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Original Article

Critical Success Factors for Enhancing the Value Engineering Studies in Construction Sector in Morocco

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Abstract *- Value Engineering (VE) studies in the Moroccan construction sector face notable challenges in their practical implementation, emphasizing the need to identify and manage Critical Success Factors (CSFs). This study aims to determine and classify these factors according to their perceived importance among construction professionals and VE experts. A quantitative research approach was employed through a structured questionnaire survey. The CSFs were identified from a comprehensive literature review and validated through expert interviews. Data were collected from professionals representing diverse roles within the Moroccan construction industry. A scale-ranking analysis was conducted to evaluate the relative importance of the CSFs, supported by factor analysis to explore their underlying dimensions. Findings reveal that respondents perceive most CSFs as moderately to highly important, with variations depending on professional background and project context. The factors "Clear objective of the VE study," "Financial and Logistical Support," and "Professional Experience of Participants" were ranked as the most influential. Factor analysis further identified four principal dimensions affecting the success of VE studies: Strategy and Resources, Team Dynamics, Technical Implementation, and Leadership and Decision-Making. The study contributes to enhancing the effectiveness of VE applications and improving project performance within the Moroccan construction sector.*

Keywords *- Construction, Critical Success Factors, Morocco, Survey, Value Engineering studies.*

1. Introduction

The construction sector plays an important role in the economic development of countries, producing infrastructure, buildings, and industrial facilities. In Morocco, the construction sector is a key sector, enabling the development of the national economy and contributing to the reduction of the unemployment rate, representing more than 6% of the national GDP. The added value of construction would have improved in 2024, stimulated by a strengthening of public investment in the sector, oriented towards the preparation of the CAN 2025 and the 2030 World Cup, in addition to the reconstruction and rehabilitation program of the areas affected by the EL Haouz earthquake. In the construction sector, Value Delivery is among the key pillars of project management by ensuring that the project delivers value to the stakeholders. This includes managing the project scope, time, cost, and benefits realization to meet the project's objectives. Value Engineering (VE) is a creative, organized effort that analyzes project requirements with the goal of achieving essential functions at the lowest total cost over the life of the project. Through workshops, utilizing experienced, multidisciplinary teams, value and economics are improved through the review and study of design alternatives, materials, and methods without compromising the Client's functional and value objectives. The use of value engineering has been widespread in the United States for over 70 years. Several developed and emerging countries have also adopted this valuable tool in several construction projects, given the results achieved in terms of value optimization and life cycle cost reduction [1]. Regardless of the lack of awareness of VE techniques and benefits among all stakeholders in the construction sector, it has been proven that their perception towards value engineering changes once they become aware of the process, practice it, and see the enormous benefits that result from it [2].

Thus, value engineering has proven to be a valuable tool in the construction sector that promotes a better understanding by stakeholders of project functions and scope, cost efficiency, improves project performance, and ensures stakeholder satisfaction. However, achieving these objectives can only be ensured by controlling critical success factors, which are key elements that significantly contribute to the successful implementation and outcomes of value engineering processes. These factors help ensure projects achieve their intended value improvements while maintaining or enhancing quality and

performance.Several research studies have been conducted to identify and evaluate critical success factors for VE studies, considering the specificities of the application context, the organization, and the means available to conduct a structured VE study [2]. That is why it was deemed appropriate to carry out this analysis in the Moroccan construction context.Thanks to this study, stakeholders in the construction sector, particularly technical design offices and project owners, will be able to appreciate and evaluate the importance of critical success factors for the promotion of value engineering studies in the construction sector in Morocco.

The research on critical success factors for value engineering in the construction sector, particularly in the MENA (Middle East and North Africa) region, focused on identifying and analyzing the elements that contribute to the successful implementation of value engineering practices. Identifying and evaluating critical success factors of value engineering implementation in Saudi Arabia has contributed to an improved understanding of VE implementation in the construction sector. The top four ranked factors were the company's ability to conduct a VE workshop, the competence of the VE facilitator, effective communication among participants, and the multidisciplinary VE team [3]. Nevertheless, this research didn't investigate the interrelationships among these CSFs and how they influence the implementation of VM in construction projects in Saudi Arabia. Furthermore, exploring the critical success factors of implementing value engineering for a sustainable residential construction project in Egypt revealed that clarifying the roles and objectives of different professions was the key success factor for the success of the VE study [4].

Indeed, identifying and highlighting these critical success factors will enable decision-makers and project managers to better understand the foundations and essential elements of VE workshops and to master the elements of successful VE studies in the specific context of the country and sector. This will answer the relevant question regarding the return on investment made for a VE study, namely the generation of substantial gains for the project in terms of improving the values defined by the Client, including initial cost, lifecycle cost, time, and quality. The results of this study provide a solid framework for stakeholders involved in launching a VE study in the Moroccan construction sector.

2. Literature Review

2.1. Value Engineering Definition and Standards

The process is typically conducted in a workshop setting with key stakeholders present and led by an experienced practitioner to lead value engineering teams through defined phases. The definitions of value engineering found in the literature share several commonalities, including:

- Lifecycle costing: In addition to design and construction costs, the focus is also on operating and maintenance costs, as well as residual value or disposal costs.
- Value optimization: The focus is on finding alternative solutions to increase value for the owner.
- Structured process: The team is required to follow a structured process.

The value engineering process is typically implemented according to a work plan consisting of eight general steps, illustrated below [5].

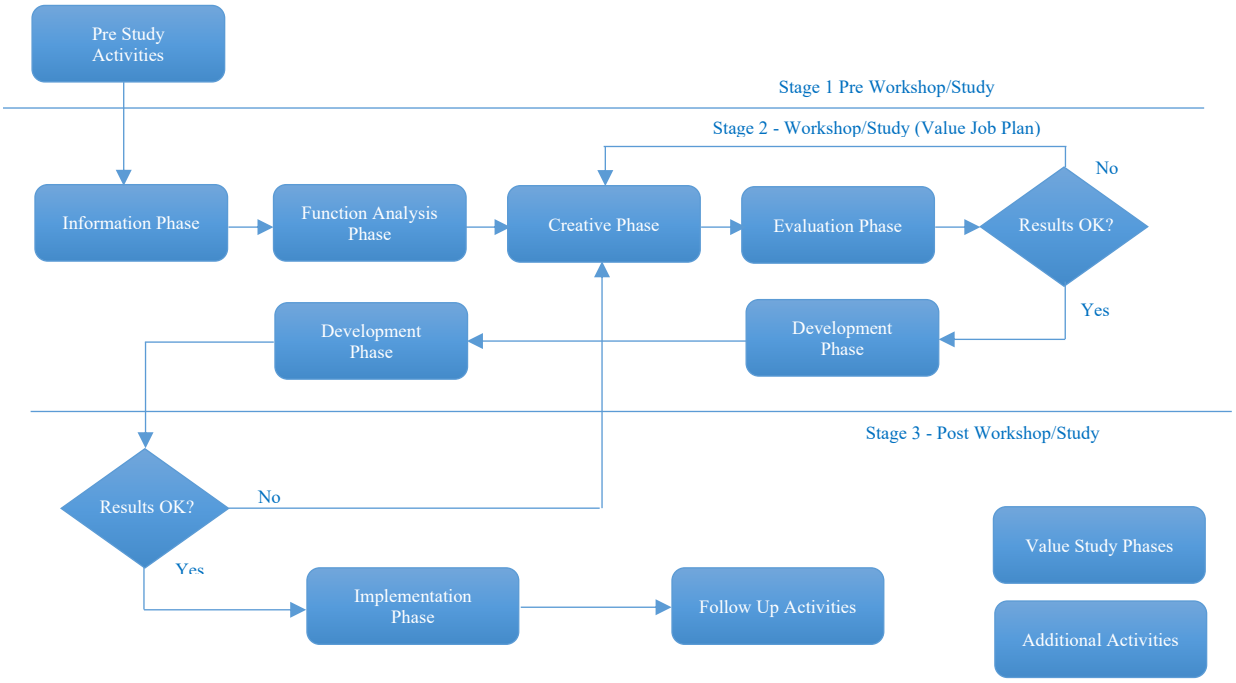


Fig. 1 Typical job plan [5]

2.2. Overview of the Implementation of VE in the Construction Sector

The use of value engineering is widely observed in various construction projects in developed countries, such as the United Kingdom and the United States [6]. Although value engineering is not as well established in the construction sector of developing countries, this concept has gained relevance in many countries, despite the lack of systematic approaches for its application in the construction sector [7]. Some emerging countries have established requirements for the mandatory integration of value engineering into their construction projects. In Malaysia, the implementation of a value engineering study is mandatory for all types of public projects costing more than approximately $11.5 million [1]. As for African countries, the last two decades have seen the beginning of awareness and adoption of this innovative approach [8]. In Morocco, although construction professionals recognize the importance of value engineering to optimize projects, it was demonstrated that the practice of value engineering, in accordance with current standards, is still in its infancy in the Moroccan construction sector. It was also noted that several techniques require additional awareness and training for successful implementation, particularly the value engineering job plan, value engineering workshops, and the FAST diagram.

2.3. VE in Enhancing Value Delivery in Construction Projects

Value engineering constitutes a valuable tool to achieve optimal project outcomes and enhance value delivery for the owner and different stakeholders. Indeed, VE enhances understanding of scope and functions, ensures significant potential savings both initial and Lifecycle Cost, early uncovering of potential design deficiencies or alternative approaches, reduction of completion times, improvement in quality, sustainability, safety, and energy consumption. VE was implemented in a sustainable energy infrastructure development project in Malaysia and helped reduce the project cost while maintaining the quality of materials [9].

The application of VE in a residential building in India shows an improvement of 26 % in the schedule of the project after adopting retained alternatives to separation and envelope walls and architectural lots [10]. In Sri Lanka, the application of VE to MEP works in building projects has improved the quality of construction and reduced life cycle cost [7]. In Malaysia, the application of VE in the RFP (Request For Proposal) stage in the D&B (Design and Build) allowed a complete analysis of the RFP package and its improvement for the effective achievement of the objectives set by the Client [11]. Value Engineering studies were carried out in the preconstruction phase for various activities of the Croatia Highway Project, providing the builder company with 6% financial savings and 17% work time reduction [12]. In a Libyan case study of an educational building where VE was applied, it was concluded that the most valuable idea does not mean having the lowest price, but achieving the required functions with minimum cost. Respect for the structured job plan, management of the attitude of participants, and use of function analysis were the most decisive factors for achieving successful outcomes, which encourages the Educational Facilities Authority to create a VE department in its organization [13].

2.4. Critical Success Factors from Previous Studies

Several studies have attempted to elucidate the critical success factors of VE studies, sometimes in a general way, sometimes specifically to a particular sector or country context. Through a benchmark study, Male et al [14] identified ten CSFs. Across different studies and contexts, it has proven very important to evaluate the importance of these factors across professionals in order to have a better understanding of their influence on the success of VE studies and the process implementation. Thus, the study conducted by Shen et al [2] allowed the development with a classification of 15 CSF, which are listed in Table 1. This study highlighted the following factors: a Clear objective of the VM study, timing of the study, interaction among participants, and cooperation from related departments.

Table 1. Ranking of Critical Success Factors for value management studies [2]

Factors	Mean	Standard deviation	Ranking
Client's support and active participation (CSF1)	4.88	0.33	1
Clear objective of VM study (CSF2)	4.88	0.56	2
Multidisciplinary composition of VM team (CSF3)	4.76	0.44	3
Qualified VM facilitator (CSF4)	4.54	0.92	4
Control of workshop (CSF5)	4.44	0.85	5
Preparation and understanding of related information (CSF6)	4.29	0.78	6
Plan for implementation (CSF7)	4.29	0.85	7
Function analysis (CSF8)	4.26	0.91	8
Timing of study (CSF9)	4.23	0.76	9
Interaction among participants (CSF10)	4.21	0.81	10
Professional experience and knowledge of participants in their own disciplines (CSF 11)	4.19	0.73	11

Personalities of participants (CSF12)	4.18	0.91	12
Adequate time for VM study (CSF 13)	4.15	0.73	13
VM knowledge and experience of participants (CSF 14)	4.12	0.86	14
Cooperation from related departments (CSF 15)	4.06	0.32	15

Indeed, the purpose of VE studies is not limited to cost analysis and finding alternative solutions that reduce life cycle costs, but rather to facilitate strategic decisions, to improve communication and reach consensus among different stakeholders, to control the scope of a project, and to prioritize project requirements.

The objectives of VE studies are determined by the Client with the help of VE facilitators. They depend on many factors, such as client expectations, client perception of value [15], and project characteristics. A clear understanding of the study objectives is essential to guide the VE study process and focus the efforts of the participants. Ramly et al identified and classified 19 CSFs for Value Management workshops in Malaysia [16]. He added, especially End-user participation in the VE workshops, Discipline and attitude of the participants, Input from the relevant governmental departments, Site visits conducted, and Venue of the VE workshops.

Table 2. Nominated success factors and definitions for value management workshops in Malaysia [12]

Code	Success factor	Definition
SF1	Clear objectives provided for the VM workshops	Extent to which the objectives of the workshop were identified by the Client through facilitation by the facilitator
SF2	Client participation (representation) in the VM workshops	Extent of the Client's representative participation throughout the workshop process according to the value methodology
SF3	Client's support of the VM workshops	Extent of the support provided by the Client in terms of financial, information, and human resources
SF4	End-user participation (representation) in the VM workshops	Extent of the end-user's representative participation throughout the workshop process according to the value methodology
SF5	Discipline and attitude of the participants	Extent of the participants' Discipline in terms of punctuality and attitude during the workshop process according to the value methodology
SF6	Background information collected	Extent of the information about the project obtained before the workshop
SF7	Decision-making authority is granted to each participant by their respective organization.	The extent of the power to make a decision by the participants on behalf of their organization as stakeholders for the project
SF8	Team mix of the participants	Extent of the discipline mix among the participants representing different stakeholders of the project
SF9	Input from the relevant governmental departments and local authorities (e.g., local planning)	Extent of support provided by the relevant stakeholders that have no direct relationship to the project, but may affect the smooth running of the workshop and the project as a whole
SF10	Years of experience of the facilitator in VM workshop facilitation	Number of years of experience gained by the facilitator in facilitating VM workshops
SF11	Professional qualification of the facilitator	Professional qualification of the facilitator through accreditation by the relevant VM societies
SF12	Pre-workshop meeting conducted	Number of meetings conducted before the workshop
SF13	Workshop intervention into the project-development cycle	The extent to which the workshop takes off at different stages of the project-development cycle
SF14	Years of relevant experience of the participants in their own field	The number of years of experience gained by the participants in their own disciplines
SF15	VM knowledge of the participants	Extent of knowledge about VM among the participants
SF16	Site visits conducted	Number of site visits conducted before the workshop
SF17	Academic qualifications of the facilitator	Level of academic qualifications of the facilitator
SF18	Facilitator and average duration of each workshop, SF18, Number of VM workshops facilitated by the	Facilitation experience of the facilitator on the basis of the duration of individual VM workshops
SF19	Venue of the VM workshops	The Venue where the workshops are held

In Singapore, Hwang et al highlighted "clear and unambiguous objectives of VM," "education on VM," "communication and interaction among participants," "appropriate risk allocation and management," and "top management commitment and support" as being the most important CSFs for VM studies for building projects [17].

3. Research Methodology

This research was conducted to determine, clarify, and evaluate the CSFs of VE studies in the Moroccan construction sector. It is worth emphasizing that the identification and prioritization of critical success factors is very important, as it will allow for proper planning of VE studies and thoughtful and appropriate allocation of limited resources if necessary [18]. Interviews conducted with experts in the field of construction in Morocco and VE made it possible to refine the CSFs identified in previous studies and to retain 17 CSFs (listed in Table 3) as the critical success factors for enhancing the VE studies in the construction sector in Morocco. The experts consulted represent various backgrounds in the construction sector and the field of value engineering. Thus, interviews were conducted with:

- An expert in project management, consulting, infrastructure, roads, and various networks with 17 years of experience
- A director at the Moroccan Highways Company (ADM) with 32 years of experience and valuable experience in value engineering
- A technical department head at the National Agency for Public Equipment with extensive experience in managing large-scale projects and technical trades
- A division head at the Moroccan Ministry of Equipment and Water with extensive experience in technical regulations
- A senior specialist in the value engineering and methods department within a leading Moroccan company in the real estate sector
- A value engineering expert in Malaysia who contributed to the introduction of this process in the country and participated in the development of practical guides for value engineering studies in Malaysia
- A value engineering expert, certified value specialist, involved in VE studies in the Middle East

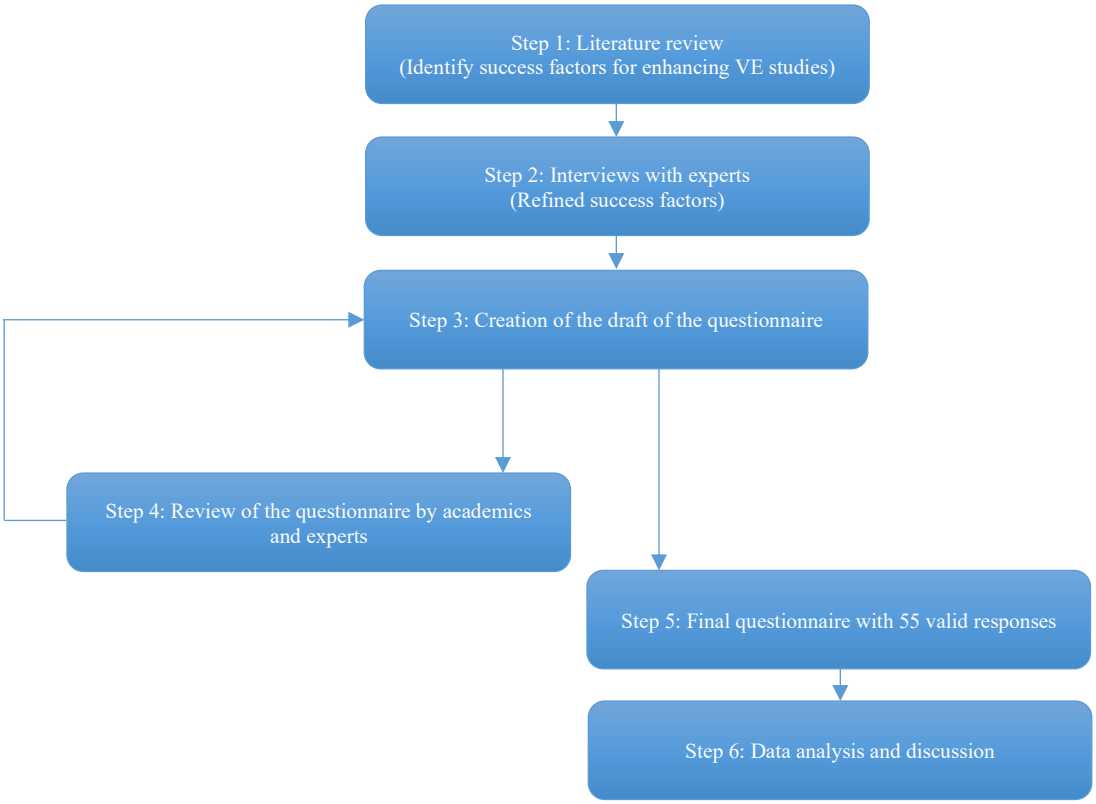


Fig. 2 Research flowchart

Table 3. Identified critical success factors for enhancing the VE studies in the construction sector in Morocco

1. Clear objective of the VE study
2. Qualified VE facilitator
3. Multidisciplinary composition of the VE team
4. Professional experience and knowledge of participants in their own disciplines

5. Preparation and understanding of related information
6. Respect for the structured job plan
7. Management of the attitude of participants
8. Presence of decision makers
9. Interaction among participants
10. Use of function analysis
11. Use of specific skills and techniques (such as brainstorming, FAST, etc.)
12. Plan for implementation of retained alternatives
13. Follow-up and support for implementation
14. Client's support and active participation
15. Cooperation from related departments
16. Adequate time for VE study
17. Financial and logistics support of VE study

In order to facilitate the evaluation of the success factors identified by professionals in the sector, it was considered useful to provide the definitions and the necessary elements of clarification regarding the aforementioned factors.

Table 4. Definitions and clarifications of identified critical success factors

Critical success factor	Definition
1. Clear objective of VE study	The Client defines specific and measurable objectives to be reached, especially value attributes to be enhanced, such as cost, life cycle cost, lead time, environmental considerations, etc.
2. Qualified VE facilitator	The VE study team leader is substantively neutral, leads the group through the VE Job Plan, and increases the group's effectiveness.
3. Multidisciplinary composition of VE team	The team led by the facilitator should be composed of all specialists according to the objectives defined by the Client and the results of the preparation phase of VE study.
4. Professional experience and knowledge of participants in their disciplines	All participants in VE workshop must master their field of knowledge in order to evaluate and interact with the generated alternatives.
5. Preparation and understanding of related information	It concerns Pre-Workshop activities, especially identifying goals and objectives, determining scope, collecting valuable data, preparing data models, budget breakdown, …
6. Respect of the structured job plan	A sequential approach for applying the Value Engineering, consisting of the eight phases: Preparation, Information, Function analysis, Creativity, Evaluation, Development, Presentation, and Implementation [19].
7. Management of the attitude of participants	The facilitator should identify all participants' attitudes, including the design office team, and manage them accordingly.
8. Presence of decision makers	The presence of decision-makers helps to facilitate the progress of the different phases of the VE study and to avoid roadblocks.
9. Interaction among participants	All stakeholders involved in the VE workshop should communicate and interact to reach the expected consensus of value improvement.
10. Use of function analysis	A detailed examination of the elements of the project to identify, classify, and organize its functions; allocate performance and resources; and prioritize functions for value improvement [19].
11. Use of specific skills and techniques (such as FAST, brainstorming, etc.)	The FAST diagram is a graphical representation that illustrates the logical relationships between project functions based on the questions "How" and "Why." It can be considered a structured tool for identifying and analyzing functions with intuitive logic, thus stimulating creative and innovative thinking.
12. Plan for implementation of retained alternatives	VE may result in changes to the design or solutions chosen by architects or technical design offices. The implementation plan contains, among others, an overall schedule for all activities necessary to implement the results of the VE study. Clauses should be detailed in the specifications of the various stakeholders.
13. Follow-up and support for implementation	The implementation meeting serves to resolve the disposition (usually acceptance or rejection) of the VE proposals developed and presented.

14. Client's support and active participation	Client monitoring throughout the process is essential, given the possible resistance of some stakeholders, particularly designers, for whom it would be a waste of time to respond to trivial or poorly thought-out suggestions.
15. Cooperation from related departments	The presence and involvement of the relevant government or technical departments are essential to avoid the failure of the process through its subsequent questioning.
16. Adequate time for VE study	Choosing the right time to conduct the VE study is very important since the gains to be generated and the implementation constraints strongly depend on it.
17. Financial and logistics support of VE study	The VE study requires a budget and logistics for the mobilization of VE specialists and stakeholders, as well as the management of the various stakeholder contracts of the modalities and monitoring of decisions resulting from the VE study.

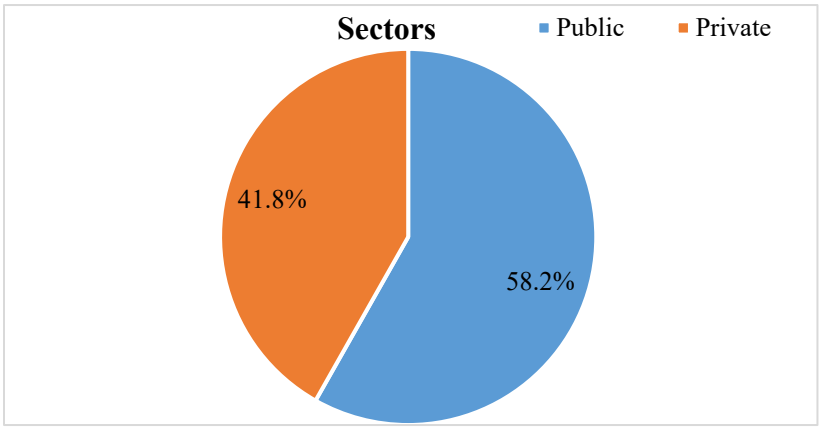
Considering participants' time and privacy, the survey design includes defining clear objectives, which are mastering the critical success factors of value engineering studies in the construction sector in Morocco, taking into account the major challenges of implementation, crafting neutral and concise questions, and arranging questions logically. The survey consisted of three parts. Part 1 aimed to collect general information and experience of respondents in the construction sector in Morocco, especially sector (public or private), type of organization (project owner or delegated project owner, technical design office, and construction company, etc), central area of intervention (building, infrastructure, or industrial), and position in the organization. The 2nd part aimed to collect a background of the respondents in terms of knowledge and practice of the principles of VE.

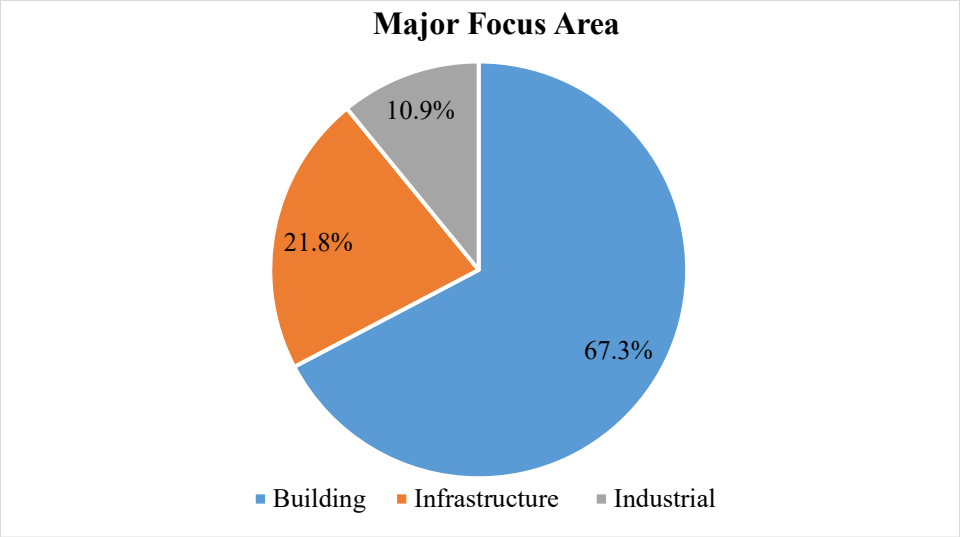
Thus, the respondents were asked to specify whether they had participated in a VE study or whether they had basic knowledge of the VE process. Part 3 required respondents to rate each of the 17 success factors listed in Table 3, which can affect the performance of Value Engineering studies in the construction sector in Morocco. Thus, the respondent indicates the degree of importance of each critical success factor based on a four-point scaling, i.e., extremely important=4, important=3, neutral=2 and unimportant=1. To ensure consistency of responses, the definition and context clarification of each factor were provided. Representative samples of potential respondents specializing in the construction sector were targeted, including project owners, technical design firms, and construction contractors. The organizations contacted included: Project owners:

ANEP (National Agency for Public Equipment), Al Omrane SA, an operator of the Ministry of National Land Use Planning, Urban Planning, Housing, and Urban Policy, CGI Management (delegated project owner and project management assistance), JESA (OCP and Worley consortium), ADM (National Motorway Company of Morocco) Technical design firms (JESA, CID, NOVEC, Omnium Technologique, TME (Tanger Med Engineering), etc.). Contracting contractors: The dissemination of the questionnaire was ensured by sending emails, WhatsApp, and LinkedIn messages containing the link to Google Forms and "The definitions and clarifications note of identified critical success factors for VE studies". The survey data were collected using Google Forms during the months of April and May 2025. In total, 55 completed questionnaires were collected.

4. Results and Discussions

A general trend emerged as responses were collected and analyzed. It is important to note that saturation (sufficient data to draw the necessary conclusions) has been reached. This study involved a wide range of sectors, organizations, areas of intervention, and practitioners with varying levels of experience, occupying different roles within the organization, and mastering the VE process, as shown in Figures 3, 4, and 5.





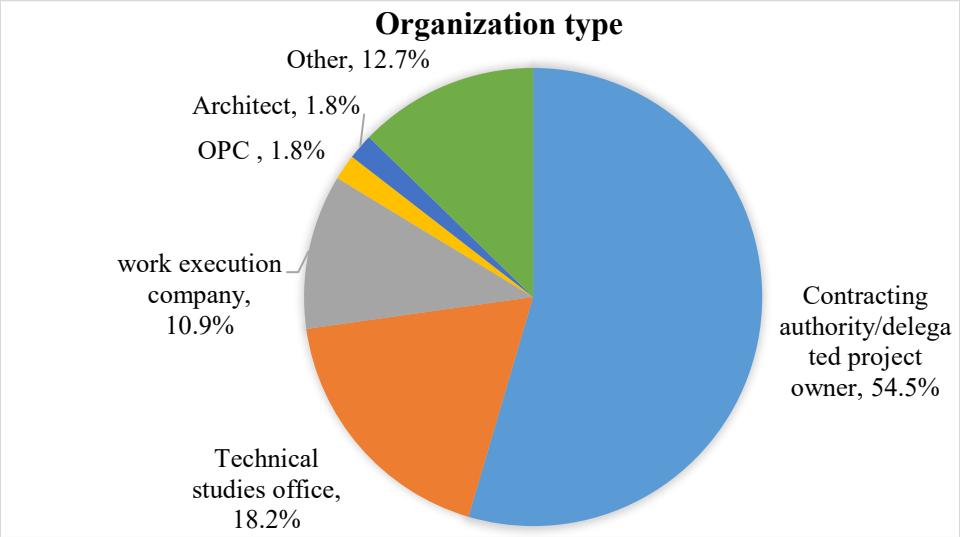
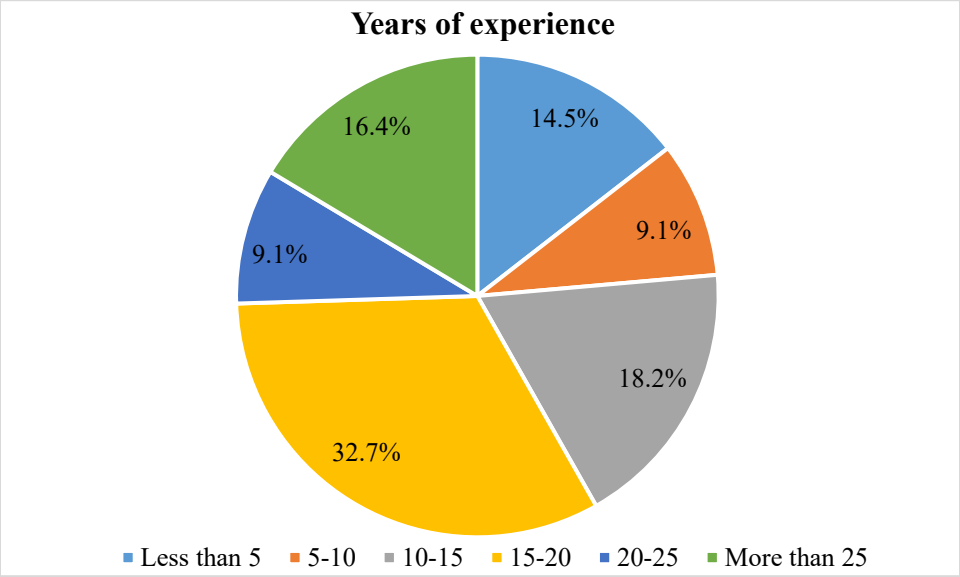


Fig. 3 Distribution of the sample of respondents (organizations cluster)



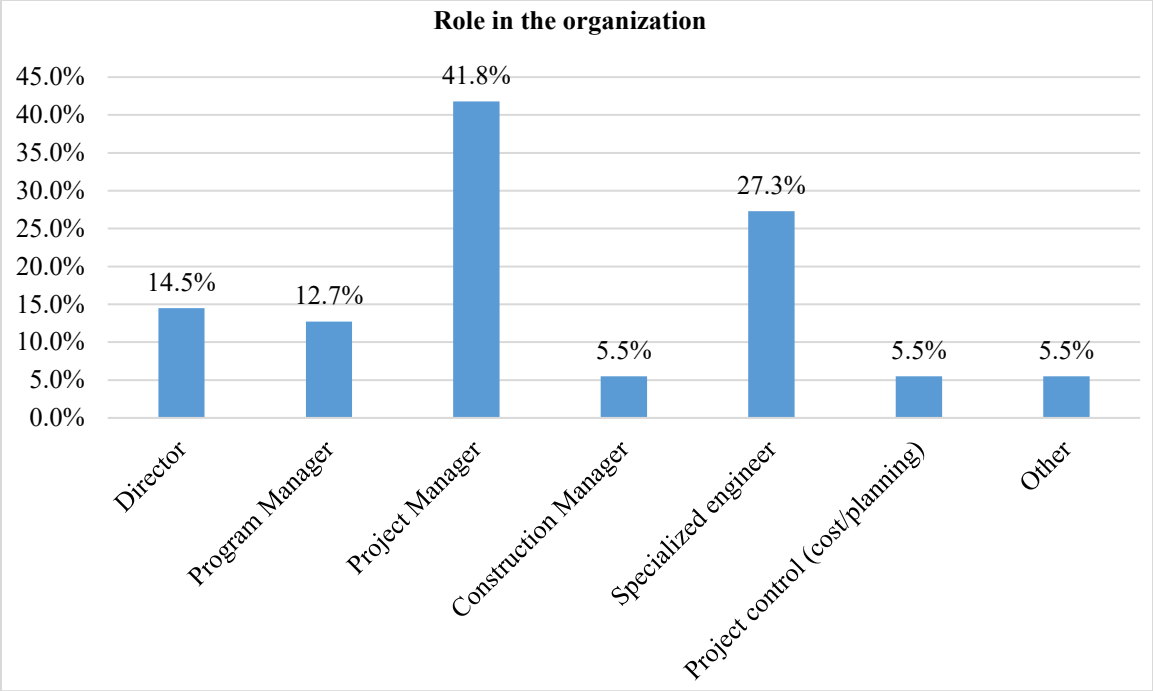


Fig. 4 Distribution of the sample of respondents (individuals cluster)

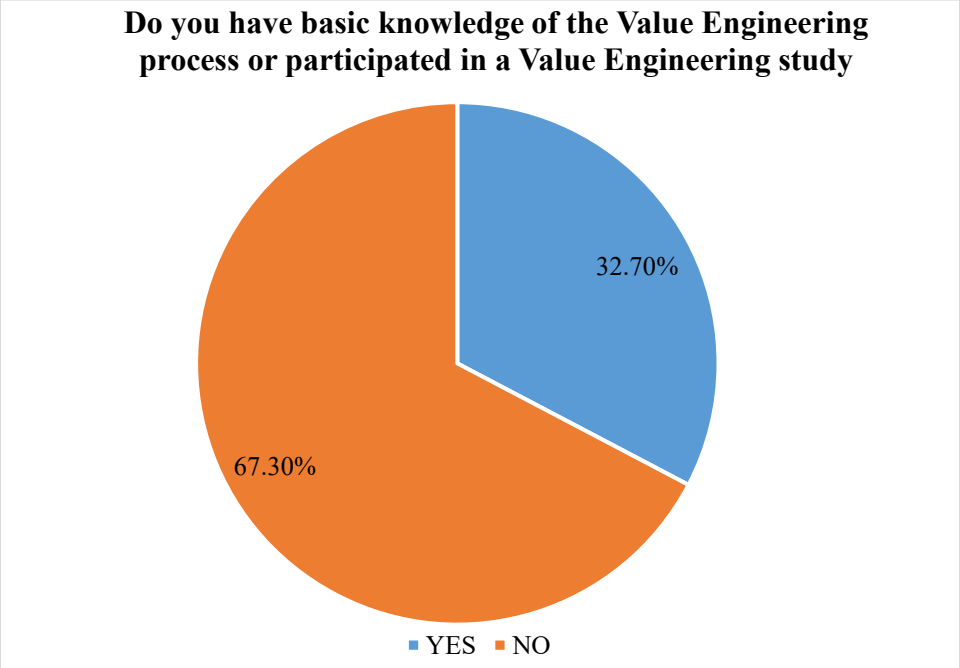


Fig. 5 Level of knowledge of the VE process

Figure 3 shows that 58 per cent of responses represent public sector and 42 per cent represent public sector; 67 per cent of respondents work in building field, 22 per cent in infrastructure and civil engineering area while 11 per cent are involved in industrial sector; 54 per cent represent contracting authorities, 18 per cent technical studies offices while 11 per cent belong to work execution companies; It is noted from Figure (4 - 15) per cent occupy the position of director, 42 per cent occupy the position of project manager, and 27 per cent are specialized engineers.

In addition, the majority of participants have senior profiles (82 per cent have more than ten years' experience). Figure 5 shows that almost 33 per cent of the surveyed population have basic knowledge of the Value Engineering process or have participated in a Value Engineering study.

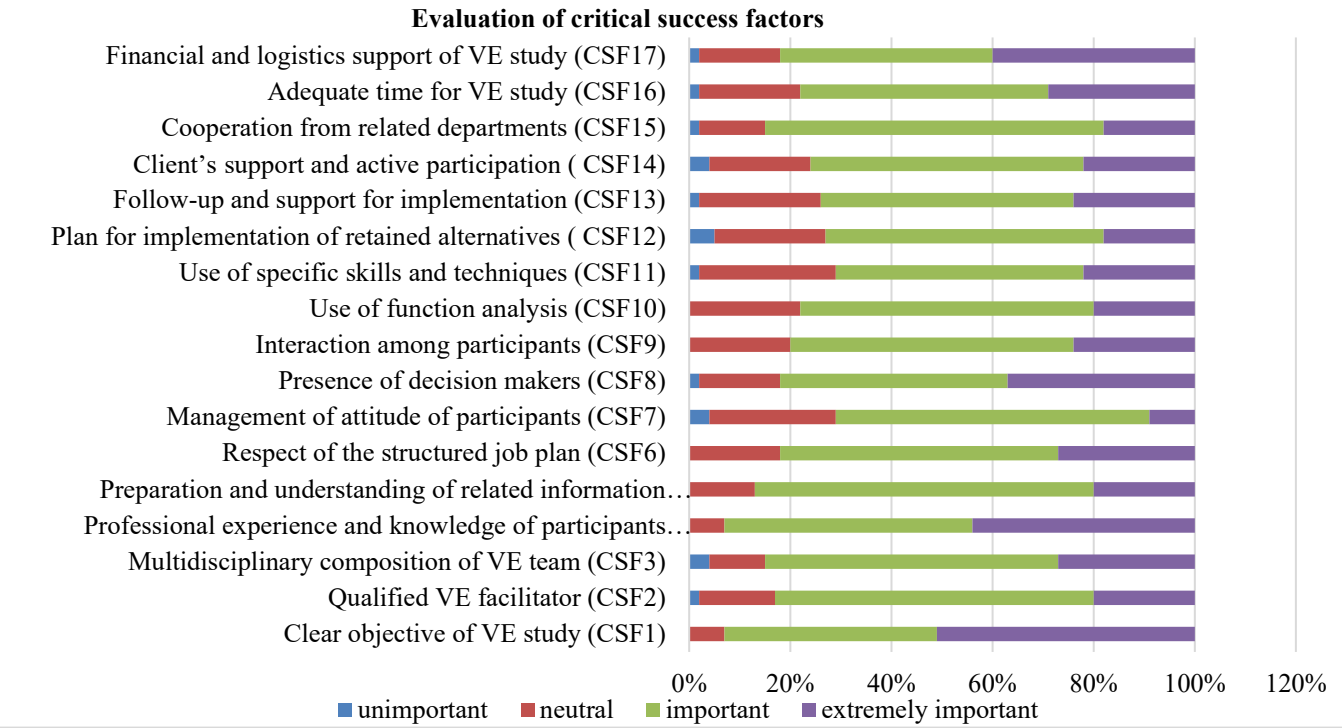


Fig. 6 Evaluation of critical success factors of the VE process

4.1. Reliability Analysis of Critical Success Factors

The reliability of data obtained is analyzed using SPSS 21, which is a computer program for data analysis and performing statistical tests. For this study, the Cronbach's alpha coefficient is equal to 0.9, which indicates excellent internal consistency according to the commonly accepted thresholds in the social sciences. This result demonstrates that the 17 items are highly correlated and measure a familiar underlying construct. Therefore, the scale is considered reliable and robust for assessing the perceived success factors in Value Engineering (VE) studies within the construction sector in Morocco.

4.2. Descriptive Analysis

Table 5. Descriptive statistics of the items

Factor	Mean	Standard Deviation	Ranking
1. Clear objective of VE study (CSF1)	3.44	0.63	1
2. Qualified VE facilitator (CSF2)	3.02	0.65	10
3. Multidisciplinary composition of VE team (CSF3)	3.09	0.73	6
4. Professional experience and knowledge of participants in their own disciplines (CSF4)	3.36	0.62	2
5. Preparation and understanding of related information (CSF5)	3.07	0.57	7
6. Respect of the structured job plan (CSF6)	3.09	0.67	5
7. Management of attitude of participants (CSF7)	2.76	0.67	17
8. Presence of decision makers (CSF8)	3.16	0.76	4
9. Interaction among participants (CSF9)	3.04	0.67	9
10. Use of function analysis (CSF10)	2.98	0.65	12
11. Use of specific skills and techniques (such as FAST, brainstorming, etc) (CSF11)	2.91	0.75	15
12. Plan for implementation of retained alternatives (CSF12)	2.85	0.78	16
13. Follow-up and support for implementation (CSF13)	2.96	0.74	13
14. Client's support and active participation (CSF14)	2.95	0.76	14
15. Cooperation from related departments (CSF15)	3.02	0.62	11
16. Adequate time for VE study (CSF16)	3.05	0.76	8
17. Financial and logistics support of VE study (CSF17)	3.20	0.78	3

The descriptive analysis of the 17 Critical Success Factors shows that participants perceive "Clear objective of the VE study" as the most important factor (M = 3.44), indicating a shared emphasis on clarity at the start of VE projects. Other highly rated factors include "professional experience", "financial and logistical support", and "the presence of decision-makers". Most items have moderate standard deviations, reflecting general agreement, though some, like implementation planning and client support, show more varied responses. Overall, the results reflect a moderate to high perceived importance of most CSFs, with some variation based on context or professional background. These insights support the relevance of the scale and its use for further statistical analysis.

4.3. Item-Total Statistics

Table 6. Item-total correlation

Critical Success Factor	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Clear objective of the VE study	48.53	48.03	0.666	0.892
Qualified VE facilitator	48.95	49.35	0.489	0.897
Multidisciplinary composition of the VE team	48.87	48.89	0.476	0.898
Professional experience and knowledge of participants	48.60	50.17	0.422	0.899
Preparation and understanding of related information	48.89	49.69	0.525	0.896
Adherence to the structured job plan	48.87	49.22	0.484	0.897
Management of participants' attitudes	49.20	50.64	0.335	0.902
Presence of decision makers	48.80	47.42	0.594	0.894
Interaction among participants	48.93	50.07	0.398	0.900
Use of function analysis	48.98	48.61	0.574	0.894
Use of specific techniques (e.g., FAST, brainstorming)	49.05	47.61	0.586	0.894
Implementation plan for selected alternatives	49.11	47.84	0.539	0.896
Follow-up and support for implementation	49.00	46.67	0.692	0.890
Client's support and active participation	49.02	47.35	0.609	0.893
Cooperation from related departments	48.95	48.76	0.587	0.894
Adequate time for VE study	48.91	45.64	0.788	0.886
Financial and logistical support for the VE study	48.76	46.18	0.705	0.889

The item-total analysis confirms strong internal consistency across the 17 critical success factors. Most items show corrected item-total correlations above 0.5, indicating good alignment with the overall scale. Notably, "Adequate time for VE study" (r = 0.788) and "Financial and logistics support of VE study" (r = 0.705) are the most strongly correlated with the total score, suggesting they are central to how respondents perceive successful VE implementation.

The item "Management of attitude of participants" shows the lowest correlation (r = 0.335) and would slightly increase Cronbach's alpha if removed (α = 0.902), indicating it contributes less to internal consistency. However, since all items contribute positively and Cronbach's Alpha remains high ($\geq$ 0.886) across deletions, the scale can be considered both stable and reliable in measuring perceived success factors in VE studies.

4.4. Scale Analysis of Critical Success Factors for Value Engineering Studies

Table 7. Scale statistics of items

Scale Statistics			
Mean	Variance	Std. Deviation	N of Items
51.96	54.258	7.366	17

The overall scale, composed of 17 items, shows a mean score of 51.96**,** a variance of 54.26, and a standard deviation of 7.37. This average suggests that respondents generally rated

the critical success factors as moderately to highly important, indicating a positive perception of their relevance in Value Engineering (VE) studies.

The standard deviation of 7.37 shows a moderate level of variability among participants' responses. This implies that while there is a general consensus about the importance of the items, some differences exist, likely due to factors such as individual roles, organizational context, or experience levels.

4.5. Ranking Analysis of Critical Success Factors for Value Engineering Studies in Construction Sector in Morocco

The 1st analysis concerned all the respondents to the survey, and it gave the following results.

Table 8. Ranking of critical success factors for value engineering studies for all respondents

Factor	Mean	Ranking
Clear objective of VE study (CSF1)	3.44	1
Professional experience and knowledge of participants in their own disciplines (CSF4)	3.36	2
Financial and logistics support of VE study (CSF17)	3.20	3
Presence of decision makers (CSF8)	3.16	4
Respect of the structured job plan (CSF6)	3.09	5
Multidisciplinary composition of VE team (CSF3)	3.09	6
Preparation and understanding of related information (CSF5)	3.07	7
Adequate time for VE study (CSF16)	3.05	8
Interaction among participants (CSF9)	3.04	9
Qualified VE facilitator (CSF2)	3.02	10
Cooperation from related departments (CSF15)	3.02	11
Use of function analysis (CSF10)	2.98	12
Follow-up and support for implementation (CSF13)	2.96	13
Client's support and active participation (CSF14)	2.95	14
Use of specific skills and techniques (e.g., FAST, brainstorming, etc.) (CSF11)	2.91	15
Plan for implementation of retained alternatives (CSF12)	2.85	16
Management of attitude of participants (CSF7)	2.76	17

The analysis of mean scores for the 17 Critical Success Factors (CSFs) highlights the perceived priorities among all participants. The highest-rated factor is **"**Clear objective of VE study" (M = 3.44), underscoring the recognized importance of having well-defined goals from the outset to ensure the success of a Value Engineering (VE) study. This is followed by "Professional experience of participants" (M = 3.36) and "Financial and logistics support" (M = 3.20), indicating that respondents also value the competencies of those involved and the availability of adequate resources as key contributors to a successful process. Conversely, "Management of attitude of participants" (M = 2.76) received the lowest average score, suggesting it may be seen as either less critical or more challenging to address in practice. Overall, the results reflect a general emphasis on strategic clarity, professional capability, and logistical support as essential drivers of adequate VE studies.The second analysis concerned only those who have participated in a VE study or have basic knowledge of the VE process, hereinafter referred to as cluster "VE knowledge".

Table 9. Ranking of critical success factors for value engineering studies for cluster "VE knowledge"

Critical Success Factor (CSF)	Mean (Cluster VE knowledge)	Ranking
Clear objective of VE study (CSF1)	3.67	1
Financial and logistics support of VE study (CSF17)	3.50	2
Professional experience of participants (CSF4)	3.39	3
Presence of decision makers (CSF8)	3.33	4
Preparation and understanding of related information (CSF5)	3.28	5
Plan for implementation of retained alternatives (CSF12)	3.22	6
Follow-up and support for implementation (CSF13)	3.22	7
Respect of the structured job plan (CSF6)	3.11	8
Qualified VE facilitator (CSF2)	3.11	9
Adequate time for VE study (CSF16)	3.11	10
Multidisciplinary composition of VE team (CSF3)	3.06	11
Client's support and active participation (CSF14)	3.06	12
Interaction among participants (CSF9)	3.06	13
Use of function analysis (CSF10)	3.00	14

Use of specific skills and techniques (e.g., FAST, brainstorming) (CSF11)	2.94	15
Cooperation from related departments (CSF15)	2.89	16
Management of attitude of participants (CSF7)	2.78	17

Among respondents with prior VE knowledge or participation, the highest-rated factor is also **"**Clear objective of VE study" (M = 3.67), reaffirming the importance of strategic direction for experienced professionals. This is closely followed by "Financial and logistics support of VE study" (M = 3.50), highlighting the greater emphasis placed on tangible resources by those familiar with the VE process.

Factors such as "Presence of decision makers" and "Preparation and understanding of related information" are also ranked highly, indicating the value these respondents place on informed decision-making and adequate preparation. In contrast, "Management of attitude of participants" (M = 2.78) and "Cooperation from related departments" (M = 2.89) are among the lower-rated factors, possibly due to their complexity or difficulty to control in real-world applications. This analysis shows that individuals with VE experience tend to prioritize strategic, operational, and resource-related elements, reflecting a more practical and nuanced understanding of what drives success in VE studies.

4.6. Factor Analysis of Critical Success Factors (CSFs)

This Exploratory Factor Analysis (EFA) aims to find the hidden structure among the 17 Critical Success Factors (CSFs) that are linked to Value Engineering (VE) studies in the Moroccan Construction Industry. This method is used to find components that can summarize the relationships between observed variables, making it easier to reduce data and make sense of it.

Sampling Adequacy and Suitability for Factor Analysis: to assess the appropriateness of the dataset for EFA, two preliminary tests were conducted:

- Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy = 0.789
- Bartlett's Test of Sphericity: Chi-square = 476.591, $p < 0.001$
- The KMO value exceeds the recommended threshold of 0.7, indicating meritorious sampling adequacy.

Furthermore, the significant result of Bartlett's test confirms the presence of sufficient correlations among the variables for factor analysis.

Communities represent the amount of Variance in each variable explained by the extracted factors. High communities (preferably >0.5) indicate that a substantial proportion of Variance is captured by the factors.

Table 10. Communities of variables of critical success factors for VE studies

Factor	Extraction
Clear objective of VE study	0.622
Qualified VE facilitator	0.760
Multidisciplinary composition of VE team	0.665
Professional experience and knowledge	0.749
Preparation and understanding of information	0.367
Respect of the structured job plan	0.635
Management of attitude of participants	0.602
Presence of decision makers	0.754
Interaction among participants	0.579
Use of function analysis	0.511
Use of specific skills and techniques	0.642
Plan for the implementation of retained alternatives	0.793
Follow-up and support for implementation	0.751
Client's support and active participation	0.667
Cooperation from related departments	0.793
Adequate time for VE study	0.712
Financial and logistics support of VE study	0.652

Most of the Critical Success Factors (CSFs) in this analysis have communities greater than 0.50, which means that the factor solution is a good representation of the original variables. For example, "Plan for implementation of retained alternatives" and "Cooperation from related departments" have the highest communities, both at 0.793. "Presence of decision makers" (0.754), "Follow-up and support for implementation" (0.751), and "Professional experience and knowledge" (0.749) are all very close behind. These numbers show that these CSFs are very well integrated into the extracted factor structure and play a significant role in explaining the differences in the data. "Qualified VE

facilitator" (0.760), "Adequate time for VE study" (0.712), "Client's support and active participation" (0.667), "Multidisciplinary composition of VE team" (0.665), "Financial and logistics support of VE study" (0.652), "Respect of the structured job plan" (0.635), "Use of specific skills and techniques" (0.642), "Management of attitude of participants" (0.602), "Interaction among participants" (0.579), and "Use of function analysis" (0.511) are some other CSFs that show acceptable communities. These results point to a consistent and clear picture of the underlying idea. But one variable, "Preparation and understanding of information," only has a community of 0.367, which is below the usual cutoff point of 0.50. This means that the extracted components don't explain this factor very well, and it could be a measure of success that is either more independent or not fully captured by the current factor structure. Total Variance Explained:

Table 11. Statistics of principal component analysis

Component	Eigenvalues	% of Variance	Cumulative % of Variance
1	6.72	39.51%	39.51%
2	1.96	11.54%	51.05%
3	1.37	8.08%	59.14%
4	1.20	7.08%	66.21%

The results illustrated in Table 11 indicate that four components have eigenvalues greater than 1.0, following Kaiser's criterion, and together they explain 66.21% of the total Variance in the dataset.

The remaining components have eigenvalues less than 1 and are not retained in the final solution. Their contributions to the total Variance are relatively minor, each explaining less than 6% of the total Variance.

This supports a 4-factor solution as a meaningful summary of the data structure, indicating that these four underlying dimensions collectively capture most of the Variance present in the original 17 variables.

This dimensionality reduction justifies further interpretation of the rotated component matrix to understand how the individual CSFs load on these components.

This result confirms the suitability of PCA (Principal Component Analysis) in identifying latent constructs among the CSFs used in the Value Engineering (VE) context.

The component matrix after varimax rotation is presented in Table 12.

Table 12. The component matrix after varimax rotation

Factor	Component 1	Component 2	Component 3	Component 4
Clear objective of VE study(CSF1)	0.731	-0.282	-0.082	-0.030
Qualified VE facilitator(CSF2)	0.568	-0.531	0.382	-0.098
Multidisciplinary composition of VE team(CSF3)	0.549	-0.521	0.016	0.302
Professional experience and knowledge(CSF4)	0.483	-0.483	0.308	0.433
Preparation and understanding of information(CSF5)	0.590	-0.009	-0.055	0.126
Respect of the structured job plan(CSF6)	0.535	0.519	0.188	-0.212
Management of attitude of participants(CSF7)	0.371	0.527	0.247	0.355
Presence of decision makers(CSF8)	0.637	0.146	-0.316	0.476
Interaction among participants(CSF9)	0.441	0.537	0.290	0.114
Use of function analysis(CSF10)	0.637	0.010	0.324	0.014
Use of specific skills and techniques (CSF11)	0.638	0.392	0.274	0.082
Plan for implementation of retained alternatives(CSF12)	0.608	0.180	-0.614	0.115
Follow-up and support for implementation(CSF13)	0.754	0.131	-0.382	-0.142
Client's support and active participation(CSF14)	0.686	-0.130	-0.231	-0.356
Cooperation from related departments(CSF15)	0.656	0.000	0.251	-0.548
Adequate time for VE study(CSF16)	0.837	-0.057	-0.008	-0.094
Financial and logistics support of VE study(CSF17)	0.775	-0.126	-0.154	-0.109

The component matrix shows the unrotated factor loadings for each of the 17 Critical Success Factors (CSFs) on the four components that were found using Principal Component Analysis (PCA). A factor loading shows how closely a variable is linked to a latent factor. Values higher than 0.5 are usually seen as important and show a strong link between the factor and the underlying component. As seen, the first component has the highest loadings on most of the variables. Variables like "Adequate time for VE study" (0.837), "Financial and logistics support of VE study" (0.775), "Follow-up and support for implementation" (0.754), "Clear objective of VE study" (0.731), "Client's support and active participation" (0.686), and "Use of specific skills and techniques" (0.638) have high loadings on Component 1.

This means that Component 1 probably captures a general underlying dimension that has to do with the overall planning, support, and structure of VE studies.

Component 2 has moderate to strong links to variables like “Interaction among participants” (0.537), “Management of attitude of participants” (0.527), “Respect of the structured job plan” (0.519), and “Multidisciplinary composition of VE team” (-0.521). This part might show how people interact with each other and how things are done in VE teams.

Component 3 has fairly strong loadings for “Plan for implementation of retained alternatives” (-0.614) and moderate contributions from “Qualified VE facilitator” (0.382) and “Professional experience and knowledge” (0.308). These could be related to how well implementation and technical execution work.

Component 4 shows that “Presence of decision makers” (0.476), “Professional experience and knowledge” (0.433), and “Cooperation from related departments” (-0.548) are all important factors. This suggests that this factor may be related to decision-making authority and leadership dynamics.

Overall, the unrotated factor structure shows that Component 1 is the most important in explaining the differences between the variables. The other components, on the other hand, capture different and understandable groups of underlying traits that are related to the success of VE studies. The presence of cross-loadings and negative signs also shows that rotation (like Varimax) is needed to make the factor structure clearer and easier to understand.

The groupings made through rotation can be summarized in the four components: Strategy and Resources (Component 1), Team Dynamics (Component 2), Technical Implementation (Component 3), and Leadership and Decision-Making (Component 4). These results help to better understand and optimize VE practices.

Table 13 clarifies the main components of successful IV studies with implications for the construction sector in Morocco.

Table 13. The main components of successful VE studies

Component	Weight	Examples of CSF Associated	Implications for the construction sector in Morocco
1. Strategy and Resources	39,5%	- Clear objectives - Financial/logistical support - Adequate time	Prioritize rigorous planning and stakeholder engagement (Client, project management, relevant external services, operators, etc).
2. Team Dynamics	11,5%	- Interaction between participants - Compliance with the job plan - Multidisciplinary composition	Promote effective collaboration and conflict management among VE teams.
3. Technical Implementation	8,1%	- Qualified facilitator - Functional analysis methods - Implementation plan	Strengthen technical skills and methodological tools (FAST, brainstorming).
4. Leadership and Decision-Making	7,1%	- Presence of decision-makers - Professional experience - Cooperation from related departments	Involve line managers to speed up decision-making.

4.7. Cultural Factors

Cultural factors are not explicitly listed among the 17 CSF identified, but in reality, they are anchored in several of them. In value engineering studies, “culture” is both organizational (hierarchies, collaboration) and professional (communication styles, attitudes towards innovation). The influence of cultural aspects can be more visible in the following factors:

CSF7. Management of the attitude of participants: cultural standards shape how open individuals are to questioning ideas, criticizing superiors, or proposing unconventional solutions. In some cultures, junior engineers can hesitate to speak if decision-makers are present. CSF9. Interaction between the participants: the dynamics of the team depends on the confidence, the style of communication, and the question of whether the brainstorming is perceived as safe. Collectivist vs individualist cultures will affect whether ideas are built in collaboration or defended in a competitive manner. CSF14. Customer support and active participation: cultural expectations concerning the authority, prestige, or status of the customer can determine how much the customer intervenes, listens, or dominates. CSF15. Cooperation of related departments: silos or interdepartmental rivalry often come from a rooted organizational culture. If there is a problem of information sharing, the VE process can be weakened.A skilled facilitator must be culturally competent: balance respect for hierarchy and encourage openness, adaptation of the facilitation style. Cultural factors are not a distinct 18th

CSF but a transversal dimension that conditions the effectiveness of several listed factors. Ignoring the risks of culture can make the value engineering a formal exercise with limited creativity. Adopting it can unlock a real interdisciplinary innovation.

4.8. Practical Implications for Professionals

The findings of this study provide several practical insights for professionals involved in Value Engineering (VE) and project management within the construction sector.

First, the identification of clear and measurable objectives for each VE study is essential to ensure that team members and decision-makers share a common understanding of the project's goals. Practitioners should invest time at the outset to define the study's purpose, expected outcomes, and evaluation criteria.

Second, the results emphasize the need for adequate financial and logistical support to facilitate VE workshops, including sufficient time allocation, access to relevant data, and appropriate working environments. Without these conditions, even well-designed VE studies may fail to achieve optimal results.

Third, the strong influence of the professional experience and multidisciplinary composition of participants highlights the importance of carefully selecting team members who combine technical expertise with creativity and communication skills. Continuous training in VE tools and techniques such as FAST diagrams, brainstorming, and function analysis should be encouraged to strengthen team capability.

Fourth, the identified dimensions, Strategy and Resources, Team Dynamics, Technical Implementation, and Leadership and Decision-Making, offer a framework for organizations to assess and enhance their VE practices. Managers can use these dimensions as diagnostic indicators to evaluate readiness for VE implementation and to prioritize improvement actions.

Finally, considering Morocco's cultural and organizational context, attention should be given to team dynamics and leadership behavior to foster open communication and cross-departmental cooperation. Creating a collaborative culture that values idea sharing and evidence-based decision-making can significantly enhance the success and sustainability of VE initiatives.

This study extends existing research on Critical Success Factors (CSFs) of Value Engineering (VE) by providing a context-specific analysis tailored to the Moroccan construction sector—an area underrepresented in prior studies. While earlier works identified generic CSFs across international or specific contexts, this research achieved more robust and contextually grounded results by combining quantitative ranking and factor analysis to uncover four key dimensions: Strategy and Resources, Team Dynamics, Technical Implementation, and Leadership and Decision-Making.

Compared with state-of-the-art frameworks, the model proposed offers a stronger explanation because it reflects contextual realities such as limited resources and hierarchical cultures; it employs statistical validation to reveal relationships among CSFs often overlooked in prior qualitative studies; and it provides a practically applicable structure that connects strategic, behavioral, and technical aspects of VE practice. These results demonstrate that successful VE implementation depends not only on technical methods but also on leadership style, team culture, and resource planning, factors seldom integrated in previous models.

5. Conclusion

This study highlights the elements and indicators of the success of the value engineering study by identifying critical success factors in the construction sector in Morocco. To this end, and taking into account previous studies in the field and the opinions of the experts consulted, 17 factors were selected as the most important for the successful conduct of VE studies from the pre-workshop phase to the post-workshop one.

A questionnaire containing the 17 factors, along with a definition and clarification note, was prepared and distributed to professionals in the Moroccan construction sector, including project owners, technical design offices, and construction companies. 55 responses were collected. Reliability analysis was performed, and excellent internal consistency was confirmed for the survey. Statistical analysis of the results enabled the classification of these factors for all respondents, on the one hand, and for professionals with basic knowledge of the process, on the other.

The findings of the study are generally in line with the conclusions of the previous relevant research, as the 17 factors identified in this study have been generally retained as important for the success of the VE study. In addition, the results obtained show that four factors were favored by the majority of respondents and ranked in the top 4, namely "clear objective of VE study", "Professional experience and knowledge of participants", "Financial and logistics support of VE study", and "Presence of decision makers".

Factor analysis conducted for this study made it possible to group the 17 factors identified into 4 key dimensions for the success of Value Engineering studies focused on precise strategic planning (objectives, resources), a united and competent team, proven technical methods and committed leadership with specific implications for different stakeholders, in particular the involvement of decision-makers

from the beginning to avoid blockages, working in collaborative mode with varied profiles, the use of structured methods (functional analysis, brainstorming), and the allocation of sufficient resources (time, budget) and active support of the process. The CSF identified by this research can benefit the stakeholders in future construction projects in Morocco and other similar countries, which will use the Value Engineering. Furthermore, these CSFs constitute a key element to encourage decision makers seeking assurance of project success to adopt this process while regulating it by taking into account the findings from this study. VE allows project managers to ask "why" and "how" to derive better value for stakeholders. The integration of AI and Value Engineering in project management can lead to more successful project outcomes. AI enhances efficiency and decision-making, while VE focuses on maximizing value and aligning project goals with stakeholder needs. Both require careful consideration of challenges and success factors to be effectively implemented. By leveraging these methodologies, project managers can achieve greater project success and stakeholder satisfaction. The CSFs confirmed in this article constitute a guiding tool for successful VE studies in the Moroccan construction sector, ensuring efficient preparation, smooth team facilitation, cost and function analysis, and successful implementation, and may be applicable to other sectors or in similar horizons.

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