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# Analysis of Critical Success Factors in Penetration Testing Delivery Projects at PT. ABCD Using a Fuzzy Delphi Method

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***Keywords***
Critical Success Factors (CSF); Project Management; Penetration testing; Fuzzy Delphi Method.

**ABSTRACT**
The success of penetration testing project delivery is influenced not only by technical factors but also by an organization's ability to manage critical operational and managerial elements in an integrated manner. At PT. ABCD, recurring challenges, such as dynamic scope changes and suboptimal resource coordination, highlight the absence of a validated critical success factor (CSF) framework. This study aims to identify, validate, and prioritize the key determinants of successful penetration testing project delivery. The research began with a comprehensive synthesis of multidisciplinary literature covering project management, information technology, agile practices, and cybersecurity domains, which was subsequently integrated with internal organizational lessons learned. This hybrid approach resulted in the identification of 11 preliminary CSF candidates. To ensure the robustness of the research instrument, classical statistical tests were conducted, including Pearson product–moment validity testing and Cronbach's alpha reliability analysis, which confirmed the consistency and adequacy of the measurement instrument. Subsequently, the CSF candidates were evaluated by 21 experts representing the Project Management Office, Sales and Business, and Technical/Penetration Tester functions. The Fuzzy Delphi Method (FDM) was employed to accommodate uncertainty in expert judgments by utilizing triangular fuzzy numbers, expert agreement levels, threshold distance (d) for consensus measurement, and alpha-cut defuzzification for final selection. The results indicate that 10 out of the 11 CSFs achieved strong consensus, satisfying the criteria of expert agreement (EA) $\geq$ 75%, d $\leq$ 0.2, and alpha-cut $\geq$ 0.75. The final prioritization identifies communication effectiveness, stakeholder coordination, technical team readiness, and adaptive management as the most influential success factors, providing PT. ABCD with a structured framework to enhance project delivery performance and reduce operational risks.

## INTRODUCTION

The development of information and communication technology in Indonesia has accelerated digital transformation across various sectors, directly contributing to the increasing complexity of cyber threats. The State Cyber and Cryptography Agency (BSSN) in Indonesia's Cybersecurity Landscape 2024 reported that national cyber incidents continue to increase, characterized by dominant threats such as malware, ransomware, and credential theft (BSSN, 2024). This trend is further supported by data from the government sector, where Kominfo-CSIRT recorded significant volumes of anomalous traffic and reported 27 cyber incidents throughout 2024, with malicious file injection identified as the most dominant incident type (KOMINFO-CSIRT, 2024). These conditions create an urgent need for organizations, particularly those operating in critical and public sectors, to routinely and systematically validate their security posture (Luckey et al., 2019; Magnusson et al., 2025; Okolo et al., 2021; Oluoha et al., 2022).

Amid this urgency, penetration testing (pentesting) has emerged as a fundamental cybersecurity assurance practice. A penetration test is a security assessment in which a penetration tester simulates real-world attacks to identify, validate, and evaluate vulnerabilities that may be exploited within systems or networks (NIST SP 800-115). Penetration testing not only identifies security weaknesses but also provides empirical validation of potential business risks arising from these vulnerabilities, making it an essential component of cybersecurity risk management processes (Alhamed & Rahman, 2023). The implementation of effective and systematic penetration testing generally follows standardized industry frameworks, such as the Penetration Testing Execution Standard (PTES), Open Source Security Testing Methodology Manual (OSSTMM), and Open Worldwide Application Security Project (OWASP) guidelines, which divide the penetration testing process into structured phases ranging from pre-engagement activities to reporting (PTES, 2022). The complexity of this process, the requirements of industry standards, and increasing market demand are reflected in the growing need for Vulnerability Assessment and Penetration Testing (VA/PT) services within government agencies (KOMINFO-CSIRT, 2024). This demonstrates that successful delivery of penetration testing services is a critical performance indicator for cybersecurity service providers.

PT. ABCD is a multinational private company engaged in cybersecurity services and listed on the Indonesia Stock Exchange (IDX), with penetration testing services representing one of the strategic offerings within its cybersecurity business unit. Based on the company's latest financial statements (2024), penetration testing services represent the second-highest revenue contributor within this business unit. However, operational implementation reveals several challenges affecting project execution, including inaccurate budget estimation related to man-days calculations, disputes regarding scope definition, unpredictable project completion timelines, disagreements regarding reporting outcomes, inconsistent coordination and communication between internal teams and clients, and the continuous availability requirements of skilled human resources . These challenges negatively affect overall project portfolio performance and the company's reputation among clients. Therefore, there is a need to identify critical success factors (CSFs) for penetration testing projects through a structured, measurable, and scientifically validated framework as a basis for improving project delivery quality at PT. ABCD (Agumba, 2024; Nugraheni et al., 2024; Sotarjua & Oktavia, 2025; Sumadireja & Dachyar, 2024).

Despite continuous efforts to improve service quality, PT. ABCD continues to encounter recurring challenges. The company has attempted to address these issues by referring to critical success factors (CSFs) summarized in lesson-learned documentation from previously delivered penetration testing projects as a basis for improvement initiatives. However, this indicates that the existing list of success factors remains partial, situational, and highly dependent on individual project managers' perspectives (Koops et al., 2016; Yeoh & Popovič, 2016). According to global project management frameworks, such as the A Guide to the Project

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Management Body of Knowledge (PMBOK Guide) – Sixth Edition, modern project success is no longer measured solely by the traditional triple constraint of scope, schedule, and cost but also by achieving business value and fulfilling stakeholder expectations and satisfaction (PMI, 2017). Therefore, achieving comprehensive project success, including efficient delivery performance and high-quality outcomes, requires further investigation into the Critical Success Factors (CSFs) influencing penetration testing project delivery (Agumba, 2024; Chen & Hai, 2024; Šeduikis, 2024).

The concept of CSFs, initially introduced by Rockart in 1979, refers to a limited number of key areas in which satisfactory results are necessary to ensure organizational, project, or managerial success (Bullen & Rockart, 1981). Previous project management studies have consistently emphasized the importance of CSFs in determining project performance (Venczel et al., 2021), and their relevance has been demonstrated specifically in information technology (IT) and cybersecurity domains (Fayaz et al., 2017; Yeoh et al., 2022). In this study, an initial list of CSFs for penetration testing projects was developed through the synthesis of relevant scientific literature and internal organizational lessons learned. Subsequently, CSF candidates were evaluated using the Fuzzy Delphi Method (FDM) based on assessments from 21 experts representing the Project Management Office (PMO), Sales and Business, and Technical/Penetration Tester functions at PT. ABCD to determine validity, consensus levels, and priority rankings for each factor. The results demonstrate that most CSF candidates achieved strong expert consensus based on Expert Agreement (EA), threshold distance (d), and alpha-cut values. This research produced a validated, measurable, and prioritized CSF framework as a foundation for improving penetration testing project delivery at PT. ABCD.

In this study, the Fuzzy Delphi Method (FDM) was applied to filter, validate consensus, and prioritize the initial list of penetration testing project CSFs. This method was selected due to its advantages in overcoming limitations associated with conventional approaches and other Multi-Criteria Decision-Making (MCDM) methods, as summarized below. (a) Classic CSF (Rockart): The classical Rockart approach functions primarily as a qualitative identification method through interviews and does not provide a quantitative mechanism for validating consensus or determining priority weights (Cooper, 2009). (b) Classic Delphi: The conventional Delphi method may require multiple lengthy iterative rounds to achieve consensus and is less effective in handling uncertainty (fuzziness) inherent in subjective expert judgments (Roldán López de Hierro et al., 2021). (c) Analytical Hierarchy Process (AHP): Although AHP is effective for developing hierarchical decision structures, it requires extensive pairwise comparisons, which increases expert workload and may introduce inconsistency risks when analyzing numerous factors (Ottaviani et al., 2025). (d) Decision-Making Trial and Evaluation Laboratory (DEMATEL): DEMATEL is primarily designed to analyze and visualize cause–effect relationships among factors (Chatzifoti et al., 2025), rather than determine absolute priority rankings, which represents the main objective of this study in allocating resources effectively.

Therefore, FDM was selected because of its ability to combine Delphi methodology efficiency with the quantitative capabilities of Fuzzy Set Theory. This integration enhances objectivity in measuring expert consensus through mathematical calculations of threshold values (Roldán López de Hierro et al., 2021) and generates quantitative results for CSF prioritization. Based on the research findings, FDM effectively facilitates expert consensus validation, measures factor importance levels, and establishes CSF priorities in a systematic and measurable manner within the context of penetration testing project delivery. Consequently, this study provides a set of validated, consensual, and prioritized CSFs that can serve as a strategic reference for improving the quality of penetration testing project delivery at PT. ABCD.

This research aims to identify, validate, and prioritize Critical Success Factors (CSFs) for penetration testing project delivery at PT. ABCD through the synthesis of multidisciplinary literature and internal lessons learned, followed by Fuzzy Delphi Method validation involving 21 experts from PMO, Sales and Business, and Technical functions. The validation process measures expert consensus using predefined criteria (EA $\geq$ 75%, d $\leq$ 0.2, and alpha-cut $\geq$ 0.75) and establishes priority rankings based on aggregate defuzzification values. The findings are expected to benefit PT. ABCD by providing a validated decision-support framework for improving project delivery performance and reducing operational risks. Furthermore, this research provides practitioners with practical guidance regarding critical factors such as communication effectiveness, stakeholder coordination, technical readiness, and adaptive management, contributes to cybersecurity project management literature by demonstrating the application of FDM within the relatively underexplored penetration testing domain, and highlights that successful penetration testing execution requires the integration of technical expertise, managerial control, and cross-functional collaboration.

## METHOD

This research employed a descriptive-exploratory design with a mixed-method approach (qualitative and quantitative) to identify, validate, and prioritize Critical Success Factors (CSFs) in the delivery of penetration testing projects at PT. ABCD. The research was conducted at PT. ABCD, Central Jakarta, from January to June 2026, with the research objects consisting of penetration testing projects and the CSFs influencing their delivery. A hybrid CSF identification approach was applied by combining two primary sources: a top-down approach through the synthesis of 13 scientific publications covering project management, IT projects, agile practices, and cybersecurity, and a bottom-up approach through the analysis of 26 internal lessons-learned documents from previous penetration testing project experiences. This synthesis process generated 11 initial CSF candidates, which were subsequently validated using the Fuzzy Delphi Method (FDM) involving 21 purposively selected expert panelists from three functional groups: Project Management/Project Management Office (PMO) (7 experts), Sales and Business (7 experts), and Technical/Penetration Tester (7 experts). The experts were selected based on a minimum of 5 years of professional experience and direct involvement in penetration testing project delivery.

The research instrument consisted of a Google Forms-based questionnaire containing 11 CSF candidates assessed using a five-level linguistic scale ranging from Very Low to Very High Importance, which was subsequently converted into Triangular Fuzzy Numbers (TFNs) to represent uncertainty in expert judgments. Primary data were obtained from expert assessments regarding the importance level of each CSF, while secondary data from literature and lessons-learned documents were used to develop the research instrument and were not directly analyzed. Data analysis was conducted through five main stages: (1) identification of initial CSF candidates through literature synthesis and lessons-learned analysis; (2)

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development of the FDM instrument; (3) collection of expert assessments; (4) supporting validity and reliability testing using Pearson Product Moment correlation and Cronbach's Alpha; and (5) FDM-based analysis, including linguistic scale conversion into TFNs, fuzzy aggregation, Expert Agreement (EA) measurement ($\geq$ 75%), dispersion threshold assessment ($d \leq 0.2$), alpha-cut evaluation ($\geq$ 0.75), and CSF defuzzification and ranking based on aggregate crisp values. The research validity was supported through content validity from literature synthesis and lessons-learned analysis, expert validity through the selection criteria of panelists, and methodological validity through the application of the established FDM approach. Reliability was assessed through internal consistency using Cronbach's Alpha and the stability of expert consensus based on dispersion threshold measurements. The entire research process followed academic ethical principles, including data confidentiality and informed consent.

## RESULT AND DISCUSSION

This chapter presents the results of research and discussion related to the identification, consensus validation, and prioritization of Critical Success Factors (CSF) in the delivery of penetration testing projects at PT. ABCD uses the Fuzzy Delphi Method (FDM) approach. The results of the research were obtained through the process of scientific literature synthesis, analysis of the company's internal lessons learned, and expert panel assessment of CSF candidates using FDM instruments based on a five-level linguistic scale.

The discussion in this chapter begins with an overview of the research object and the characteristics of the expert panel involved in the research. Furthermore, the results of the research instrument testing, the results of FDM analysis were presented which included expert consensus measurement, CSF candidate validation, and the prioritization process based on defuzzification values. In the final part, a discussion was conducted on the results of the research to explain the meaning and implications of the Critical Success Factors (CSF) obtained in the context of the delivery of the penetration testing project at PT. ABCD.

### Discussion of the Suitability of Classical Statistics to Fuzzy Delphi Method

Although the testing of instruments using classical statistics (Pearson Validity Test and Cronbach's Alpha Reliability) is still presented in this study as a supporting analysis, there are differences in results between classical statistics and FDM. This difference does not indicate a flaw in the data, but rather is rooted in differences in the philosophy, basic assumptions, and methodological principles of the two approaches.

In depth, the reason why classical statistical results can be different and cannot be used as a determining tool (main analysis) in FDM is based on the following five philosophical principles:

Respondent Philosophy - Random Sample (Population Inference) vs. Expert Panel (Expert Consensus). In classical statistics, respondents are seen as samples taken from a population for generalization purposes (statistical inference). The larger and more random the sample, the better the model. On the contrary, FDM is rooted in the expert judgment paradigm. Respondents in FDM are individuals who are purposively selected because of their specific expertise (expert panel), not to represent the population statistically, but to build an experience-based "consensus".

Assumption of Measurement Constructs - Homogeneous (One-Dimensional) vs. Heterogeneous (Multidimensional). The Pearson and Cronbach's Alpha validity test assumes that all question items in the questionnaire measure a single homogeneous (unidirectional) construct (variable). In fact, the 11 Critical Success Factors (CSF) candidates in this study are heterogeneous and multidimensional. A pentest project is assessed from the technical dimension, the managerial dimension, the administrative dimension, to the communication. The weak statistical correlation (low r-count) of a classical CSF item does not mean that the factor is "unimportant", but merely indicates that the factor is independent and comes from a different dimension to the other factors.

Validity Principle - Linear Correlation vs. Majority Agreement (Expert Agreement & Alpha-cut). Classical statistical validity (Pearson) measures the strength of the linear correlation between the score of one item and the total score. FDM rejects this assumption for critical factor assessment cases. In FDM, a factor is declared "valid" or "important" if it successfully reaches the percentage of expert agreement (Expert Agreement >= 75%) and its defuzzification value crosses the interest threshold (Alpha-cut >= 0.75). Factors that are not correlated with the total score can still be a Critical Success Factor if the majority of experts agree on it.

Reliability Principle - Internal Consistency vs. Stability and Consensus Distance (Dispersion Threshold). In classical statistics, reliability (Cronbach's Alpha) looks at whether respondents answer consistently (uniformly) to all questions. In FDM, reliability is interpreted as the stability (convergence) of opinions between experts on one specific factor. FDM measures this reliability using distance or dispersion (dispersion threshold/d). If the value of d <= 0.2 , then the opinions of the experts are considered to be close and stable, regardless of how they answer the other factors.

Uncertainty Handling - Crisp vs. Triangular Fuzzy Number. Classical statistics forces respondents to provide a rigid exact number (e.g. a scale of 1 to 5) and treats it as a definite interval distance. FDM realizes that human perception of the concept of "Important" or "Very Important" has linguistic uncertainty (ambiguity). FDM solves this by converting the value into a set of triangular-shaped fuzzy numbers (lower, middle, upper) before aggregation

Therefore, if there is a CSF candidate whose R-count value is low but passes the FDM consensus test, this factor should be maintained. Classical statistics is only tasked with looking at the distribution patterns and consistency of data matrices on the surface, while the final decision (accept/reject the CSF) is fully the authority of the mathematical analysis of the Fuzzy Delphi Method, which is specifically designed to validate multidimensional and linguistic expert judgment

**Conclusion of Research Instrument Test Results (Reliability and Validity)**

Based on the results of validity and reliability testing, the research instruments generally show a very adequate level of measurability and internal consistency. Although there are several CSF candidate items that have relatively low classical (Pearson) statistical validity values, these items are still maintained and further analyzed using the Fuzzy Delphi Method (FDM) approach, considering that this study philosophically focuses more on the achievement of expert consensus than on population statistical inference. Furthermore, the results of the reliability test (Cronbach's Alpha) also confirmed that the instrument had a good level of answer stability. Thus, the instruments and data of the results of the questionnaire that have

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been validated are methodologically considered very feasible to be used as the main input in the FDM mathematical analysis process to determine the consensus level and final priority of CSF on the delivery of the penetration testing project at PT. ABCD.

**Fuzzy Delphi Method (FDM) Analysis Results**

Once the questionnaire results data have been collected, converted into a Triangular Fuzzy Number (TFN) form, and tested using classical statistical approaches as a supporting analysis, the next stage is to conduct the main analysis using the Fuzzy Delphi Method (FDM). The FDM analysis in this study was used to test the level of consensus of the expert panel, determine the feasibility of Critical Success Factors (CSF) candidates, and compile CSF priorities based on defuzzification values.

FDM analysis is carried out in stages through Expert Agreement (EA) testing, threshold value or dispersion/distance value (d) testing, alpha-cut testing, and rating based on aggregate defuzzification values. This stage is the main analysis in the study because FDM is more suitable for processing expert judgment-based assessments than the classic statistical approach oriented to population inference.

**Test Results % Expert Agreeement (EA%)**

The Expert Agreement (EA) percentage (Equation 2.6) is used to determine the level of agreement of the majority of the expert panel on each Critical Success Factors (CSF) candidate. In this study, a CSF candidate was declared to meet the initial consensus criteria if he obtained an EA score of ≥ 75%. The EA score is obtained from the percentage of the number of expert panels that scored in the categories "High Importance (SL Score 4)" and "Very High Importance (SL Score 5)" for each CSF candidate. The fulfillment of expert consensus in the initial phase was filtered using the Expert Agreement (EA) value whose percentage level for each CSF was tabulated in Table 4.18 and then compared by visually reflecting it into the vertical bar graph in Figure 2.

| LS Score (k) | Meaning of LS Score | Linguistic Score (LS) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | LS - C#1 | LS - C#2 | LS - C#3 | LS - C#4 | LS - C#6 | LS - C#7 | LS - C#8 | LS - C#9 | LS - C#10 | LS - C#11 |
| 5 | Very High Importance | 7 | 15 | 16 | 16 | 8 | 17 | 12 | 10 | 15 | 8 |
| 4 | High Importance | 10 | 6 | 5 | 5 | 10 | 4 | 8 | 9 | 5 | 9 |
| 3 | Moderate Importance | 3 | 0 | 0 | 0 | 4 | 0 | 1 | 2 | 1 | 3 |
| 2 | Low Importance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 1 | Very Low Importance | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total Experts | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 |
| | Sum of Scores 4+5 | 17 | 21 | 21 | 21 | 21 | 17 | 21 | 19 | 20 | 17 |
| | % Expert Agreement Rate | 80.95% | 100.00% | 100.00% | 100.00% | 100.00% | 80.95% | 95.24% | 90.48% | 95.24% | 80.95% |

**Figure 1. Presses Expert Agreement (EA%) for all CSF#i**

Source: Primary data processed by the author (2026)

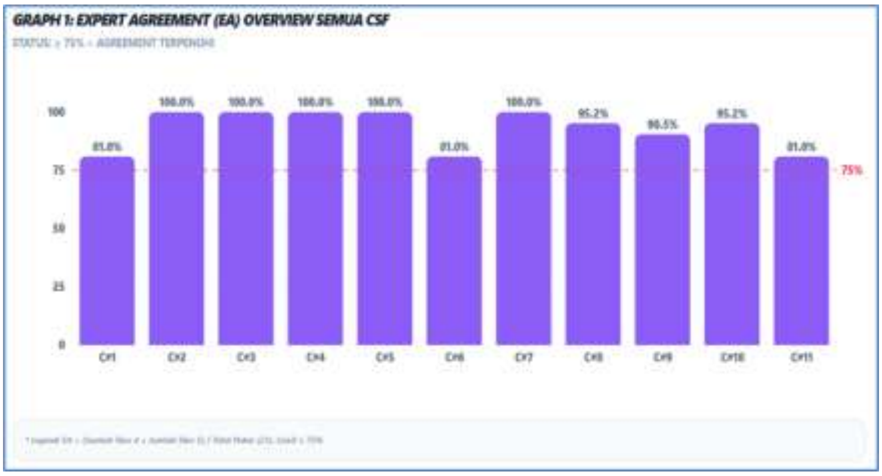


**Figure 2. Test Result Graph % Expert Aggrement for all CSF#i**
Source: Primary data processed by the author (2026)

Based on the results of the calculation of the Expert Agreement, all CSF candidates obtained an EA score above the 75% threshold. This shows that all expert panels gave high ratings to the CSF candidates used in the study. Thus, CSF candidates who meet the EA value can proceed to the next stage of consensus testing using the dispersion/distance threshold value.

**Dispersion /Distance Threshold Test Results (d)**

After the consensus test with % Expert Agreement, the next stage is consensus testing with the proximity of the assessment between the expert panels through the dispersion/distance threshold value (d) (Equation 2.9 and Equation 2.10). This value is used to determine whether the assessment between experts has a low spread and can be considered to have reached consensus.

In this study, CSF candidates were declared to meet the consensus if they had a value of $d \leq 0.2$. The smaller the value of d, the closer the assessment between experts to the CSF candidate, so that the stronger the level of consensus formed. Consensus maturation is evaluated from the measurement of the proximity of the dispersion threshold (d). The anatomy of the partial dispersion distance calculation for the CSF#1 variable is detailed in Figure 3. The average of this dispersion value for the eleven factors is recapitulated in full in Figure 4, and the distribution is profiled in Figure 5.

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| Expert Code | Linguistic Score (LS) | | TFN - C#1 | | | | | |
|---|---|---|---|---|---|---|---|---|
| | LS - C#1 | Expert Code | T-L-C#1 | T-M-C#1 | T-U-C#1 | Defuzz / Crisp-i Per Expert | Distance - I Per Expert | |
| | | | | | | | | |
| AP#1 | 4 | AP#1 | 0.50 | 0.75 | 1.00 | 0.75 | 0.01 | Formula 2.9 |
| AP#2 | 4 | AP#2 | 0.50 | 0.75 | 1.00 | 0.75 | 0.01 | |
| AP#3 | 4 | AP#3 | 0.50 | 0.75 | 1.00 | 0.75 | 0.01 | |
| AP#4 | 5 | AP#4 | 0.75 | 1.00 | 1.00 | 0.92 | 0.18 | |
| AP#5 | 4 | AP#5 | 0.50 | 0.75 | 1.00 | 0.75 | 0.01 | |
| AP#6 | 4 | AP#6 | 0.50 | 0.75 | 1.00 | 0.75 | 0.01 | |
| AP#7 | 5 | AP#7 | 0.75 | 1.00 | 1.00 | 0.92 | 0.18 | |
| | | | | | | | | |
| | | | | | | | | |
| ASB#1 | 4 | ASB#1 | 0.50 | 0.75 | 1.00 | 0.75 | 0.01 | |
| ASB#2 | 5 | ASB#2 | 0.75 | 1.00 | 1.00 | 0.92 | 0.18 | |
| ASB#3 | 4 | ASB#3 | 0.50 | 0.75 | 1.00 | 0.75 | 0.01 | |
| ASB#4 | 5 | ASB#4 | 0.75 | 1.00 | 1.00 | 0.92 | 0.18 | |
| ASB#5 | 3 | ASB#5 | 0.25 | 0.50 | 0.75 | 0.50 | 0.24 | |
| ASB#6 | 4 | ASB#6 | 0.50 | 0.75 | 1.00 | 0.75 | 0.01 | |
| ASB#7 | 3 | ASB#7 | 0.25 | 0.50 | 0.75 | 0.50 | 0.24 | |
| | | | | | | | | |
| | | | | | | | | |
| AT#1 | 5 | AT#1 | 0.75 | 1.00 | 1.00 | 0.92 | 0.18 | |
| AT#2 | 1 | AT#2 | 0.00 | 0.00 | 0.25 | 0.08 | 0.65 | |
| AT#3 | 5 | AT#3 | 0.75 | 1.00 | 1.00 | 0.92 | 0.18 | |
| AT#4 | 4 | AT#4 | 0.50 | 0.75 | 1.00 | 0.75 | 0.01 | |
| AT#5 | 3 | AT#5 | 0.25 | 0.50 | 0.75 | 0.50 | 0.24 | |
| AT#6 | 5 | AT#6 | 0.75 | 1.00 | 1.00 | 0.92 | 0.18 | |
| AT#7 | 4 | AT#7 | 0.50 | 0.75 | 1.00 | 0.75 | 0.01 | |
| Total | 85.00 | | | | | | | |
| Average | 4.05 | Total/Sum | 11.00 | 16.00 | 19.50 | 15.50 | 2.74 | |
| | | Fuzzy Average = | 0.52 | 0.76 | 0.93 | 0.73810 | 0.1304 | Formula 2.10 |
| | | Crisp Average = | 0.73810 | | | | consensus distance | |

**Figure 3. Dispersion/Distance Threshold CSF#1 & Per Pakar CSF#1**

*Source: Primary data processed by the author (2026)*

| Kode Pakar | Skor Linguistik (SL) | | | | | | | | | | | Tot | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LS - C#1 | LS - C#2 | LS - C#3 | LS - C#4 | LS - C#5 | LS - C#6 | LS - C#7 | LS - C#8 | LS - C#9 | LS - C#10 | LS - C#11 | Total Per Ahli | |
| AP#1 | 4 | 5 | 4 | 5 | 4 | 4 | 5 | 4 | 4 | 5 | 4 | 48 | |
| AP#2 | 4 | 5 | 5 | 5 | 4 | 4 | 5 | 4 | 4 | 3 | 5 | 50 | |
| AP#3 | 4 | 5 | 5 | 5 | 4 | 3 | 5 | 5 | 3 | 4 | 2 | 45 | |
| AP#4 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 5 | 5 | 4 | 3 | 49 | |
| AP#5 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 5 | 4 | 51 | |
| AP#6 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 53 | |
| AP#7 | 5 | 4 | 4 | 5 | 5 | 5 | 4 | 4 | 4 | 5 | 4 | 48 | |
| ASB#1 | 4 | 4 | 5 | 4 | 4 | 4 | 5 | 5 | 4 | 4 | 4 | 47 | |
| ASB#2 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 54 | |
| ASB#3 | 4 | 4 | 5 | 5 | 5 | 4 | 5 | 5 | 4 | 5 | 5 | 51 | |
| ASB#4 | 5 | 5 | 5 | 4 | 4 | 4 | 5 | 4 | 5 | 4 | 4 | 49 | |
| ASB#5 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 3 | 43 | |
| ASB#6 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 3 | 5 | 54 | |
| ASB#7 | 3 | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 4 | 51 | |
| AT#1 | 5 | 5 | 5 | 4 | 3 | 3 | 5 | 4 | 5 | 3 | 5 | 40 | |
| AT#2 | 1 | 4 | 4 | 4 | 4 | 3 | 4 | 5 | 5 | 3 | 3 | 40 | |
| AT#3 | 5 | 4 | 5 | 5 | 5 | 4 | 5 | 3 | 3 | 5 | 4 | 51 | |
| AT#4 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 54 | |
| AT#5 | 3 | 5 | 4 | 4 | 4 | 3 | 5 | 5 | 4 | 5 | 4 | 48 | |
| AT#6 | 5 | 4 | 5 | 5 | 4 | 3 | 5 | 5 | 3 | 5 | 5 | 49 | |
| AT#7 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 53 | |
| Jumlah | 85.00 | 99.00 | 100.00 | 100.00 | 95.00 | 88.00 | 101.00 | 95.00 | 92.00 | 98.00 | 87.00 | 1040.00 | |
| Rata2 (Mean) | 4.05 | 4.71 | 4.76 | 4.76 | 4.76 | 4.19 | 4.81 | 4.52 | 4.38 | 4.17 | 4.14 | 4.50 | |
| Tot Skor 4 | 10 | 6 | 6 | 5 | 10 | 9 | 4 | 8 | 9 | 5 | 6 | | |
| Total Skor 5 | 7 | 15 | 16 | 16 | 11 | 8 | 17 | 12 | 10 | 15 | 8 | | |
| Uji Konsensus: | | | | | | | | | | | | | |
| 1. Expert Agreement (%EA) | 81.0% | 100.0% | 100.0% | 100.0% | 100.0% | 81.0% | 100.0% | 95.2% | 90.5% | 95.5% | 81.0% | >=75% | |
| 2. Distance/Dispersion Threshold (d) | 0.1304 | 0.0680 | 0.0650 | 0.0600 | 0.0831 | 0.1149 | 0.0514 | 0.0952 | 0.1058 | 0.0850 | 0.1240 | <=0.2 | |

**Figure 4.** ***Dispersion/Distance Threshold*** **for All CSF#i**

*Source: Primary data processed by the author (2026)*

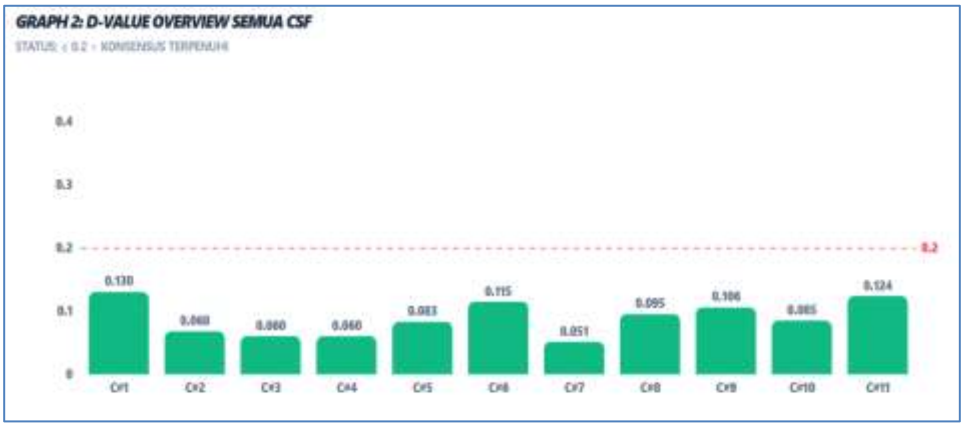


**Figure 5. Hajj Test Graph Dispersion for all CSF#i**

Source: Primary data processed by the author (2026)

Based on the results of the calculation of the dispersion/distance threshold value, all CSF candidates have a value of d ≤ 0.2 indicating that the assessment between experts on CSF candidates is relatively close and does not have too high a spread and this means that it can be stated that all CSF candidates have met the consensus of the expert panel.

**Alpha Cut/Importance Threshold Test Results**

Once the CSF candidate meets the consensus parameters through the Expert Agreement and the dispersion/distance value, the next stage is to conduct alpha-cut testing. Alpha-cut is

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used to determine whether the value of a CSF candidate's interest has crossed the minimum threshold set in the study.

In this study, the alpha-cut value used was 0.75. CSF candidates are declared to meet the level of importance if the aggregate defuzzification value is ≥ 0.75. In contrast, CSF candidates with an aggregate defuzzification/average defuzzification value below 0.75 are not included as final CSFs, although they may have met the initial consensus. The aggregate single decimal value components for the CSF#1 simulation can be reviewed again in Figure 6. The aggregate examination of the comparative defuzzification score of all CSF candidates versus the standard of 0.75 is presented as finalized in Figure 7. To clarify the factors that successfully cross this pass limit and which factors stall, the comparison of the scores is clearly illustrated through the cut-off line in Figure 8.

| Expert Code | TFN - C#1 | | | Defuzz / Crisp-i per Expert |
|---|---|---|---|---|
| | T-L-C#1 | T-M-C#1 | T-U-C#1 | |
| AP#1 | 0.50 | 0.75 | 1.00 | 0.75 |
| AP#2 | 0.50 | 0.75 | 1.00 | 0.75 |
| AP#3 | 0.50 | 0.75 | 1.00 | 0.75 |
| AP#4 | 0.75 | 1.00 | 1.00 | 0.92 |
| AP#5 | 0.50 | 0.75 | 1.00 | 0.75 |
| AP#6 | 0.50 | 0.75 | 1.00 | 0.75 |
| AP#7 | 0.75 | 1.00 | 1.00 | 0.92 |
| | | | | |
| | | | | |
| ASB#1 | 0.50 | 0.75 | 1.00 | 0.75 |
| ASB#2 | 0.75 | 1.00 | 1.00 | 0.92 |
| ASB#3 | 0.50 | 0.75 | 1.00 | 0.75 |
| ASB#4 | 0.75 | 1.00 | 1.00 | 0.92 |
| ASB#5 | 0.25 | 0.50 | 0.75 | 0.50 |
| ASB#6 | 0.50 | 0.75 | 1.00 | 0.75 |
| ASB#7 | 0.25 | 0.50 | 0.75 | 0.50 |
| | | | | |
| | | | | |
| AT#1 | 0.75 | 1.00 | 1.00 | 0.92 |
| AT#2 | 0.00 | 0.00 | 0.25 | 0.08 |
| AT#3 | 0.75 | 1.00 | 1.00 | 0.92 |
| AT#4 | 0.50 | 0.75 | 1.00 | 0.75 |
| AT#5 | 0.25 | 0.50 | 0.75 | 0.50 |
| AT#6 | 0.75 | 1.00 | 1.00 | 0.92 |
| AT#7 | 0.50 | 0.75 | 1.00 | 0.75 |
| | | | | |
| Sum | 11.00 | 16.00 | 19.50 | 15.50 |
| Fuzzy Average = | 0.52 | 0.76 | 0.93 | 0.73810 |
| Crisp Average = | 0.73810 | | | Formula 2.8 |
| Alpha Cut Check = | Alpha Cut not met | | | |

**Figure 6. CSF#1 and Per CSF#1 Expert Aggregate**

*Source: Primary data processed by the author (2026)*

| Expert Code | Linguistic Score (LS) | | | | | | | | | | | Tot |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LS - C# | LS - C2 | LS - C3 | LS - C4 | LS - C5 | LS - C6 | LS - C7 | LS - C8 | LS - C9 | LS - C10 | LS - C#1 | Total Per Expert |
| | | | | | | | | | | | | |
| AP#1 | 4 | 5 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 5 | 4 | 48 |
| AP#2 | 4 | 5 | 5 | 5 | 4 | 4 | 5 | 4 | 4 | 5 | 5 | 50 |
| AP#3 | 4 | 5 | 5 | 5 | 4 | 3 | 5 | 5 | 3 | 4 | 2 | 45 |
| AP#4 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 5 | 5 | 4 | 3 | 49 |
| AP#5 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 5 | 4 | 51 |
| AP#6 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 53 |
| AP#7 | 3 | 4 | 4 | 5 | 5 | 4 | 4 | 4 | 4 | 5 | 4 | 51 |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| ASB#1 | 4 | 4 | 5 | 4 | 4 | 4 | 5 | 5 | 4 | 4 | 4 | 47 |
| ASB#2 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 54 |
| ASB#3 | 4 | 4 | 5 | 5 | 5 | 4 | 5 | 5 | 4 | 5 | 5 | 51 |
| ASB#4 | 5 | 5 | 5 | 4 | 4 | 4 | 5 | 4 | 5 | 4 | 4 | 49 |
| ASB#5 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 3 | 43 |
| ASB#6 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 54 |
| ASB#7 | 3 | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 4 | 51 |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| AT#1 | 5 | 5 | 5 | 5 | 5 | 3 | 5 | 4 | 5 | 3 | 5 | 52 |
| AT#2 | 1 | 4 | 4 | 4 | 4 | 3 | 4 | 5 | 5 | 3 | 3 | 40 |
| AT#3 | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 3 | 5 | 5 | 4 | 51 |
| AT#4 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 54 |
| AT#5 | 3 | 5 | 4 | 4 | 4 | 3 | 5 | 5 | 4 | 5 | 4 | 48 |
| AT#6 | 5 | 4 | 5 | 5 | 4 | 3 | 5 | 5 | 3 | 5 | 5 | 49 |
| AT#7 | 4 | 5 | 5 | 5 | 5 | 3 | 5 | 5 | 3 | 5 | 4 | 53 |
| | | | | | | | | | | | | |
| Total/Sum | 85.00 | 99.00 | 100.00 | 100.00 | 95.00 | 88.00 | 101.00 | 92.00 | 92.00 | 98.00 | 87.00 | 1040.00 |
| Average (Mean) | 4.05 | 4.71 | 4.76 | 4.76 | 4.52 | 4.19 | 4.81 | 4.52 | 4.68 | 4.67 | 4.14 | 4.50 |
| Alpha Cut Test : | | | | | | | | | | | | |
| Defuz | 0.7381 | 0.8690 | 0.8770 | 0.8770 | 0.8373 | 0.7659 | 0.8849 | 0.8333 | 0.8056 | 0.8571 | 0.7540 | >= 0.75 |

**Figure 7. Test Results *Alpha Cut* for All CSF#i (Aggregat)**

*Source: Primary data processed by the author (2026)*

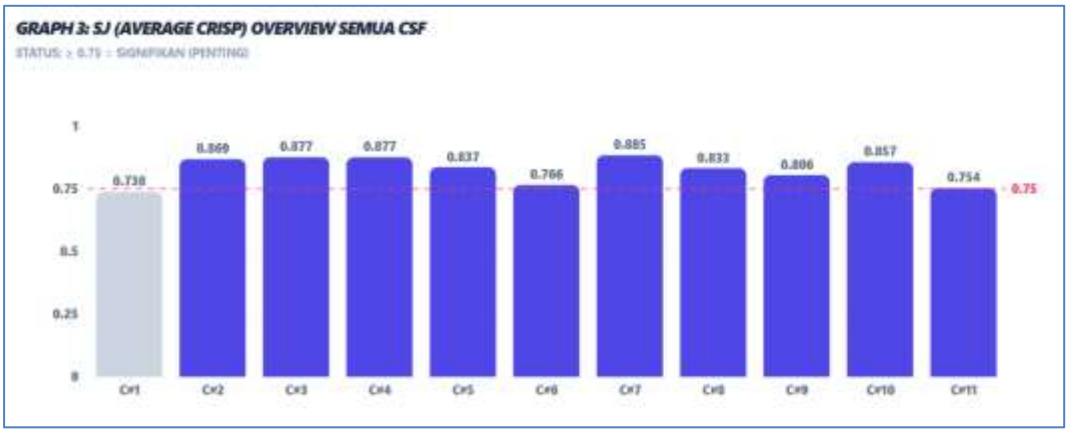


**Figure 8. Graphic Uji *Alpha Cut* for all CSF#i**

Source: Primary data processed by the author (2026)

Based on the alpha-cut results, there was one CSF candidate that had an aggregate defuzzification value slightly below the threshold value of 0.75, namely CSF#1 with a value of 0.73810. This shows that although CSF#1 remains a fairly high level of importance and can gain support from a section of the expert panel, its importance value has not yet reached the minimum limit set as the final CSF in this study. Therefore, CSF#1 is not included in the list of the final CSF prioritized.

The elimination of this factor is not an anomaly, but an empirical finding that is very logical and can be accounted for when examined from the operational characteristics of *the delivery* of the penetration testing *(*pentest*) project* at PT. ABCD. There are four fundamental

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analyses that explain why experts provide assessments that make this factor not pass the *alpha-cut test*:

**1. Cross-Validation between Literature (Theory) vs. *Lesson Learned* (Practice).** Based on the initial synthesis matrix in Table 4.6, CSF#1 (*Top Management* Support) is one of only two factors adopted **purely from the general scientific literature** (in particular *Project Management* and IT at large), and **never appears in the list of 26 *internal* lessons learned** records of the *pentest* project PT. ABCD. The elimination of this factor by the expert panel actually proves that *the hybrid* approach method (combining theory and practice) works very well. Experts validate the reality on the ground: factors that are often considered important in the macro-scale IT project literature (such as ERP implementation or large-scale infrastructure) are not perceived as critical factors or major *blockers* in the day-to-day operations of *pentest projects*.

**2. Characteristics of *Pentest* Projects that are Tactical and Operational.**The pentest *project* has a relatively short duration and is very technical execution oriented (*agile-waterfall hybrid approach*). Once the contract is signed in the initiation phase, the center of gravity for the project's success immediately shifts to the implementers in the field, namely *the Project Manager* (PM), *Pentester*, and the client team. The involvement of *Top Management* from the vendor (PT. ABCD) is generally only needed in rare crisis escalations. Therefore, experts give scores that do not reach the graduation limit because they realize that the *delivery pentest* will still be successful as long as the implementation team has high capabilities (CSF#3) and a clear scope (CSF#4), regardless of whether or not there is daily intervention from *Top Management.*

**3. "Support" Object Shift: *Vendor* vs. *Client*.** In *pentest* execution, the biggest obstacles often come from delays in granting *environment access*, authorization, or response from the party whose system is being tested. Therefore, the "Management Support" that is actually most needed is the support from the Client**'s leadership** (so that the cooperative client team opens access), not the leadership of **PT. ABCD**. This is reflected in the very high value given by experts to **CSF#5 (Stakeholder/Client Engagement & Resiliency),** which successfully qualified for the CSF Final. The expert panel was well aware of these contextual differences, so they did not give CSF#1 a maximum score.

**4. Evidence of Rational Expert Consensus (Not Total Rejection)**. It is important to note that CSF#1 **still managed to pass the consensus test** with an *Expert Agreement* (EA) percentage of 75% and *a dispersion* distance (d) of 0.2. This means that experts (both from the PMO, Sales, and Technical divisions) **agree** uniformly that *the support of top management* is "heading towards a high level of importance" (*crisp* figure 0.73810). They did not consider this factor to be useless (the score did not fall below 0.2 or 0.4). However, when compared to operationally crucial aspects—such as Communication (CSF#2) or Clarification *Scope* (CSF#4)—CSF#1 is considered not urgent enough (critical) to be labeled "*Critical*" and pass the hard line of the 0.75 threshold.

Thus, *the gap* between the 11 CSF synthesized and the 10 CSF produced by FDM is a form of **natural *filtering (sequential* filtering)** which is the main advantage of FDM. *This gap* confirms the findings of the research that management priorities in the operational phase or *delivery* of *penetration testing projects* must be shifted from the aspect of structural bureaucracy (*Top Management*) to strengthening the team's technical capabilities, operational communication clarity, and client stakeholder management in the field.

**Final CSF Determination Results**

Based on the results of *the Expert Agreement*, *dispersion/distance* value, and *alpha-cut* tests, this study determined CSF candidates who met all FDM criteria as the final *Critical Success Factors*. CSF candidates who meet these criteria are those who have the support of a majority of the expert panel, have a low spread of assessments, and have an aggregate defuzzification value above the alpha-cut limit. **Fugure 9** shows the final list of *Critical Success Factors*.

| CSF# | CSF Title | CSF ID | Lesson Learned | Scientific Ref. | PIC | PMPg (I-P-E-MC-C) | EA% | d | Defuzz Aggregate | Final Status |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Top Management Support | C#1 | N/A | Y | PM+Sales | I-P | 80.95% | 0.1303855 | 0.73809524 | Did Not Enter Final CSF |
| 2 | Effective Communication | C#2 | N/A | Y | PM+Sales | I-P | 100.00% | 0.0980272 | 0.86904756 | Entered Final CSF |
| 3 | Team Capabilities & Expertise | C#3 | Y | Y | PM+Sales+Teknis | E-MC | 100.00% | 0.0690772 | 0.86904782 | Entered Final CSF |
| 4 | Scope & Methodology Clarification | C#4 | Y | Y | PM+Teknis | P-E | 100.00% | 0.0604686 | 0.87698413 | Entered Final CSF |
| 5 | Stakeholder Involvement & Readiness (Client) | C#5 | Y | Y | PM+Sales+Teknis | I-P-MC | 100.00% | 0.0604686 | 0.87699413 | Entered Final CSF |
| | | C#5 | Y | Y | PM+Sales | P-E-C | 100.00% | 0.0831444 | 0.83730159 | Entered Final CSF |
| 6 | Pentest Risk Management | C#6 | Y | Y | Sales+PM+Teknis | P-E-MC | 80.95% | 0.1149904 | 0.76587302 | Entered Final CSF |
| 7 | Trust & Professional Ethics | C#7 | N/A | Y | Sales+PM+Teknis | E-C | 100.00% | 0.0513383 | 0.88492063 | Entered Final CSF |
| 8 | Planning & Scheduling | C#8 | Y | Y | PM+Teknis | P-MC | 90.24% | 0.1058201 | 0.80555555 | Entered Final CSF |
| 9 | Troubleshooting/Workaround | C#9 | Y | Y | PM+Teknis | E-MC | 90.48% | 0.1058201 | 0.80555556 | Entered Final CSF |
| 10 | Report Quality & Recommendations | C#10 | Y | Y | PM+Teknis | E-C | 95.55% | 0.085001 | 0.85742286 | Entered Final CSF |
| 11 | Administrative & Contract Readiness | C#11 | Y | Y | PM+Sales | I-P-C | 80.95% | 0.1239007 | 0.75396825 | Entered Final CSF |

**Figure 9. CSF Final Determination (10/11 CSF Final#)**

Source: Primary data processed by the author (2026)

Based on the recapitulation of the FDM selection results, as many as 10 out of 11 CSF candidates were declared to meet all FDM criteria and were determined as the *final Critical Success Factors* in the *delivery of* the penetration testing *project* at PT. ABCD. Meanwhile, one CSF candidate was not included in the final CSF list because its aggregate defuzzification value was below the alpha-cut value used in the study.

**Pemeringkatan *Critical Success Factors (CSF)***

Once the final CSF list is determined, the next stage is to rank based on the aggregate defuzzification value. This ranking is carried out to find out the order of priority of the factors that have the most influence on the success of the delivery of penetration testing *projects*.

In **Figure 10,** it can be seen that the higher the aggregate defuzzification value of a CSF, the higher the level of importance of the factor according to the consensus of the expert panel. Thus, the CSF ranking can be used as a basis for determining the priority of managerial attention and improving *the delivery strategy* of the penetration testing *project* at PT. ABCD.

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| Ranking | CSF# | CSF Title | CSF ID | Lesson Learned | Scientific Ref. | PIC | PMPg (I-P-E-MC-C) |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| 1 | 7 | Trust & Professional Ethics | C#7 | N/A | Y | Sales+PM+Teknis | E-C |
| 2 | 3 | Team Capabilities & Expertise | C#3 | Y | Y | PM+Teknis | P-E |
| 3 | 4 | Scope & Methodology Clarification | C#4 | Y | Y | PM+Sales+Teknis | I-P-MC |
| 4 | 2 | Effective Communication | C#2 | Y | Y | PM+Sales + Teknis | E-MC |
| 5 | 10 | Report Quality & Recommendations | C#10 | Y | Y | PM+Teknis | E-C |
| 6 | 5 | Stakeholder Engagement & Readiness (Cl | C#5 | Y | Y | PM+Sales | P-E-C |
| 7 | 8 | Planning & Scheduling | C#8 | Y | Y | PM+Teknis | P-MC |
| 8 | 9 | Troubleshooting / Workaround | C#9 | Y | Y | PM+Teknis | E-MC |
| 9 | 6 | Pentest Risk Management | C#6 | Y | Y | Sales+PM+Teknis | P-E-MC |
| 10 | 11 | Administrative & Contract Readiness | C#11 | Y | Y | PM+Sales | I-P-C |
| Not in Final CSF | 1 | Top Management Support | C#1 | N/A | Y | PM+Sales | I-P |

**Table 10. Project Final CSF Rating Penetration Testin PT. ABCD**

*Source: Primary data processed by the author (2026)*

Based on the results of the ranking, the CSF with the highest aggregate defuzzification value is the most prioritized factor in supporting the successful *delivery of* penetration testing *projects*. The results of this ranking are an important basis for discussing research results and preparing strategic recommendations in the next section.

**Conclusion of FDM Analysis Results**

Based on the results of the *Fuzzy Delphi Method* analysis, it can be concluded that the majority of CSF candidates have met the consensus criteria of the expert panel and the level of importance set in the research. Of the 11 CSF candidates analyzed, as many as 10 CSF candidates met all FDM parameters and were determined as *the final Critical Success Factors* in the *delivery* of penetration testing *projects* at PT. ABCD.

The results of the analysis also showed that one CSF candidate, namely CSF#1, was not included in the final CSF list because its aggregate defuzzification value of 0.73810 was still below the alpha-cut value of 0.75. Thus, the FDM results not only produce a list of CSFs that are validated based on expert consensus, but also produce a sequence of CSF priorities that can be used as a basis for improving the *delivery strategy of* the penetration testing *project*.

## CONCLUSION

This study concludes that the delivery of penetration testing projects at PT. ABCD was influenced by a combination of technical and managerial critical success factors (CSFs). Through the application of the Fuzzy Delphi Method (FDM), 11 initial CSF candidates were identified based on the synthesis of relevant literature and internal organizational experience. The validation process involving expert judgment confirmed that 10 out of 11 CSFs met the predefined consensus thresholds, while one factor was excluded because it did not achieve the minimum defuzzification value. Furthermore, the study established a clear prioritization of CSFs based on aggregate defuzzification scores, indicating that communication effectiveness, stakeholder coordination, technical readiness, scope management, and risk control were the most dominant determinants of project success. These prioritized factors provided PT. ABCD with a structured reference for improving penetration testing project delivery by focusing on areas with the greatest impact on project performance and operational efficiency. Overall, the findings demonstrated that successful penetration testing execution was not solely dependent on technical expertise but also required effective managerial control, cross-functional collaboration, and adaptive project governance. This study reinforced the importance of integrating technical and organizational dimensions in cybersecurity project management to minimize operational risks and consistently improve project delivery outcomes.

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