CRITICAL SUCCESS FACTORS OF AGILE SOFTWARE DEVELOPMENT IN WATERFALL PROJECT: A CASE STUDY APPROACH

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Abstract—*The evolution of software development methodologies has seen Agile rise in response to the limitations of traditional approaches like Waterfall, characterized by its iterative, collaborative, and adaptable nature. However, integrating Agile within the rigid, structured frameworks of organizations accustomed to Waterfall presents significant challenges. This study addresses how to effectively combine these methodologies to mitigate conflicts and achieve successful project outcomes by identifying and analyzing the Critical Success Factors (CSFs) that enable a harmonious integration of Agile into Waterfall environments. Conducted at PT ABC, a firm balancing formal client interactions and contract creation with internal adoption of Scrum, this research uses the Analytic Hierarchy Process (AHP) to systematically prioritize CSFs through literature review, questionnaire development, data collection, and pairwise comparison analysis. The findings reveal that "Communication and Team Environment" is the most influential factor, with a priority vector weight of 0.178, followed by "Project Management and Strategy," "Leadership and Management Support," and "User and Customer Engagement." These factors are pivotal in achieving a balance between control and flexibility in software development projects. The study's implications for PT ABC and other organizations, especially those handling multiple projects and requiring on-site presence while managing other projects, demonstrate how to leverage the strengths of both methodologies for optimal project outcomes. This research provides a model for other organizations striving for similar integrative efforts, showcasing practical strategies to enhance project flexibility and coordination.*

Keywords: Agile, AHP, CSF, Waterfall.

Intisari— Dalam evolusi metodologi pengembangan perangkat lunak, Agile muncul sebagai respons terhadap keterbatasan metode tradisional seperti Waterfall, yang ditandai dengan sifat iteratif, kolaboratif, dan adaptifnya. Meskipun memiliki keuntungan, mengintegrasikan Agile dalam kerangka kerja yang kaku dan terstruktur dari organisasi yang terbiasa dengan Waterfall menimbulkan tantangan yang signifikan. Studi ini membahas bagaimana menggabungkan kedua metodologi ini secara efektif untuk mengurangi konflik dan mencapai hasil proyek yang sukses dengan mengidentifikasi dan menganalisis Critical Success Factors (CSFs) yang memungkinkan integrasi Agile yang harmonis dalam lingkungan Waterfall. Dilakukan di PT ABC, sebuah perusahaan yang menyeimbangkan interaksi formal dengan klien dan pembuatan kontrak dengan adopsi internal Scrum, penelitian ini menggunakan Analytic Hierarchy Process (AHP) untuk memprioritaskan CSFs secara sistematis melalui tinjauan literatur, pengembangan kuesioner, pengumpulan data, dan analisis perbandingan berpasangan. Temuan menunjukkan bahwa "Komunikasi dan Lingkungan Tim" adalah faktor yang paling berpengaruh, dengan bobot vektor prioritas sebesar 0,178, diikuti oleh "Manajemen Proyek dan Strategi," "Dukungan Kepemimpinan dan Manajemen," dan "Keterlibatan Pengguna dan Pelanggan." Faktor-faktor ini penting dalam mencapai keseimbangan antara kontrol dan fleksibilitas dalam proyek pengembangan perangkat lunak. Implikasi studi ini bagi PT ABC dan organisasi lain, terutama yang menangani beberapa proyek dan memerlukan kehadiran di lapangan sambil mengelola proyek lain, menunjukkan bagaimana memanfaatkan kekuatan kedua metodologi untuk hasil

proyek yang optimal. Penelitian ini menyediakan model bagi organisasi lain yang berupaya untuk upaya integratif serupa, menunjukkan strategi praktis untuk meningkatkan fleksibilitas dan koordinasi proyek.

Kata Kunci: *Agile, AHP, CSF, Waterfall.*

INTRODUCTION

The software development industry has undergone significant evolution in recent decades, particularly with the emergence of Agile methodology. Agile emerged as a response to the limitations of traditional approaches like Waterfall, emphasizing iteration, team collaboration, and adaptability [1]. Although Agile has gained widespread popularity, many large and complex organizations still rely on the Waterfall methodology due to its emphasis on generating explicit knowledge through detailed documentation, which is crucial for managing complexity in such environments [2]. However, the use of Agile methodology has been widely adopted in organizations that previously relied on traditional or structured methods, such as Waterfall, with significant success rates [3]. Recent research highlights several key conflicts and integration challenges between Agile and Waterfall methodologies. Agile methodology is favored over the Waterfall model in software development due to its adaptability to frequent changes and focus on customer satisfaction and faster development. In contrast, the Waterfall model, while older and more structured, is often criticized for being time-consuming [4]. Additionally, Agile projects tend to have a higher success rate compared to Waterfall projects. For instance, Agile projects have a failure rate of 10%, while Waterfall projects fail 30% of the time [3]. Despite these benefits, Agile methodologies like Scrum and Kanban have limitations in addressing project requirement documentation, planning, scheduling, estimation, and clear product vision at the initial project stage. This often leads to the integration of Waterfall methodology to form hybrid approaches like 'Scrumbanfall' for a more holistic approach in software development [5].

The conflict between Agile and Waterfall methodologies often becomes a major challenge in software development projects. Agile software development projects executed in larger project environments often struggle to succeed, mainly due to cultural barriers and value conflicts between Agile and non-Agile teams [6]. Agile, with its flexible and adaptive nature, is often seen as conflicting with the linear and structured approach of Waterfall. The integration of Agile's adaptability and Waterfall's

structured planning is a challenge that requires careful management of stakeholder expectations and planning differences, as these two methodologies have inherently different strengths [7]. This conflict arises because Agile emphasizes iterative progress, constant feedback, and adaptability, whereas Waterfall relies on a sequential, phase-based process with strict documentation and upfront planning [8]. At PT ABC, an IT consulting firm involved in system development, this conflict is faced head-on. PT ABC takes an approach by integrating Agile within the Waterfall project framework. Integrating Agile within the rigid, structured frameworks of organizations accustomed to Waterfall presents significant challenges. The specific problem this research addresses is how to effectively combine these methodologies to mitigate conflicts and achieve successful project outcomes. This involves identifying and analyzing the Critical Success Factors (CSFs) that enable a harmonious integration of Agile into Waterfall environments.

In its business processes, PT ABC implements the Waterfall method in formal aspects such as contract creation and interaction with clients. This approach, consistent with traditional practices in software development, ensures structured planning and clear documentation of all client requirements. This provides management with essential evidence for project control and oversight, particularly in environments where predictable outcomes are [7]. However, in terms of system development, PT ABC internally adopts Scrum, which is part of the Agile methodology. The implementation of Scrum enhances flexibility and efficiency in system development by enabling rapid iterations, adaptive planning, and improved responsiveness to changes, making it a vital methodology for addressing dynamic development needs [9]. This Agile methodology can be integrated into traditional project management practices to ensures sustainability in rapidly evolving environments, allowing for the benefits of Agile's adaptability alongside the structured planning of traditional methods [10]. Despite the extensive adoption and documented benefits of Agile methodologies, several research gaps remain. There is limited empirical research on effective strategies for integrating Agile practices within traditionally Waterfall-dominated environments. Studies often

focus on either methodology in isolation, neglecting the nuanced challenges of hybrid implementation. While various critical success factors (CSFs) for Agile implementation have been identified, critical success factors implementasi Agile software development in Waterfall project remains underexplored. This includes understanding how organizational culture, management support, and team dynamics influence the success of such integrations [11]. Furthermore, resistance to adopting Agile methodologies in organizations accustomed to Waterfall practices is a significant barrier. The existing literature does not sufficiently address practical solutions to overcome this resistance, particularly in large and complex organizations [12].

The implementation of Agile in a Waterfall environment at PT ABC requires a deep understanding of the critical success factors in its implementation. This integration is not just about adopting Agile practices, but also about adjusting the overall culture and processes of the organization. The case study at PT ABC provides a unique opportunity to explore these dynamics and understand how both methodologies can effectively work together. Important factors in the suitability of software development methodologies include organizational culture and project team empowerment, which are crucial for fostering adaptability in Agile teams and driving continuous innovation [13]. Integrating Agile in a Waterfall environment is not just about adopting Agile practices, but also about adjusting the overall culture and processes of the organization. Efficiency in software processes requires structured project management activities to ensure proper task execution, which is often a challenge for Agile methods like Scrum, despite the improvements in project performance through time-boxed progression [14]. Additionally, understanding the interaction between organizational culture and Agile methods is crucial in integrating software development methodologies, as different organizational cultures support distinct facets of Agile, indicating a complex relationship [15].

Resistance to change is one of the major challenges in adopting Agile, especially in organizations accustomed to using the Waterfall methodology. In large-scale Agile processes, factors such as company culture, prior experience with Agile, management support, and value alignment are critical to success [16]. In the context of integrating Agile and Waterfall, understanding and implementing these Critical Success Factors is crucial to facilitate a smoother transition between

the two methodologies, allowing organizations to leverage the advantages of both approaches.

To achieve the study's objectives, this research will employ the Analytic Hierarchy Process (AHP) methodology. AHP will be used to systematically prioritize the identified Critical Success Factors (CSFs) by conducting pairwise comparisons among them. This method allows for a structured evaluation of each factor's relative importance and impact on the successful integration of Agile within the Waterfall framework at PT ABC. The results from AHP will provide a clear prioritization of CSFs, guiding the organization in focusing on the most influential factors to enhance their project management practices.

This research is expected to provide insights into how a balance between control and flexibility can be achieved in software development projects. Given that each methodology has its strengths and limitations, this research will explore how PT ABC leverages the strengths of both methodologies to achieve optimal results in their projects. This will provide valuable guidance for other organizations wishing to adopt a similar approach in their software development.

MATERIALS AND METHODS

The author conducted a comprehensive literature review with the aim of analyzing Critical Success Factors (CSF) in agile software development within waterfall projects. The primary focus of this research is to identify and understand CSF in the context of integrating agile methodology into the waterfall project framework. This literature review was carried out using a systematic approach to ensure a comprehensive and relevant analysis of existing studies. Sources from various academic databases and research repositories were explored to gather literature related to CSF in agile software development, technology adaptation, and change management in waterfall projects. Keywords used in the search include "Critical Success Factors", "agile software development", "waterfall project", "technology adaptation", and "organizational change". This literature review involved studies from various industries to gain a broader perspective. Although there is a limitation in literature specifically focusing on CSF in the merging of agile and waterfall, this review includes articles that discuss CSF in a broader context of software development, technology adaptation, and organizational transformation. The reviewed articles provide in-depth insights into various factors that contribute to the success of integrating agile methodology in waterfall projects.

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The literature review specifically addresses the challenges mentioned in the introduction, such as the conflict between Agile's iterative, flexible approach and Waterfall's linear, structured process. It explores how organizations can adjust their cultures and processes to accommodate both methodologies effectively. This includes examining the importance of management support, team communication, and adaptability in overcoming resistance to change. Additionally, the review highlights strategies for maintaining documentation and formal processes required in Waterfall while implementing Agile practices to enhance responsiveness and efficiency.

Table 1. Critical Success factors

No	Criteria	Literature
1	Team Empowerment and Commitment	[17], [18]
2	Competencies and Expertise Development	[17],
3	Leadership and Management Support	[17], [18], [19]
4	Agile-friendly Organizational Culture	[17], [19]
5	Clear Vision, Objectives, and Goals	[17], [18], [19]
6	Effective Communication and Team Environment	[17], [19]
7	Agile Methodologies Implementation	[20], [19]
8	Agile-style Delivery and Project Execution	[20], [19]
9	Resource and Infrastructure Management	[18], [19], [21]
10	Project Planning and Definition Process	[18], [19]
11	Quality and Innovation Management	[18], [21]
12	User/Client and Customer Involvement	[18], [21]
13	Dynamic, Flexible Project Management	[19]
14	High-caliber Team Capability	[19]
15	Human Resource Management Related Issues	[21]
16	Supplier-Related Issues	[21]
17	Concurrent Engineering	[21]
18	Monitoring and Controlling	[22]
19	Mentoring and Culture Adjustment	[17]
20	Strategy and Effective Project Management Skills	[17], [18]

Source : (Research Results, 2024)

In the proposed research methodology, the Analytic Hierarchy Process (AHP) will be used to analyze and prioritize CSF in the context of agile software development in a waterfall project environment. The AHP methodology is a widely recognized multi-criteria decision-making method used to prioritize critical factors across different domains [23]. This method allows decision-makers to systematically compare and prioritize factors based on pairwise comparisons.

By incorporating the AHP methodology into this research methodology, the study aims to provide a systematic approach in analyzing and understanding CSF in the context of agile software development in a waterfall project environment.

The use of AHP enables decision-makers to make informed decisions by considering various criteria and their relative levels of importance. The research objectives will be achieved by following the steps of the proposed research methodology discussed below.

A. Establish Criteria and Hierarchy

At this stage, the author establishes the factors and sub-factors relevant to the CSF identified in the Literature Review. This subsection involves defining the factors and sub-factors that will be used to evaluate and prioritize the CSF. These factors should align with the research objectives and cover various dimensions of the CSF. Building a hierarchy is important to create a structured framework for evaluating the relative importance of various CSF. The author will determine the relationships and dependencies between factors and sub-factors, organizing them into a hierarchical structure. This hierarchical structure will enable systematic analysis of the CSF and provide a basis for subsequent steps, such as the development of a questionnaire.

The challenge of integrating Agile within the rigid, structured frameworks of organizations accustomed to Waterfall will be the primary focus while establishing these criteria and hierarchy. Factors such as organizational culture, management support, and team communication will be included to reflect these challenges.
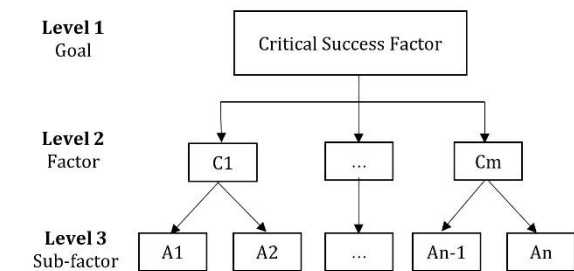
Source : (Research Results, 2024)
Figure 1. Hierarchal Tree of CSF

In the following table, the results of the determination of factors and sub-factors of CSF that have been identified from the Literature Review can be seen.

Table 1. Factor and Sub Factor

Factor	Sub-factor
Project Management and Strategy	Strategy and Effective Project Management Skills
	Project Planning and Definition Process
	Dynamic, Flexible Project Management
Team Development and Skills	Team Empowerment and Commitment

Factor	Sub-factor
Communication and Team Environment	Competencies and Expertise Development
	High-caliber Team Capability
	Human Resource Management Related Issues
	Effective Communication and Team Environment
	Agile-friendly Team Environment
	Mentoring and Culture Adjustment
User and Customer Engagement	User/Client and Customer Involvement
Leadership and Management Support	Leadership and Management Support
Agile Approach and Implementation	Agile Methodologies Implementation
	Agile-style Delivery and Project Execution
	Agile-friendly Organizational Culture
Resource Management	Resource and Infrastructure Management
	Supplier-Related Issues
	Concurrent Engineering
Quality and Innovation	Quality and Innovation Management
	Monitoring and controlling

Source : (Research Results, 2024)

B. Questionnaire Development

The author will develop a questionnaire based on the CSF identified in the literature review. The questionnaire serves as a data collection tool to gather information from the IT team at PT. ABC. The questionnaire will specifically focus on pairwise comparisons of the identified CSF, asking participants to rate the relative importance of each factor. This comparative approach will help in understanding the prioritization of CSF in the context of integrating Agile and Waterfall methodologies. The questions will be designed to assess various CSF, thus allowing a comprehensive understanding of CSF in the context of agile software development in a waterfall project environment.

The questionnaire development process involves translating the identified CSF into specific items or statements that can be rated or answered by participants. The author ensures that the questionnaire is clear, concise, and relevant to the research objectives. It is important to consider the validity and reliability of the questionnaire by conducting a pilot test and making necessary revisions based on feedback. By developing a well-structured questionnaire, the author can collect quantitative data that will be used to assess the relative importance of various CSF. This will provide valuable insights into the perceptions and experiences of the IT team in conducting agile software development in a waterfall project environment. Additionally, the questionnaire will explore specific aspects of how Scrum is used in system development at PT ABC and how it is integrated with the Waterfall framework, reflecting practical implementation and integration of the two methodologies.

C. Data Collection and Analysis

The author distributes the developed questionnaire to the participants. The participants in this study are the IT team members who are directly involved in agile software development in a waterfall project environment. The number of respondents for this study is 10 people. The author will provide the questionnaire and collect the questionnaire results from the participants, ensuring confidentiality and anonymity.

D. Pairwise Comparison

The author will use the data collected from the questionnaire responses to calculate the relative weights or priorities of the CSF. The Analytical Hierarchy Process (AHP), a mathematical algorithm, can be used to calculate weights based on pairwise comparison data. AHP provides a structured and consistent approach in determining the relative importance levels of factors by considering both direct comparisons and the overall hierarchy of criteria and sub-criteria.

E. Calculation of Weights

This step involves calculating the weight or priority of the Critical Success Factors (CSF) based on the results obtained from pairwise comparisons. The Analytical Hierarchy Process (AHP) algorithm will be applied to analyze the pairwise comparison data and calculate the relative weight of the CSF within each criterion and sub-criterion. By assigning weights to the CSF, author can identify and prioritize the most influential factors. The calculation of weights provides a quantitative basis for understanding the relative importance of the CSF, allowing for data-driven decision-making and resource allocation.

F. Interpretation and Analysis

This stage focuses on the interpretation and analysis of the results obtained from the AHP analysis. The author will interpret the calculated weights and their implications in the context of agile software development in a waterfall project environment. This interpretation will involve identifying the most significant CSF and their impact on the success of software development. The analysis of the AHP results will provide a prioritized list of CSF based on their relative importance levels.

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The author can identify the factors that have the greatest influence. Additionally, this analysis will include a comparison of how Agile and Waterfall methods are integrated within the research context, addressing the specific challenges identified in the introduction. By doing so, the research will provide a clear understanding of the effectiveness of the integrated approach and its implications for project success at PT ABC. The interpretation and analysis of the AHP results will contribute to an overall understanding of CSF in the context of agile software development in a waterfall project environment.

RESULTS AND DISCUSSION

The objective of this study is to analyze Critical Success Factors (CSF) in the context of agile software development within a waterfall project environment. The study utilizes a literature review to identify the CSF. Additionally, the questionnaire will explore specific aspects of how Scrum is used in system development at PT ABC and how it is integrated with the Waterfall framework, reflecting practical implementation and integration of the two methodologies. This research focuses on identifying the most influential CSF for integrating Agile methodologies with Waterfall in order to overcome the significant challenges of this integration at PT ABC, as outlined in the introduction. Once the factors were established as criteria and sub-criteria, the author then conducted pairwise comparisons developed as part of the research methodology. A matrix was created to systematically compare the importance and influence of each factor and sub-factor identified in Table 3. The pairwise comparison method allows the author to assign relative weights to these factors based on perceived significance. The comparison values were obtained from questionnaires distributed to participants.

Table 3. Pair-Wise Comparison Matrix

CSF	PMS	TDS	CTE	UCE	LMS	AAI	RM	QI
Project Management and Strategy (PMS)	1	1.28	0.84	0.93	1	0.91	2.81	1.15
Team Development and Skills (TDS)	0.78	1	0.82	0.58	1.03	0.72	1.08	1.01
Communication and Team Environment (CTE)	1.18	1.21	1	2.1	1.28	2.14	0.9	2.21
User and Customer Engagement (UCE)	1.07	1.73	0.48	1	1.24	0.8	1.24	0.94
Leadership and Management Support (LMS)	1	0.97	0.78	0.81	1	1.98	1.63	0.85
Agile Approach and Implementation (AAI)	1.1	1.38	0.47	1.25	0.5	1	1.32	0.95
Resource Management (RM)	0.36	0.93	1.12	0.81	0.61	0.76	1	0.5
Quality and Innovation (QI)	0.87	0.99	0.45	1.06	1.17	1.05	1.98	1

Source : (Research Results, 2024)

After conducting the pairwise comparisons, the next step involves creating a normalized matrix. This process involves dividing all the numbers in the pairwise comparison matrix by the sum of their respective columns. This procedure is crucial to ensure that the values within the matrix have a consistent scale and can be objectively compared. By dividing each number in a column by the total sum of that column, the normalized matrix reflects the relative weight of each factor or sub-factor in comparison to other factors or sub-factors.

The normalized matrix provides a quantitative method for analyzing the relative importance of each factor and sub-factor. This step is essential in the Analytical Hierarchy Process (AHP) to derive precise and reliable results. The normalization process helps in balancing the varying magnitudes of the original matrix, providing a fair comparison across all factors and ensuring that the final priority weights are accurately calculated, as shown in Table 4.

Table 4. Normalized Matrix

CSF	PMS	TDS	CTE	UCE	LMS	AAI	RM	QI
Project Management and Strategy (PMS)	0.14	0.13	0.14	0.11	0.13	0.1	0.23	0.13
Team Development and Skills (TDS)	0.11	0.11	0.14	0.07	0.13	0.08	0.09	0.12
Communication and Team Environment (CTE)	0.16	0.13	0.17	0.25	0.16	0.23	0.07	0.26
User and Customer Engagement (UCE)	0.15	0.18	0.08	0.12	0.16	0.09	0.1	0.11
Leadership and Management Support (LMS)	0.14	0.1	0.13	0.09	0.13	0.21	0.14	0.1
Agile Approach and Implementation (AAI)	0.15	0.15	0.08	0.15	0.06	0.11	0.11	0.11
Resource Management (RM)	0.05	0.1	0.19	0.09	0.08	0.08	0.08	0.06
Quality and Innovation (QI)	0.12	0.1	0.08	0.12	0.15	0.11	0.17	0.12

Source : (Research Results, 2024)

In the subsequent stage, the author carries out the calculation of priority vectors. In this analysis, the average of each row is used to create priority vectors for all factors. It is important to note that the total sum of the priority vectors equals 1, indicating that all factors have been appropriately

weighted and have a proportional contribution in the evaluation. This step ensures that the significance of each factor is accurately represented, allowing for a balanced and comprehensive understanding of their impact in the context of the study.

Table 5. Priority Vectors

CSF	Priority vectors
Project Management and Strategy	0.139
Team Development and Skills	0.104
Communication and Team Environment	0.178
User and Customer Engagement	0.123
Leadership and Management Support	0.13
Agile Approach and Implementation	0.114
Resource Management	0.091
Quality and Innovation	0.121

Source : (Research Results, 2024)

The consistency ratio is used to measure the consistency of the inputs given in the pairwise comparison analysis. After calculating the values for the pairwise comparison factors, the consistency ratio is computed to evaluate the extent to which the inputs adhere to the established criteria. In this context, if the consistency ratio is less than 0.1, then the inputs are considered good and consistent. However, if the consistency ratio exceeds 0.1, the inputs are deemed to require re-evaluation. This is done to ensure that the assessments and comparisons made have an adequate level of consistency, making the analysis results reliable and a solid basis for decision-making. In this study, the consistency ratio is 0.034, which is less than 0.1. Table 6 show result indicates that the inputs received are considered good and consistent.

Table 6 Consistency Index and Consistency Ratio

CI	RI	CR
0.049	1.41	0.034

Source : (Research Results, 2024)

The Consistency Index (CI) for this study is 0.049. The Random Index (RI) for the same number of factors (in this case, 8 factors) is 1.41. Using these values, the Consistency Ratio (CR) is calculated to be 0.034. Since this value is less than 0.1, it indicates that the inputs provided in the pairwise comparison are consistent and reliable.

The low consistency ratio of 0.034 demonstrates that the judgments made by the participants in the pairwise comparisons are consistent. This means that the relative importance assigned to each factor and sub-factor is logical and adheres to the established criteria. Consequently, the priority weights derived from this analysis are considered reliable and can be confidently used to inform decision-making processes. The consistent judgments help ensure that the final rankings of the

Critical Success Factors (CSF) accurately reflect their true importance in the context of integrating Agile and Waterfall methodologies.

This research provides insights into Critical Success Factors (CSF) in the context of agile software development within waterfall project environments. The study reveals that among various factors, Communication and Team Environment emerged as the most influential factor in contributing resistance. This factor encompasses Effective Communication and Team Environment, Agile-friendly Team Environment, and Mentoring and Culture Adjustment. Based on priority vectors, Effective Communication and Team Environment emerged as the most significant sub-factor with a weight of 0.511. Success in effective communication among team members and an environment supportive of agile methodologies is crucial in successful agile implementation, emphasizing the importance of open and collaborative dialogue to overcome challenges in the waterfall project environment.

The second most important sub-factor is Agile-friendly Team Environment, with a weight of 0.282. This sub-factor underscores the importance of creating a teamwork environment that supports agile practices. This includes adopting flexible and adaptive approaches in team operations, and fostering a work culture that is innovative and responsive to change. This factor becomes critical, especially in the context of PT ABC, where the integration of agile and waterfall methodologies requires significant organizational culture adjustments to effectively embrace and implement agile practices.

Mentoring and Culture Adjustment appears as a significant sub-factor, albeit with a lower weight of 0.206. This sub-factor emphasizes the importance of mentoring in facilitating cultural and attitude adjustments within organizations transitioning to the integration of agile methodologies in waterfall projects. Mentoring aids in developing a better understanding of agile values, enhancing change management skills, and assisting individuals and teams in adapting to new ways of working. This factor is important in the context of PT ABC as it eases the transition to agile practices, ensuring that the entire team understands and accepts the necessary changes.

Project Management and Strategy is another significant factor identified in this study. It includes Strategy and Effective Project Management Skills, Project Planning and Definition Process, and Dynamic, Flexible Project Management. According to priority vectors, Project Planning and Definition Process emerged as the most significant sub-factor

with a weight of 0.534. This indicates that systematic and structured project planning and definition are key in integrating agile methodologies into waterfall projects. Effective planning ensures that all aspects of the project, including objectives, scope, and methodology, are clearly defined, facilitating a smoother and more effective transition between the two methodologies.

The second most important sub-factor is Dynamic, Flexible Project Management, with a weight of 0.246. This factor emphasizes the importance of adopting a dynamic and flexible project management approach to adjust to changing conditions and project complexities. In the context of PT ABC, the ability to adapt to environmental changes and project requirements, while maintaining strategic control and direction, is critical in managing projects that combine agile and waterfall practices.

Strategy and Effective Project Management Skills obtained a relatively lower weight of 0.219. Although its weight is lower, this factor remains important in the context of the research. A clear strategy and effective project management skills provide the foundation for successfully implementing agile methodologies within waterfall projects. These skills include the ability to formulate strategies that align with the organization's and project's goals, as well as effectively managing resources, risks, and stakeholders. In the context of PT ABC, the application of a coherent strategy and efficient project management is key to successfully integrating agile practices into the existing waterfall project framework.

Leadership and Management Support occupies the third rank as a Critical Success Factor (CSF) in the context of agile software development in a waterfall project environment. The importance of leadership and management support cannot be underestimated in this context. Effective leadership and management support provide direction, motivation, and the necessary resources to ensure that agile initiatives can be successfully implemented. This support acts as a catalyst that enables teams to adapt to changes, overcome obstacles, and effectively integrate agile methodologies within the waterfall framework. At PT ABC, this support is crucial in creating an environment where innovation and adaptation to agile practices are not only accepted but also encouraged.

User and Customer Engagement, as one of the CSF, emphasizes the importance of involving users and customers in the agile development process. Their active participation ensures that the products developed are aligned with user needs and expectations, enhancing the relevance and value of the final product. In the context of agile software development in a waterfall project environment, user and customer participation plays a vital role in providing continuous feedback, which is key to product iteration and improvement. At PT ABC, this involvement helps ensure that the transition to agile methodologies remains focused on delivering value to customers, while also enhancing customer satisfaction and loyalty to the product.

Quality and Innovation are identified as the next important factors as a Critical Success Factor (CSF) in the context of agile software development. Quality and Innovation include Quality and Innovation Management as well as Monitoring and Controlling. This factor highlights the importance of maintaining high quality standards while encouraging continuous innovation in software development. Quality and innovation management are key to ensuring that the software developed not only meets but also exceeds customer expectations. Meanwhile, effective monitoring and controlling ensure that the development process stays on the right track and aligns with project objectives. At PT ABC, a focus on quality and innovation ensures that the integration of agile methodologies in waterfall projects results in high-quality and innovative products, strengthening market position and customer satisfaction.

Agile Approach and Implementation, along with Team Development and Skills, and Resource Management, are identified as CSF with the lowest priority vector values of 0.114, 0.104, and 0.091, respectively. However, it is important to note that despite their relatively lower priority vector values, these factors remain very important in the context of agile software development. Agile Approach and Implementation emphasize the importance of properly applying agile methodologies, while Team Development and Skills relate to building and enhancing team capabilities. Resource Management, on the other hand, pertains to the effective management of resources. Together, these factors play a significant role in the overall success of agile software development, indicating that success is not determined by one or two factors, but by a combination of various interrelated aspects. At PT ABC, this understanding aids in optimizing team resources and capabilities, as well as in efficiently and effectively implementing agile practices.

In addition to the analysis of the CSF, it is crucial to understand how Agile and Waterfall methods are integrated within PT ABC's projects to grasp the practical implications of this integrated approach. PT ABC employs a traditional Waterfall approach for project scope, contract creation, and

client interactions. This ensures that all specifications are clearly defined and approved, providing a structured framework for managing client expectations and project deliverables. However, while the project scope and contracts are managed using Waterfall, the actual application development processes utilize Agile methodologies. This allows for iterative development, frequent feedback, and adaptability to changing requirements.

During the development phase, PT ABC plans and documents development milestones and major deliverables upfront as part of the project management process, adhering to Waterfall principles. However, for the development process itself, Agile sprints are used to iteratively build and refine the application. This iterative process enables the development team to respond quickly to changes and incorporate continuous feedback. The importance of Dynamic, Flexible Project Management (weight 0.246 from Table 5) is evident here, as the ability to adapt to environmental changes and project requirements is critical for the success of integrating Agile within the Waterfall framework.

In the testing phase, PT ABC plans final system testing and validation as major milestones within the project timeline to ensure the application meets all documented requirements before deployment, consistent with the Waterfall approach. Concurrently, Agile promotes continuous testing throughout each sprint, allowing for early detection and resolution of issues, which complements the final validation process. Effective Communication and Team Environment (weight 0.178 from Table 5) is crucial during this phase to ensure that any issues are promptly identified and addressed, facilitating smooth integration between the methodologies.

For release and maintenance, major releases are planned and executed in a structured manner once all project phases are complete, following the Waterfall methodology. At the same time, Agile facilitates incremental releases and ongoing maintenance, enabling the application to evolve based on user feedback and emerging requirements. This phase benefits significantly from Leadership and Management Support (weight 0.130 from Table 5) to provide the necessary direction and resources for both structured and flexible approaches to coexist.

By integrating Agile and Waterfall methodologies, PT ABC effectively balances structured project management with flexible development processes. This integrated approach addresses the specific challenges identified, such as

the need for rigorous documentation and contract management alongside adaptive and responsive development practices. User and Customer Engagement (weight 0.123 from Table 5) plays a vital role here, ensuring that the final product meets user needs and expectations through continuous feedback and involvement. The findings suggest that such integration enhances project flexibility, improves client satisfaction, and leads to more efficient project execution, ultimately contributing to the successful delivery of software projects at PT ABC.

The impact of CSF on project outcomes for PT ABC is substantial, particularly given the organization's need to manage multiple projects simultaneously, with PMs and team members often engaged in more than one project. Effective Communication and Team Environment (weight 0.178) ensures that project teams can seamlessly collaborate and adapt to changes, which directly affects the timeliness and quality of deliverables. Given that some PMs and team members might need to be on-site for extended periods ranging from one week to one month, maintaining robust communication channels is crucial. This CSF helps mitigate the risk of project delays and ensures continuous progress despite geographical separation. Project Management and Strategy (weight 0.139) involves systematic and structured planning and definition processes that are key in integrating agile methodologies into waterfall projects. Effective planning ensures that all aspects of the project, including objectives, scope, and methodology, are clearly defined, facilitating a smoother and more effective transition between the two methodologies. For PT ABC, this CSF is critical as it enables the organization to manage the complexities of multiple projects efficiently, ensuring that each project is well-coordinated and strategically aligned with overall business goals, even when PMs and teams are spread across various locations. Leadership and Management Support (weight 0.130) provides the necessary backing and resources to implement agile practices, which is crucial for maintaining project momentum and addressing challenges that arise. At PT ABC, effective leadership ensures that remote or on-site teams receive the support they need to continue their work without interruption. This support is vital for sustaining productivity and focus across all ongoing projects. Lastly, User and Customer Engagement (weight 0.123) ensures that the developed product meets user needs and expectations, thereby increasing customer satisfaction and reducing the likelihood of project failure. At PT ABC, where project conditions can be

dynamic, involving users and customers continuously helps align project outcomes with client expectations. This engagement is vital for obtaining timely feedback and making necessary adjustments, ensuring that the project remains on track to deliver value despite the complexities of managing multiple concurrent projects.

The practical implications of these findings are significant for PT ABC and other organizations. By focusing on the most influential CSFs, such as effective communication, strategic planning, leadership support, and user engagement, organizations can improve their project management practices. For PT ABC, this means better coordination and alignment of multiple projects, enhanced flexibility in adapting to changes, and improved client satisfaction through continuous engagement and feedback. Other organizations, especially those where team members handle multiple projects simultaneously and may need to be on-site while managing other projects, can also benefit from these insights. By applying similar strategies to balance agile and waterfall methodologies, these organizations can achieve better coordination, maintain project momentum, and ensure project success even when team members are geographically dispersed or temporarily working on-site. This leads to more efficient project execution and successful project outcomes.

CONCLUSION

This research reveals that in the context of agile software development within a waterfall project environment, there are several Critical Success Factors (CSF) that play a significant role. "Communication and Team Environment" is the most significant factor, with a priority vector value of 0.178, crucial for ensuring effective communication and a supportive environment that facilitates the integration of agile practices. "Leadership and Management Support" (0.130) and "User and Customer Engagement" (0.123) also provide essential direction, resources, and feedback for successful agile implementation.

Other important sub-factors include "Agile-friendly Team Environment" (0.282) and "Mentoring and Culture Adjustment" (0.206), which support the transition to agile practices by fostering a conducive culture. "Project Management and Strategy," with sub-factors "Project Planning and Definition Process" (0.534) and "Dynamic, Flexible Project Management" (0.246), is critical for adapting to changing project requirements and complexities.

Although "Agile Approach and Implementation" (0.114), "Team Development and Skills" (0.104), and "Resource Management" (0.091) have lower priority values, they remain essential for the proper application of agile methodologies, enhancing team capabilities, and managing resources effectively. The practical implications of these findings are significant for organizations like PT ABC. By focusing on the most influential CSFs, such as communication, leadership support, and user engagement, organizations can create an environment that supports the seamless integration of agile within waterfall frameworks. The consistency ratio of 0.034 indicates a high level of reliability in the prioritization of these factors.

This study emphasizes that the success of agile software development in a waterfall project depends on a combination of various interrelated factors. By addressing these CSFs, organizations can enhance project flexibility, improve client satisfaction, and achieve more efficient project execution, ultimately contributing to the successful delivery of software projects.

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