness.

The respondents were questioned via the questionnaire about the completeness of the altering aspects, where 83% of the respondents confirmed that the provided list covers all potential altering aspects, as shown in the pie chart in Fig. 3.

The significance of the correlation of the respondents' feedback about confirming the altering aspects list completeness was checked among the VE experience groups via Pearson's Correlation, which assured the

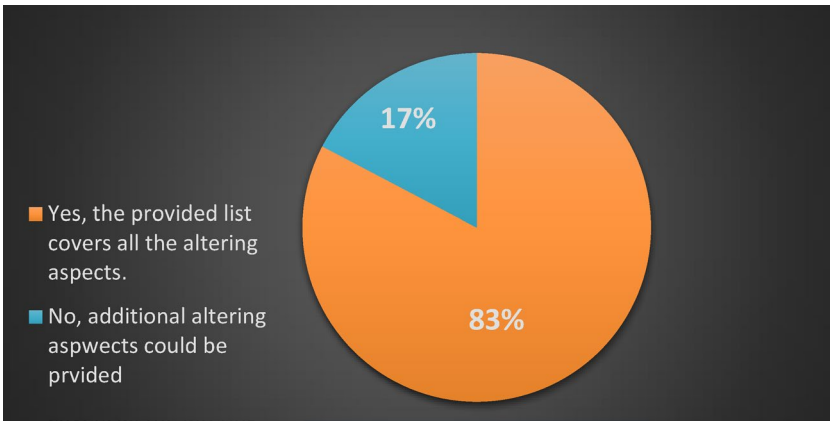

Fig. 3. OCM creativity approaches completeness assessment.

Correlations

		Experience with the VE	ALTCOM
Experience with the VE	Pearson Correlation	1	.373**
	Sig. (2-tailed)		.000
	N	156	156
ALTCOM	Pearson Correlation	.373**	1
	Sig. (2-tailed)	.000	
	N	156	156

**. Correlation is significant at the 0.01 level (2-tailed).

Fig. 4. OCM creativity approaches completeness significance (SSPS output).

statistical significance of the confirmation completeness as seen in the snip of SPSS output shown in Fig. 4, where COMALT refers to the cumulative number of responses confirmed that the provided list within the survey covers the possible altering aspects.

Altering aspects effectiveness assessment

To validate further the OCM as a proposed solution, the questionnaire aimed to collect feedback from the respondents about the efficiency in enhancing the value of the altering aspects (creativity approaches) and their completeness, along with exploring the additional proposed altering aspects.

Figure 5 shows the evaluations' arithmetic mean for each pre-listed altering aspect, where the received efficiency evaluations for the listed altering aspects showed a satisfactory level regarding their efficiency in enhancing the value.

The additional proposed altering aspects

The responses included some proposed additional altering aspects. By reviewing those proposals, only one proposal could be adopted as an optional other altering aspect subjected to the user's preference, which is "the project or item location. "So, this altering aspect could be included via one of the following three procedures:

1. Consider it one of the constraints proposed to be tackled by the OCM, as illustrated earlier in the pre-questionnaire analysis.
2. Include it within the geometric altering aspect of the OCM, as illustrated previously in the pre-questionnaire analysis.
3. Add it as a stand-alone altering aspect.

The responses received were reviewed and answered, and Table 8 shows the proposed additional altering aspects and the response to each.

Study limitations

Although the study was targeting the application of the OCM within Saudi Arabia, the results could be applied in other countries, considering the differences in the Altering Aspects' priorities. For instance, the priority of

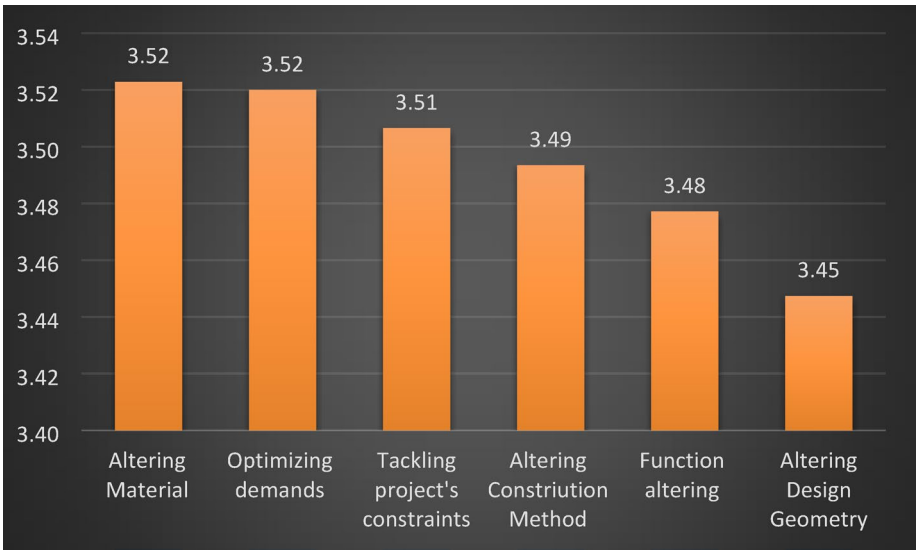

Fig. 5. Effectiveness assessment for the listed creativity aspects.

Sq	Altering Aspects List completion responnse	Remarks
1	The project objectives are among the main reasons that must be achieved.	the objectives might include function, material specs, quality, requirements, or other constraints that are already included in the provided list.
2	Changing the procurement strategy	Already included as constraints should be respected or worked around.
3	Sometime project location (site) is altered. Some time project is deleted (not required function) and many	Could be adopted as additional altering aspect, however in many project the location is to be respected as constraint or treated within geometric alteration. So it will be introduced in this research as a choice subjected to the user preference
4	Elimination of unwanted functions or deletion of the whole project etc.	Already included the function alteration.
5	Data visibility, Enriching data availability	The proposal is not an altering aspect.
6	Changing the conventional procurement system used in the country which is mainly based on low cost offers; Also adopting PPP or DBOM procurement methods and involving the Contractor from project conceptualization phase	Already included as constraints should be respected or worked around.
7	Life cycle costing for High energy consuming systems,	it is included in the demand reduction
8	Workmanship competency	this is not an altering aspect
9	Sustainability, Energy Efficiency…	Irrelevant proposal, it is a result to be achieved by the alteration
10	Assessing risk and opportunities to mitigate risk in other ways, improving contract clarity and evaluation/selection process	These aspects are already included in the constraints that part of the provided altering aspects list
11	study the availability of material alterations that enhance the function and saving cost	already included in the material alteration
12	Altering contracting strategies.more into agile approach rather than water fall and not always every project or program is lump sum fixed price	already included in the phasing's alteration aspect
13	timing of VE proposal during the project phases	it is not an altering aspect
14	System alteration,	it is combination of the the function, geometric, and material alterations
15	I think all of the participants must have the same objective. I felt in the studies in which I participated the designer tried to avoid any modifications and changes in the original design. I think: they can't get the purpose of these studies and they try to pass the workshop days as a commitment to the organization without any enhancement objectives.	No additional altering aspect is proposed, unifying the team objectives is one of the OCM method ojectives.
16	Added in company procedure, further at country level	it is included in the constraints treatment alteration aspect
17	Budgeting and Cost Estimation also monitoring the AC	already included in the financial constraints
18	Fire Resistance, LEED/MOSTADAAM, TQM	irrelevant proposal, as it is discussing the reasons behinde the need for alteration.
19	structural design system, sustainability aspects, operator requirement	already included in the constraints, material, function, and geometric altering aspects
20	Selection of VE Team	it is not an altering aspect
21	We need VE to be conducted and VEP implemented by laws and regulations	already included in the regulation aspect

Table 4. Responses to the proposed altering aspects for OCM.

alignment with client commitment that is to be included within "Tackling Project's Constraints", Altering Aspect could vary highly based on the flexibility level adopted with the client corporation; however, such variance will not impact the benefits of using the OCM. Rather, OCM's methodology is designed to be easily tailored to adopt such variance.

Conclusion

This study set out to address the long-standing challenges associated with the creativity stage in value engineering (VE), where conventional brainstorming often produces a large number of impractical or irrelevant ideas, limiting the efficiency of the overall process. To overcome these limitations, the Oriented Creativity Matrix (OCM) was developed as an innovative tool that guides creativity in a structured manner by subdividing the main problem into predefined altering aspects and systematically combining sub-alternatives into workable solutions. The methodology was quantitatively validated through a large-scale survey of specialists, and its potential contribution to overcoming implementation barriers was critically examined. Based on the results, the following conclusions can be drawn:

1. The OCM provides a structured and systematic approach to idea generation, ensuring that alternatives are aligned with project objectives and reducing the risk of impractical proposals.
2. By subdividing the ideation process into altering aspects, the OCM facilitates the development of sub-alternatives that can be combined into comprehensive solutions, thereby enhancing both creativity and feasibility.
3. The survey of 156 VE specialists confirmed the completeness of the altering aspects, with 83% agreement, statistically validated using ANOVA, which confirms the methodological soundness of the OCM.
4. The findings revealed that the OCM can directly contribute to mitigating 26 out of 30 previously documented implementation challenges, particularly those related to proposal viability, decision-maker support, and implementation follow-up.
5. Future research should apply the OCM methodology in practical case studies and explore additional altering aspects tailored to different project contexts, further enhancing its adaptability and impact on VE practice.
6. Findings assure the completeness of the Altering Aspects list that could be used as a guide to the participants' ideation during creativity workshop. Using this tool contributes to overcoming the difficulties that might be faced during implementation of the value engineering as shown within this paper. The future effort is expected to apply using the OCM tool on a case study and to propose additional Altering Aspects per the field where it will be used.

Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Ehab A. Mlybari: Conceptualization, data curation, formal analysis, investigation, writing - original draft. Emaduddin M. Alghamrawi : Methodology, formal analysis, writing - review & editing.

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Declarations

Competing interests

The authors declare no competing interests.

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