

AHP Approach for Selecting Application Development Methodology

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Abstract—The digital transformation of an Indonesian oil and gas company has significantly increased the demand for and complexity of application development, making the selection of an appropriate development methodology a critical factor for project success. This study proposes a decision-making model integrating the Six-Pointed Star Framework with the Analytical Hierarchy Process (AHP) as a Multi-Criteria Decision-Making (MCDM) technique to evaluate and select among three software development methodologies: Waterfall, Agile, and Hybrid, in the oil and gas industry. The evaluation is based on the Six-Pointed Star Framework derived from PMBOK, which includes scope, budget, time, resources, risk, and quality, further elaborated into relevant sub-criteria reflecting organizational conditions. The results indicate that the Agile method achieves the highest priority value (0.361), demonstrating its suitability for projects characterized by dynamic requirements, shorter development cycles, and high uncertainty; followed by Waterfall (0.333), which performs better in environments with well-defined requirements and strong cost control; and Hybrid (0.306), which provides a balanced alternative but does not outperform the other methods. Sensitivity analysis confirms that the priority rankings are stable under variations in criteria weights, indicating the robustness of the proposed model. This study contributes to both theory and practice by demonstrating the applicability of AHP to support strategic decision-making in methodology selection for application development. The findings provide practical insights for organizations to align development methodologies with project characteristics, thereby improving efficiency, reducing risks, and improving overall project outcomes.

Index Terms—Application development, analytical hierarchy process, multi-criteria decision-making, six-pointed star framework.

I. INTRODUCTION

In the current era of rapid digitalization, every sector must adapt to the evolving digital landscape, including agriculture,

education, oil and gas, and business ecosystems. The importance of digital transformation in business ecosystems is steadily increasing. Adapting to technology has proven to be a key determinant of a company's competitive future. With the aid of technology, business processes become more streamlined and less complex, allowing employees to focus fully on their tasks without being hindered by peripheral factors that were previously common [1], [2]. Companies operating with traditional business processes must now reconsider their strategies and incorporate technological advancements into their business models. The development of new business strategies has introduced novel operational frameworks. With technology playing a larger role, it has become easier for companies to excel and remain competitive [3].

This article presents a case study on an oil and gas company in Indonesia. As one of the largest oil and gas companies in Indonesia, hereafter referred to as "the company," it has also embraced digital transformation to support its business operations. Digital application development is a crucial element of digital transformation, enabling businesses to create innovative and engaging digital products and services that meet customer needs. The development of digital applications, coupled with technological advancements, is accelerating business growth by providing unprecedented software capabilities. Applications now play a central role in business growth and improve organizational efficiency [4]. In line with its ongoing digital transformation, the company has received a growing number of requests for application development. Based on the statistics, the fulfillment rate for application development requests over the past three years remains low [5].

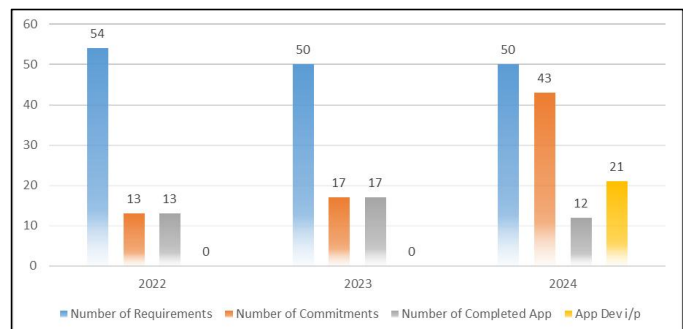


Fig. 1. Requirements and fulfillment comparison.

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Figure 1 illustrates a growing demand for application development, with notable improvements in commitment levels over time. However, the gap between committed and completed projects in 2024, along with the emergence of a significant development backlog, indicates potential challenges in execution capacity, project complexity, or delivery efficiency. This trend highlights the need for improved project management strategies and possibly adopting more iterative development approaches to ensure timely delivery.

To address the increasing demand for application development, the company has adopted three primary methodologies: Waterfall, Agile, and a hybrid approach combining elements of both. The decision regarding which methodology to use is currently based on a pragmatic, case-by-case evaluation of project conditions, rather than a standardized organizational policy. Three major factors influence this decision-making process: clarity of user requirements, system complexity, and delivery time. Figure 2 presents the distribution of software development methodologies adopted by the company over the past two years.

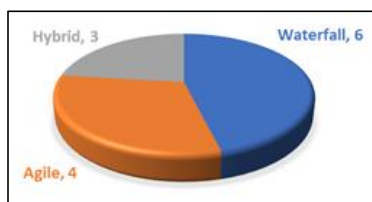


Fig. 2. Application development methods.

First, clarity of requirements is a central determinant. When user requirements are well-defined and stable, the Waterfall model is often chosen. This approach aligns with the sequential structure of the Waterfall model, which assumes that comprehensive requirement documentation is available upfront [6]. However, when requirements remain ambiguous or subject to change, Agile is preferred due to its iterative cycles, flexibility, and continuous stakeholder involvement [7]. The Hybrid model emerges as a compromise, applied when requirements are only partially defined, but project deadlines are strict, necessitating both structured planning and iterative adaptability [8].

Second, system complexity plays a critical role. Applications that require detailed analysis and robust architectural design are typically developed using the Waterfall method, which emphasizes predictability and control. In contrast, simpler applications that prioritize speed and adaptability are better aligned with Agile principles [9]. The Hybrid model serves as a middle ground, enabling projects of moderate complexity to balance design discipline with the need for flexible delivery [10].

Third, time constraints significantly influence the selection of methodology. The company often faces urgent requests for rapid application delivery, which makes Agile or hybrid methods the default choice. Waterfall, with its inherently longer development cycle, often fails to meet these accelerated timelines. This observation is consistent with findings from

prior studies, which suggest that Agile methodologies increase the likelihood of project success when strict deadlines and dynamic business environments are present.

While this pragmatic approach allows the company to remain flexible and responsive, it also reveals several critical gaps:

1) *Lack of a formal governance framework*

Decisions are made based on subjective evaluations by project managers rather than a structured selection framework. This procedure risks inconsistency across projects and may affect long-term quality assurance [11].

2) *Over-reliance on time is the dominant factor*

While time-to-delivery is crucial, prioritizing it without systematically considering scope, risk, budget, and quality may lead to suboptimal decisions.

3) *Absence of multi-criteria evaluation*

Existing practice oversimplifies methodology selection into three parameters, whereas the literature emphasizes the need for multi-dimensional decision-making in project management [12].

4) *Limited empirical evidence in the oil and gas context*

Prior studies often examine Agile and Waterfall adoption in general industries, but research specifically addressing oil and gas companies in emerging economies remains scarce. This fact creates a research gap in context [13].

Several factors contribute to the failure of application development projects, including frequently changing or poorly documented requirements, insufficient resources and competencies, poor team or organizational management, delays in development timelines, and the inappropriate selection of development methodologies and application platforms [14], [15], [16].

As previously mentioned, one of the main causes of low fulfillment rates in application development is the selection of an unsuitable development methodology. When initiating application development projects, it is crucial to adopt the appropriate methodology to increase the likelihood of success [17]. A report from the Standish Group International in 2020 [18] on project success rates highlights that only 31% of projects are successful (delivered on time, within budget, and with required features), representing a 1% decrease compared to the previous report; 50% encounter challenges (delayed, over budget, and/or with fewer features), representing a 6% increase; and 19% fail (cancelled before completion or delivered but never used), representing a 5% decrease. Choosing the right methodology plays a vital role in application development, ensuring projects are delivered on schedule, within budget, and meet user requirements [19], [20].

The spiral model emphasizes iterative development combined with continuous risk assessment. In modern software engineering, this model has evolved into hybrid approaches by integrating Agile practices to improve flexibility, adaptability, and project outcomes [21], [22]. When organizations insist on applying a linear approach, such as Waterfall, to dynamic application development projects, projects are likely to fail to meet user requirements. This fact highlights the chosen methodology's lack of adaptability, which is a primary cause of

unmet development objectives. The choice of software development methodology is widely recognized as a critical factor influencing project success. A mismatch between the selected model and the actual project conditions can lead to schedule delays and, ultimately, project failure [23].

Recent studies emphasize that software project failure is not caused by a single issue but rather by a combination of managerial, technical, and organizational factors, which must be systematically managed to improve project success [24]. Reference [25], in the study "What Factors Lead to Software Project Failure," identifies "misuse of development methodology" as one of the key factors contributing to project failure. An inappropriate choice of development methodology may result in a lack of flexibility in responding to changing requirements and may fail to reflect project complexity adequately. Such misalignment increases the risk of projects becoming over-budget, delayed, and of poor quality [26].

A well-documented example of application development failure is the launch of HealthCare.gov, widely known as Obamacare. The website was intended to provide health insurance support for uninsured citizens in the United States. However, shortly after its release, the system became inaccessible, leaving millions of Americans unable to enroll. Multiple reports identified this as a result of fundamental project management failures. Specifically, the project lacked a clearly defined and agreed-upon scope during the planning phase, which created major challenges for the technical team in prioritizing requirements and delivering a stable system, as the scope continued to shift.

One of the key factors contributing to this failure was the use of an inappropriate development model, namely a non-iterative Waterfall approach, combined with organizational and contractual structures that did not support agility. As another study explains in "Lessons Learned in Agile Project Management using HealthCare.gov" [18], the essence of Agile lies in rapid iteration, open communication, early risk mitigation, and modular deliverables, all of which were absent in the traditional approach adopted in the HealthCare.gov project. Selecting the optimal methodology for a project is a pressing issue in software development, as the process has not yet been properly formalized and remains highly dependent on interrelated factors [19].

Previous studies have applied AHP to support the selection of software development methodologies, primarily focusing on general criteria such as cost, time, and flexibility. However, these studies often lack integration with comprehensive project management frameworks that capture multi-dimensional project constraints, such as scope, risk, and quality. As a result, the decision-making process remains partially structured and may not fully reflect the complexity of real-world projects, particularly in the oil and gas industry. Therefore, this study addresses this gap by integrating the Six-Pointed Star framework with AHP to provide a more holistic and structured

evaluation model.

The AHP was chosen because it provides a clear hierarchical structure that breaks down complex problems into goals, criteria, sub-criteria, and alternatives. AHP also measures the consistency of judgments using the Consistency Ratio (CR), which helps prevent inconsistent decisions [28]. The criteria used are based on the Six-Pointed Star Framework from the PMBOK [3]. At the same time, the specific conditions at the company are reflected in the sub-criteria. The Six-Pointed Star Framework was selected to ensure that all aspects of project management in application development are assessed objectively, systematically, and in line with industry standards. Sub-criteria derived from this framework accommodate the company's specific context [29].

Based on these considerations, the study aims to analyze the selection of Waterfall, Agile, and hybrid application development methodologies by employing AHP and the Six-Pointed Star framework in the context of an Indonesian oil and gas company. The main contribution of this study is the development of a structured evaluation approach that integrates project management dimensions and decision-making analysis to support organizations in determining the most appropriate software development methodology. The findings are expected to enrich the existing literature on software development methodology selection and provide practical implications for enterprise digital transformation projects [30].

II. RESEARCH METHOD

This study analyzes the selection of three application development methodologies: Waterfall, Agile, and hybrid, using the AHP method, which is a comprehensive decision-making approach that accounts for both qualitative and quantitative factors.

The initial criteria for structuring the AHP are based on the Six-Pointed Star framework, which consists of six main elements: scope, budget, time, resources, risk, and quality. These six elements are used because they enable a balanced, structured, and holistic evaluation, derived from PMBOK and based on well-established project management standards. These elements provide structured, measurable, and comparable criteria, making them well-suited to an evaluation method such as AHP.

The six main criteria are then further broken down into sub-criteria. These sub-criteria are defined based on the company's specific conditions, including its application development environment, business needs, financial context, and particular challenges, while ensuring that all aspects of project management are assessed objectively, systematically, and in line with industry standards.

The specific conditions of the company were identified through an analysis of 13 projects implemented over the last two years. The selection of 13 historical projects was based on data availability and relevance to the study context, ensuring

representation of various project characteristics, including size, complexity, and implementation duration. These projects reflect typical IT initiatives within the organization, thereby providing a realistic basis for analysis. Between five and six sub-criteria were elaborated and developed to reflect the company's context and serve as references in constructing the AHP structure.

Table 1.

Problem Analysis of Application Development Projects in the Company				
Name of App.	Planned Duration	Realization	Analysis Cause	App Dev Method
App Dev Project 1	10 Mo	> 10 Mo	- App Dev Team Competencies - Coordination with other teams (IT Infrastructure, IT Security, IT Business Relations, IT Governance) - Type of Integration App (Stand-alone, Integrated, Integrated Complex)	Waterfall
App Dev Project 2	10 Mo	> 10 Mo	- App Dev Team Competencies - Dependence on Business HQ	Hybrid
App Dev Project 3	11 Mo	> 11 Mo	- App Dev Team Competencies - Dependence on IT HQ	Waterfall
App Dev Project 4	6 Mo	> 6 Mo	- Technology and Platform - Type of Consistency of Requirements (Clarity, Not Clear, Changes all the time)	Waterfall
App Dev Project 5	6 Mo	> 6 Mo	- App Dev Team Competencies - Type of Consistency of Requirements (Clarity, Not Clear, Changes all the time)	Hybrid
App Dev Project 6	6 Mo	> 6 Mo	- App Dev Team Competencies - Type of Consistency of Requirements (Clarity, Not Clear, Changes all the time)	Waterfall
App Dev Project 7	7 Mo	> 7 Mo	- Type of Urgency (Low, Medium, High) - App Dev Team Competencies - Type of Consistency of Requirements (Clarity, Not Clear, Changes all the time) - Number of App Dev Requests at the same time (Parallel App Dev) - Type of Requestor (Management, Users, HQ)	Hybrid

App Dev Project 8	5 Mo	> 5 Mo	- Type of Urgency (Low, Medium, High) - Type of Consistency of Requirements (Clarity, Not Clear, Changes all the time) - Type of Requestor (Management, Users, HQ) - Number of App Dev Requests at the same time (Parallel App Dev)	Agile
App Dev Project 9	6 Mo	> 6 Mo	- Type of Consistency of Requirements (Clarity, Not Clear, Changes all the time) - Type of Requestor (Management, Users, HQ)	Agile
App Dev Project 10	5 Mo	> 5 Mo	- Type of Consistency of Requirements (Clarity, Not Clear, Changes all the time) - Type of Requestor (Management, Users, HQ)	Agile
App Dev Project 11	5 Mo	> 5 Mo	- Type of Consistency of Requirements (Clarity, Not Clear, Changes all the time) - Type of Requestor (Management, Users, HQ)	Agile
App Dev Project 12	9 Mo	> 9 Mo	- App Dev Team Competencies - Technology and Platform	Waterfall
App Dev Project 13	9 Mo	> 9 Mo	- App Dev Team Competencies - Technology and Platform - Type of Requestor (Management, Users, HQ) - Type of Integration App (Stand-alone, Integrated, Integrated Complex) - Number of App Dev Requests at the same time (Parallel App Dev)	Waterfall

Table 1 presents a problem analysis of application development projects between 2023 and 2024. It compares planned durations and actual completion times, along with the identified causes of delay and the development methods applied. The data indicate that all projects experienced schedule overruns, with actual completion exceeding the planned timeline, reflecting a persistent challenge in project delivery performance across development approaches. Several recurring factors contributing to these delays include limitations in the application development team's competencies, inconsistent and

frequently changing requirements, and dependencies on internal and external stakeholders, such as IT infrastructure, IT security, and the headquarters. In addition, challenges related to technology platforms, project urgency, and the increasing number of parallel development requests further complicate project execution.

Despite using different development methods (Waterfall, hybrid, and Agile), delays consistently occurred across projects. This phenomenon suggests that the selection of development methodologies has not been optimally aligned with specific project characteristics and organizational conditions. This fact reflects a fundamental issue not only in execution but also in the decision-making process for selecting appropriate development approaches. The absence of a structured, systematic framework for evaluating and matching project requirements with suitable methodologies highlights a critical gap in current practice.

The results of this analysis were then categorized using the Six-Pointed Star Framework to identify the factors contributing to application development challenges within the company, as presented in Table 2. To ensure that each criterion in the Six-Pointed Star Framework closely reflects the actual issues, additional sub-criteria were developed and elaborated based on objective and frequently recurring observations to represent the underlying causes of application development issues. This approach aims to better align the subsequent AHP process with the company's actual conditions.

Table 2.
Application Development Cause Analysis

Causes	Number	Percentage	Criteria
App Dev Team Competencies	8/13	62%	Resources
Type of Consistency of Requirements (Clarity, Not Clear, Changes all the time)	8/13	62%	Scope
Type of Requestor (Management, Users, SHU)	6/13	46%	Risk
Technology and Platform	3/13	23%	Quality
Number of App Dev Requests at the same time (Parallel App Dev)	3/13	23%	Time
Type of Integration App (Stand-alone, Integrated, Integrated Complex)	2/13	15%	Scope
Type of Urgency (Low, Medium, High)	2/13	15%	Time
Coordination with other teams (IT Infrastructure, IT Security, IT BR, IT Governance)	1/13	8%	Time
Dependence on Business HQ	1/13	8%	Scope
Dependencies from IT HQ	1/13	8%	Scope

The hierarchical structure of the AHP model in this study is as follows: the goal of the hierarchy is to identify the most suitable application development methodology for the company. The criteria are derived from the Six-Pointed Star Framework, which is widely recognized in project management for balancing scope, time, cost, resources, risk, and quality. Each criterion is further refined into five to six sub-criteria, formulated by combining theoretical foundations with the specific organizational conditions of the company.

At the alternative level, three methodological options are considered: Waterfall, Agile, and Hybrid. The inclusion of the Hybrid approach enables the analysis to capture the potential advantages of combining sequential and iterative practices.

In summary, the AHP hierarchy consists of six main criteria, five or six sub-criteria under each criterion, and three alternatives to be evaluated. This structure ensures that the decision-making process reflects both theoretical rigor and practical relevance to the organization's context.

A survey was conducted over 11 days among all IT personnel within the company to maximize the number of respondents. The survey yielded 32 respondents, a number considered sufficient for AHP analysis, as the method prioritizes expert judgment rather than large sample sizes, and exceeds the target of 18 respondents (based on Slovin's formula) [31] from a total population of 59 IT personnel in the company (Fig. 3). Each respondent assessed the relative importance of criteria and sub-criteria using Saaty's 1–9 scale. The individual judgments were aggregated using the geometric mean method to obtain a group decision matrix. The following presents the respondent distribution based on population segmentation. The composition of the 32 survey respondents is as follows:

- Two respondents from management (6%), serving as team leaders in IT Business Solution and IT Governance, contributed strategic and decision-making perspectives. Their input is important for reflecting organizational priorities and aligning with business objectives.
- Twenty-four respondents from the core application development teams (75%), comprising the majority, are from teams including IT Business Solution, IT Upstream Solution, Business Relations, and Data Management, indicating that the survey is predominantly represented by individuals directly involved in the development process. This fact ensures that the judgments provided in the AHP pairwise comparisons are grounded in strong technical and operational experience.
- Six respondents from non-core application development teams, namely IT Operations and IT Governance, represent supporting functions that contribute indirectly, such as through coordination, governance, or integration-related activities. Their inclusion provides additional perspectives beyond the core development function, enriching the evaluation process.

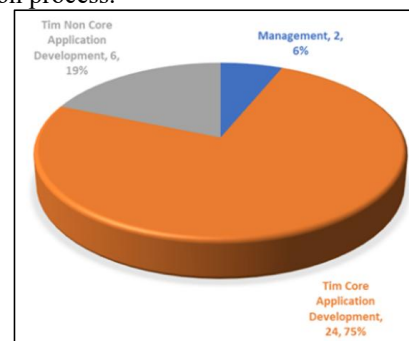


Fig. 3. Respondent distribution of the IT team.

The study workflow, shown in Fig. 4, consists of 12 steps. Steps 8 through 10 constitute the AHP calculation, including the Consistency Ratio verification, while Step 11 presents the priority results based on the AHP calculation.

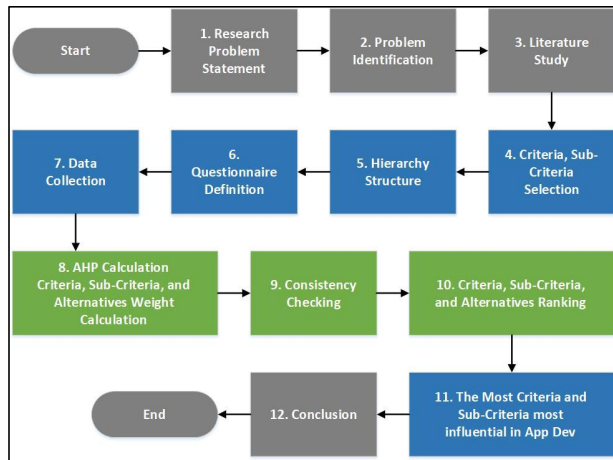


Fig. 4. Study workflow.

To ensure the robustness and reliability of the decision-making results, a sensitivity analysis was incorporated as a complementary step following the AHP calculation. The analysis was conducted using the One-at-a-Time (OAT) approach [32], in which the weight of each main criterion within the Six-Pointed Star framework was systematically varied over a predefined range ($\pm 10\%$). In contrast, the remaining criteria were held constant. This approach allows evaluation of how changes in individual criteria affect the overall priority ranking of the alternatives.

The purpose of this analysis is to assess the model's stability and identify the most influential criteria affecting the final decision. By isolating the impact of each parameter, the sensitivity analysis provides additional validation of the AHP results. It ensures that the selected development method is not highly dependent on specific weight configurations. The detailed results of this sensitivity analysis are presented and discussed in the 'Results' and 'Discussion' section.

III. RESULT

Based on the defined criteria, sub-criteria, and alternatives, the AHP hierarchical structure was constructed, consisting of four main levels, as shown in Table 3.

Table 3.
AHP Structure

Level 1: Goal
The main objective of the decision-making process. Value: Selection of application development methods in the company.
Level 2: Criteria
The key dimensions that influence the achievement of the goal. Value: Scope, Budget, Time, Resources, Risk, Quality (Six-Pointed Star Framework).
Level 3: Sub-Criteria
A more specific breakdown of each criterion to clarify the focus of the assessment. Value: As defined in the established sub-criteria.
Level 4: Alternative
The potential solutions or options are to be selected based on the evaluation

of criteria and sub-criteria.
Value: Agile, Waterfall, Hybrid.

The alternatives in the AHP method consist of three application development methodologies already familiar within the company: Waterfall, Agile, and a hybrid that combines both. This Hybrid method provides an additional option for exploring respondents' preferences and assessing options beyond the two commonly used methods. Fig. 5 illustrates the model developed using AHP for selecting the most appropriate application development methodology. At the first level ('Goal'), the model's objective is to determine the optimal application development method. At the second level ('Criteria'), the decision is evaluated against six main criteria derived from the Six-Pointed Star framework: Scope, budget, time, resources, risk, and quality. These criteria represent the key dimensions that influence project success and the suitability of the methodology. At the third level ('Sub-Criteria'), each criterion is further decomposed into several parameters that reflect specific project conditions (e.g., scale, cost range, duration, number of resources, level of risk, and quality expectations). Due to space limitations, these sub-criteria are represented using abbreviated symbols; at the fourth level ('Alternatives'), the three application development methodologies: Waterfall, Agile, and hybrid are evaluated.

Table 4.
Criteria and Sub-Criteria

Main Criteria	Sub Criteria Defined
Scope	Number of users (scope size: Regional, zona, limited users, all) Type of integration (stand-alone, integrated, integrated complex) Complexity of features (low/medium/high) Consistency of requirements (clear, unclear, frequent changes)
Budget	Scope dependencies (business & IT dependency on HQ) Budget size (small < 20KUSD, medium 20KUSD < x < 60KUSD, large > 60KUSD) Budget flexibility (fixed/flexible) Budget source (IT vs user) Budget planning status (allocated vs not allocated) Budget variance risk (lack of budget vs over-budget)
Time	Duration of development (< 3 mo, 3–6 mo, > 6 mo, flexible) Type of App Dev request (planned/unplanned) Urgency level (low/medium/high) Parallel development load (number of concurrent requests) Time consumed for coordination with another team
Resources	Team size (small < 5, medium 5–10, large > 10) Team composition completeness (PMO, BA, SA, Dev, CM, etc.) Team type (internal, outsourcing, joint) User and other party involvement (involved/not involved)
Risk	Team competencies (low/medium/high) Risk type (financial, technology, HSSE, business, social) Requestor influence (top Mgmts. vs user vs HQ) 3rd party involvement Security risk (high/medium/low)
Quality	Organizational changes (change of PIC in user/dev team) Coordination Complexity with Users/Parent Org Quality attributes (satisfaction, scalability, compatibility, modularity, enhance bility) Technology & platform alignment Team gap level of knowledge (low/medium/high) Development phasing Application stability (update frequency, enhancement required)

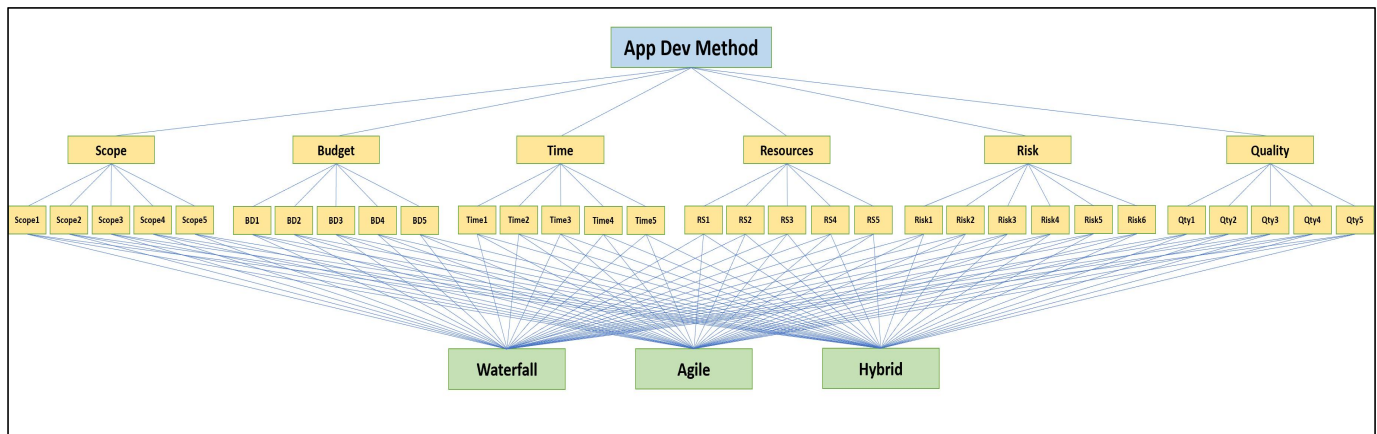


Fig. 5. Hierarchy structure for AHP.

Overall, this hierarchical structure enables a systematic evaluation process by breaking a complex decision into multiple levels, allowing each alternative to be assessed against relevant criteria and sub-criteria in a structured, quantitative manner. The complete criteria and sub-criteria constituting the AHP structure are shown in Table 4. The AHP computation was performed using AHP software from SpiceLogic Inc. (spicelogic.com), based on data collected from 32 valid survey responses. The use of this tool ensured consistency in pairwise comparisons and in the accurate derivation of priority weights. The AHP computation followed a structured procedure. First, the geometric mean was calculated for each pairwise comparison to ensure consistent aggregation of multiple respondents' judgments. For example, the pairwise comparison between the Scope and Budget criteria was derived using the following formula:

$$GM_{Scope \text{ vs } Budget} = \left(\prod_{k=1}^{32} a_{Scope \text{ vs } Budget}^{(k)} \right)^{\frac{1}{32}} \quad (1)$$

where $a_{Scope \text{ vs } Budget}^{(k)}$ denotes the pairwise comparison value provided by the k th respondent for the criteria Scope versus Budget, n represents the total number of respondents, which is 32, and $GM_{Scope \text{ vs } Budget}$ represents the geometric mean value obtained from all pairwise comparison responses between the Scope and Budget criteria.

Criteria	Budget	Time	Resources	Risk	Quality
Scope	0.995	0.715	0.589	0.757	0.471

Criteria	Time	Resources	Risk	Quality
Budget	0.966	0.842	0.846	0.496

Criteria	Resources	Risk	Quality
Time	0.576	0.79	0.585

Criteria	Risk	Quality
Resources	0.837	0.579

Criteria	Quality
Risk	0.608

Fig. 6. Geometric Means for Pairwise Comparison Criteria

The study employed Saaty's fundamental scale of pairwise comparison, which is based on a Likert-type ratio scale with the following values: 1/9, 1/7, 1/5, 1/3, 1, 3, 5, 7, and 9 [33]. Using this scale, the geometric mean was calculated for each pairwise comparison across all respondents. The resulting geometric mean values for each pairwise comparison of criteria are presented in Fig. 6. Based on the geometric mean values, the pairwise comparison matrix for the criteria was developed, which serves as the foundation for deriving priority weights in the AHP process (Table 5).

Table 5.
Pairwise Comparison Matrix for the Criteria

Criteria	Scope	Budget	Time	Resources	Risk	Quality
Scope	1	0.995	0.715	0.589	0.757	0.471
Budget	1	1	0.966	0.842	0.846	0.496
Time	1.4	1.03	1	0.576	0.79	0.585
Resources	1.7	1.19	1.74	1	0.837	0.579
Risk	1.32	1.18	1.27	1.19	1	0.608
Quality	2.12	2.02	1.71	1.73	1.64	1
Total	8.540	7.415	7.401	5.927	5.870	3.739
Pairwise						

Based on the geometric mean results from all respondents and the pairwise comparison matrix for the criteria, the normalized pairwise comparison matrix for the criteria and priorities was constructed, as shown in Table 6.

Table 6.
Normalized Pairwise Comparison Matrix for the Criteria

Criteria	Scope	Budget	Time	Resources	Risk	Quality	Priority
Scope	0.117	0.134	0.097	0.099	0.129	0.126	0.117
Budget	0.117	0.135	0.131	0.142	0.144	0.133	0.134
Time	0.164	0.139	0.135	0.097	0.135	0.156	0.138
Resources	0.199	0.160	0.235	0.169	0.143	0.155	0.177
Risk	0.155	0.159	0.172	0.201	0.170	0.163	0.170
Quality	0.248	0.272	0.231	0.292	0.279	0.267	0.265

The robustness of the decision-making process is validated by a global Consistency Ratio of 0.007, which is significantly lower than the 0.1 threshold defined by Saaty [12], [34]. This fact indicates that the pairwise comparisons provided by the 32 IT personnel are consistent and reliable. The same process was applied for each sub-criterion using the AHP method, as shown in Table 7.

Table 7.
Priority Result Main Criteria, Sub Criteria, and Alternatives

Main Criteria	Priority (%)	Waterfall	Agile	Hybrid
Scope				
Number of users (scope size: regional, zona, limited users, all)	11.96	0.286	0.393	0.321
Type of integration (stand-alone, integrated, integrated complex)	16.46	0.36	0.35	0.291
Complexity of features (low/medium/high)	21.63	0.277	0.361	0.362
Consistency of requirements (clear, unclear, frequent changes)	28.15	0.36	0.359	0.281
Scope dependencies (business & IT dependency on HQ)	21.8	0.382	0.314	0.304
Budget				
Budget size (small < 20KUSD, medium 20KUSD<x<60KUSD, large >60KUSD)	16.75	0.378	0.325	0.298
Budget flexibility (fixed/flexible)	17.87	0.385	0.297	0.318
Budget Source (IT vs user)	15.65	0.38	0.32	0.30
Budget planning status (allocated vs not allocated)	25.24	0.394	0.318	0.288
Budget variance risk (lack of budget vs over-budget)	24.48	0.376	0.332	0.292
Time				
Duration of development (<3 mo, 3–6 mo, >6 mo, flexible)	19.12	0.33	0.34	0.33
Type of App Dev request (planned/unplanned)	22.06	0.304	0.40	0.296
Urgency level (low/medium/high)	26.67	0.314	0.377	0.31
Parallel development load (number of concurrent requests)	17.58	0.328	0.375	0.297
Time consumed for Coordination with another team	14.58	0.35	0.36	0.289
Resources				
Team size (small <5, medium 5–10, large >10)	21.59	0.376	0.348	0.276
Team composition completeness (PMO, BA, SA, Dev, CM, etc.)	20.12	0.368	0.324	0.309
Team type (internal, outsourcing, joint)	16.19	0.309	0.338	0.353
user and other party involvement (involved/not involved)	17.6	0.395	0.326	0.279
Team competencies (low/medium/high)	24.5	0.324	0.364	0.312

Risk				
Risk type (financial, technology, HSSE, business, social)	15.24	0.294	0.353	0.352
Requestor influence (top mgmts. vs user vs HQ)	15.57	0.31	0.364	0.326
3rd party involvement security risk (high/medium/low)	14.46 21.16	0.32 0.374	0.37 0.326	0.31 0.30
Organizational changes (change of PIC in user/dev team)	17.36	0.331	0.382	0.287
coordination complexity with users/parent org	16.22	0.324	0.378	0.297
Quality				
Quality Attributes (satisfaction, scalability, compatibility, modularity, enhance bility)	25.59	0.338	0.38	0.283
Technology & platform alignment	16.92	0.325	0.368	0.307
team gap level of knowledge (low/medium/high)	24.56	0.316	0.381	0.302
Development phasing				
application stability (update frequency, enhancement required)	14.64 18.29	0.307 0.312	0.366 0.385	0.327 0.303

The consistency ratio for sub-criteria and alternatives was calculated, yielding values below the 0.1 threshold. Based on the AHP results for all parameters: criteria, sub-criteria, and alternatives, the total priority scores of each alternative for every criterion are shown in Table 8.

Table 8.
Alternatives Priority

Alternative	Priority
Waterfall	0.333338
Agile	0.361585
Hybrid	0.306430

Based on an AHP analysis of a survey of 32 respondents, the highest priority was assigned to the Agile application development method. This condition indicates that, given the company's specific conditions and context, the Agile method is the most suitable approach for application development.

To ensure reproducibility, this study utilized the Aggregation of Individual Judgments (AIJ) method, where geometric means of all respondents were calculated prior to deriving priority weights [35], [36]. This approach treats the IT function as a unified entity, ensuring the final preference for Agile (0.361) reflects a stable organizational consensus despite minor variations in sub-criteria preferences among management and non-core teams [37], [38] with the following considerations:

- All respondents are considered a single, unified team within the company's IT function, as they operate under the same management.
- AIJ provides more stable consistency, as evidenced by the AHP calculations described above, in which the aggregated

Consistency Ratio remains below the acceptable threshold of 0.1.

However, in this study, the aggregation results across different respondent groups are also considered as a reference to supporting the final decision-making process regarding the most suitable application development method, as shown in Table 9. Why do the priority results differ across respondent groups? This priority arises because, in AHP, individual or group preferences are represented through subjective pairwise comparisons, which, in this case, are highly dependent on respondents' roles in the application development process, their perspectives, and prior experience [37]. Based on an empirical study of Agile software development methodologies [39], stakeholders with different roles tend to have varying preferences regarding application development approaches. Consequently, each respondent group may produce different AHP outcomes.

Table 9.
Results by Respondent Group

Respondents Type	Highest Priority
All Respondents	Agile
Management	Agile
Core App Dev Team	Agile
Non-Core App Dev Team	Waterfall

According to [38], AHP can be used to analyze consensus and conflicts in stakeholder preferences. The AHP results can then be presented separately, grouped by category, or aggregated; the method is intentionally designed to accommodate differences in individual or group assessments.

One relevant study on this aspect of AHP is "Aggregating Individual Judgments and Priorities with AHP" [36], which explains that AHP results can be processed either individually or collectively. Two methods are introduced: Aggregation of Individual Judgments (AIJ) and Aggregation of Individual Priorities (AIP). Aggregation of Individual Judgments (AIJ) combines all respondents' pairwise comparisons into a single aggregate matrix. The pairwise judgments are aggregated (using the geometric mean) before deriving the priority weights. In this approach, the group of respondents acts as a single entity, with each respondent contributing to the collective decision.

Aggregation of Individual Priorities (AIP), on the other hand, calculates AHP individually. After obtaining the priority weights of each respondent, aggregation is then performed to derive the final priorities. AIP treats each evaluator as an independent decision-maker. While AIJ provides a consistent group judgment matrix, it may introduce bias by assuming that respondents' preferences are homogeneous. In contrast, the AIP approach captures individual-level variations more explicitly. Therefore, this limitation should be taken into account when interpreting the results.

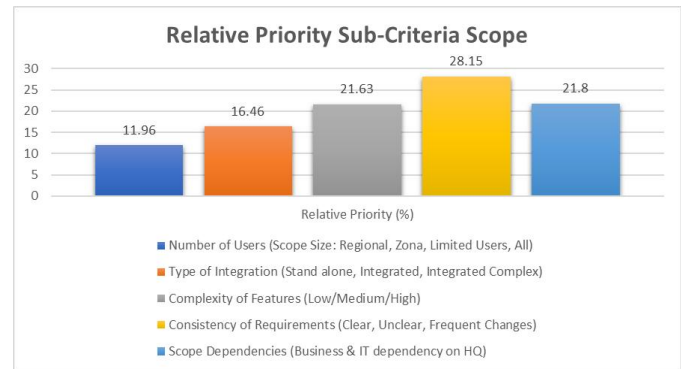


Fig. 7. Relative Priority Ranking of Sub-Criteria Scope

Beyond identifying Agile as the top priority, the AHP results also generate relative rankings of both criteria and sub-criteria. These rankings offer valuable insights that can serve as a reference to enhance the quality of the company's application development projects.

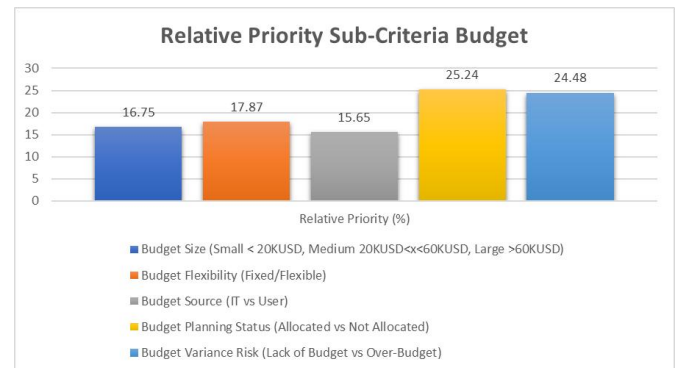


Fig. 8. Relative Priority Ranking of Sub-Criteria Budget

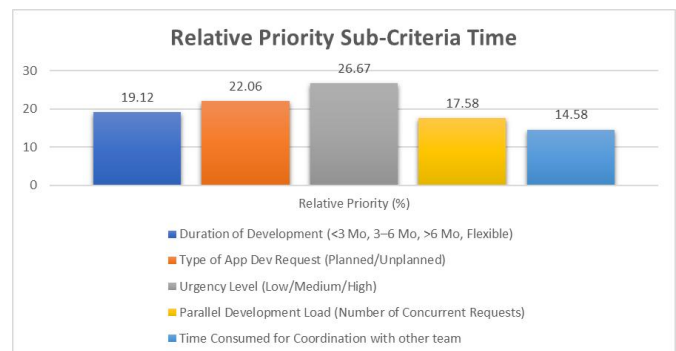


Fig. 9. Relative Priority Ranking of Sub-Criteria Time

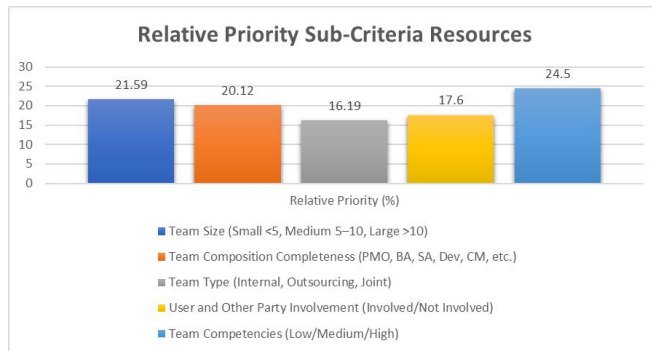


Fig. 10. Relative Priority Ranking of Sub-Criteria Resources

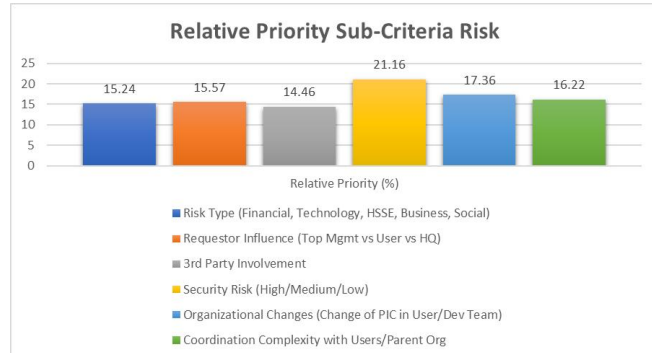


Fig. 11. Relative Priority Ranking of Sub-Criteria Risk

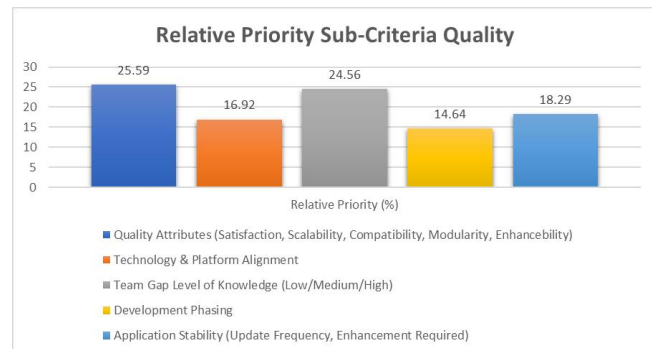


Fig. 12. Relative Priority Ranking of Sub-Criteria Quality

The results indicate that among the application development methodologies evaluated using AHP, Agile is considered the most suitable for meeting the company's needs, based on the six main criteria of the Six-Pointed Star framework: Scope, budget, time, resources, risk, and quality, along with their supporting sub-criteria, given the dynamic nature of IT projects in the oil and gas industry.

Agile emerged as the top-ranked alternative, driven by its strong performance in the quality (25.59%) and resources (21.59%) criteria. This performance indicates that the organization places significant emphasis on application reliability and team capability. In particular, the sub-criteria of Application Stability and Team Competencies suggest that the company operates in a dynamic environment that requires continuous feedback and iterative development, characteristics inherent to Agile frameworks [7], [40], [41].

While Waterfall remains suitable for projects requiring high stability in "Security Risk" and "Budget Planning," its sequential and rigid structure may limit adaptability in rapidly

changing conditions. In contrast, the organization's ongoing digital transformation initiatives demand greater flexibility and responsiveness, which Agile is better positioned to provide. This alignment between project characteristics and methodology selection is critical, as misalignment may contribute to lower project fulfillment rates, currently reported at below 50% [19].

These findings are consistent with the characteristics of Agile, which support incremental development, short iterations (sprints), strong adaptability to change, and continuous improvement based on user feedback. According [40], the Agile method is recommended for application development teams as it improves project management practices by providing more opportunities for communication, collaboration, and feedback, all of which can contribute to the successful delivery of software development projects. The study also notes that future development projects should focus on addressing communication and trust issues in project management.

Although implementing Agile in the company may pose several challenges, the advancement of current technologies and the increasing demand from business users for rapid solution development make Agile a suitable approach to meet those needs. Agile is considered a solution to common problems associated with the Waterfall method, such as inflexibility in changing requirements, limited user involvement, and delayed feedback and testing results, all of which can lead to project delays.

In the context of this oil and gas company in Indonesia, Agile implementation is expected to make the IT function more responsive in addressing internal application demands. These demands require quick adaptation to regulations and operational conditions, effective cross-functional collaboration, and risk minimization by breaking development tasks into modular units or short sprints. Agile is therefore well-suited for companies aiming to increase adaptability and responsiveness to technical risks and shifting priorities, challenges that the company currently faces.

The selection of Agile as the preferred application development method carries the following implications:

- A mindset shift is required among all team members involved in application development, as they must embrace an Agile mindset to ensure the effective implementation of the new development methodology.
- Role distribution within the development team must adhere to the Agile structure, including the product owner, Scrum master, and development team members.
- Cross-functional communication and user engagement must be strengthened to ensure feedback is promptly received and incorporated.

The sensitivity analysis was conducted using the One-at-a-Time (OAT) approach by adjusting each main criterion weight by $\pm 10\%$ while maintaining proportional normalization across the other criteria. This method enables the identification of the impact of individual criteria on the final ranking of alternatives. This step is essential in multi-criteria decision-making to ensure that the resulting ranking remains consistent under potential variations in judgment and decision

priorities [42].

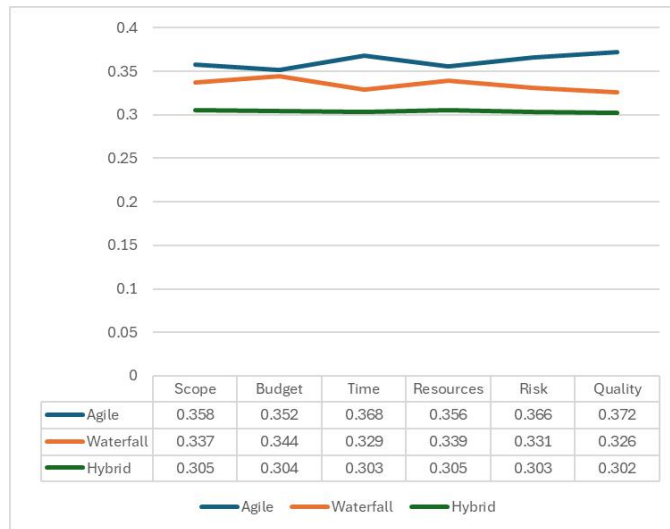


Fig. 13. Sensitivity analysis results for alternatives.

Figure 13 shows that increasing the weight of the Quality criterion results in a noticeable increase in the Agile method's priority value, reinforcing its dominance. Similar effects are observed when increasing the weights of Time and Risk, indicating that these criteria strongly support Agile as the preferred development approach.

In contrast, increasing the weight of the Budget criterion results in a higher priority value for the Waterfall method, narrowing the gap between Agile and Waterfall. This phenomenon suggests that Waterfall is more appropriate in cost-sensitive environments. However, the increase is not sufficient to change the overall ranking.

Variations in Scope and Resources have relatively minor impacts on the final results, indicating that these criteria are less influential in determining the decision outcome. Overall, the sensitivity analysis confirms that the ranking of alternatives remains unchanged across all scenarios, with Agile consistently ranked first. This fact demonstrates that the proposed AHP model is robust and stable, and that the decision is not highly dependent on specific weight configurations.

IV. CONCLUSION

This study evaluates the selection of software development methodologies using the Analytical Hierarchy Process (AHP) integrated with the Six-Pointed Star Framework. The results indicate that Agile is the most suitable development methodology for the company, reflecting its ability to address dynamic project requirements, improve application quality, and leverage team competencies effectively.

This outcome reinforces the notion that Agile's adaptive, iterative, and collaborative characteristics are well-suited to the business needs of an oil and gas company operating in a highly dynamic environment. Agile offers flexibility to accommodate

user requests, enables incremental feature improvements, and maintains application quality and stability through regular updates. This conclusion aligns with previous research findings supporting Agile implementation in organizations with complex environments, cross-functional teams, and a need to respond rapidly to emerging risks.

The sub-criteria identified as the most influential factors in application development at the company may serve as a basis for further analysis aimed at improving the quality of future application development. Consequently, the results of this research are expected to provide valuable input to the company's management when formulating future policies for application development methodologies.

Based on the findings of this research, several recommendations can be made:

- Before implementing Agile, it is necessary to establish a strong Agile team that fully understands Agile principles. As an initial step, a mindset shift toward Agile thinking should be encouraged among all team members involved in application development to ensure a smooth transition. The distribution of roles within the development team should follow the Agile framework, including product owner, Scrum master, and development team members.
- Cross-functional communication and user engagement should be strengthened to ensure feedback is received and incorporated promptly.
- To support the Agile process, the company should adopt tools that support Agile, such as backlog management systems, continuous integration, and version control, to facilitate regular iterations and feature updates.
- Periodic evaluations of application development projects should be conducted to ensure that Agile implementation remains aligned with the company's objectives. These evaluations should include assessments of development outcomes, user satisfaction, and team performance.

The present research extends this line of inquiry by applying a project-management-oriented framework (the Six-Pointed Star) within the oil and gas industry, thereby offering both theoretical enrichment and practical insights for organizations seeking to align software development methodologies with their strategic and operational contexts.

Future research should conduct comparative studies across multiple organizations to improve the generalizability of the findings. Longitudinal studies could also be undertaken to assess the stability and consistency of decision outcomes over time. Furthermore, integrating other Multi-Criteria Decision-Making (MCDM) methods, such as TOPSIS or ANP, may provide methodological triangulation and deeper analytical insights. Expanding respondent diversity and project scope may also improve the robustness of future analyses. Overall, this study provides a structured, context-aware approach to aligning software development methodologies with organizational and project characteristics, thereby improving decision-making in complex industrial environments.

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