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Application of Agile Project Methodology in Computational Fluid Dynamics Engineering Project

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***Abstract*—**Agile methodology is a popular project management methodology and is widely used in many engineering projects. In the recent years agile methodology is successful in countering the inherent problems seen in traditional methodology. The application of the Agile methodology in the computational fluid dynamic project had improved the project delivery performance. Computational Fluid Dynamics (CFD) is the method to solve and analyze the fluid flow problems by the application of the numerical analysis. In this paper, study is conducted using agile methodology and results are compared with waterfall methodology. The result shows that the agile methodology is improves the final delivery of the project.

***Keywords*—**Agile methodology, traditional methodology, engineering management, engineering technology, Computational Fluid Dynamics, project management.

I. Introduction

CFD employs numerical methods and algorithms to analyze and simulate fluid flow phenomena. From aerospace and automotive engineering to biomedical research and environmental studies, this field has numerous applications. Fluids such as liquids and gases, as well as their interactions with solid objects, can be modeled using CFD. With the recent advancement in the software and high-speed supercomputer, the usage of CFD increased and the project results have improved. CFD usage increased in past few years but the computation resources have not kept in pace with it. This have led to constraint in many projects' delivery. In order to improve the projects delivery, project management technique is employed. There are always limitations and risk associated with the project. The primary constraints in any projects are scope, time and budget. The resources should be allocated wisely in order to solve the project. The time constraint, scope constraint and cost constraint are triple constraints in project management. These constraints are linked to each other. One of the problems faced by the CFD industry is related to time constraint. In order to solve the time constraint problem, a proper scheduling is essential. Generally, the following steps are taken into account: planning, scheduling, monitoring and control. Planning includes defining goals in the project, how to achieve the goals, and the steps need to reach the goals. Scheduling includes completing the project goal in realistic timeframe. Monitoring includes how the past stage of the project performed, future trends, goals performance analysis and reporting to various stakeholders. Control step includes a result analysis to determine if the project is proceeding as planned; if the outcome can be replicated and continued; and if the results are not as anticipated, to investigate the deviation and correct it for future project objectives.

A project management methodology is a collection of processes, principles, and practices that govern the planning, execution, monitoring, and controlling of a project from inception to completion. A project management methodology provides a framework for organizing, prioritizing, and coordinating project activities, resources, and stakeholders in order to achieve specific objectives within a specified timeline, budget, and quality standards. There are numerous methodologies for project management, including the traditional or waterfall methodology, agile methodology, hybrid methodology, and lean methodology, among others. Each methodology has its own approach to project management, with distinct phases, tasks, responsibilities, and tools that define the planning, execution, and control of the project. Traditional or waterfall methodology, for example, employs a sequential approach to project management in which each phase is concluded before moving on to the next. The agile methodology, on the other hand, uses an iterative approach in which the project is developed in cycles or sprints and the requirements and deliverables are continuously reviewed and adapted to suit the project's changing needs. A project management methodology provides a structured approach to administering a project, allowing project managers to optimize resource utilization, manage risks, and guarantee project success. The selection of a project management methodology is contingent upon the project's nature, scope, and complexity, as well as the organization's culture, objectives, and stakeholders. In the paper, the CFD results are compared with waterfall methodology and agile methodology.

II. Literature Review

Previous researchers have compared the effectiveness of agile and waterfall/traditional methodologies. Turner and Cochrane mentioned that mangers need to deliver the project on time, within budget even if the product is useful or not [1]. This emphasizes the benefit of an agile methodology as it can be iterated or tried many times. To maintain control on distributed large projects, there is a natural inclination to add more management layers, with enhanced policy and checkpoints and process [2] by building manager competencies [3], [4]. Serrador and Pinto [5] shows the positive impact on the success of the project using agile methodology.

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In tradition methodology, requirement, analysis, design, development, testing, deployment, and maintenance are performed concurrently [4]. Verification is performed at the conclusion of the process [7]. All the integration in traditional projects occurs between development and testing [8].

Computational fluid dynamics simulation is performed using software [22]. Sajeev et al. [10] performed CFD simulation for particle transportation in pipeline. The result provides insight into the time needed for the project completion and also different process methodology used. Parsi et al. [16] performed CFD in particle transportation in elbow and demonstrated the project's time constraints. Arabnejad et al. [24] & Vieria et al. [12] performed CFD simulation and have seen advantage in the applicability of project management methodology. The differences between traditional development and agile development are in fundamental assumption, management style, knowledge management, communication, development model, desired organizational form/structure, quality control [11], [18], [20].

Success in a project is defined differently by various authors. Atkinson [13] and Kerzner [15] measured the project success using traditional method of producing sufficient functioning quantity while keeping the triple constraint. Some authors have defined it in a broader way. Munns and Bjeirmi [17] defined the requirement of project delivered to customer and project ends. Jugdev and Müller [19] looked at the project success as measure of the impact at the organization. Thomas et al. [21] showed that even if the project objective is not met but client is satisfied then the project can be called success. Shenhar et al. [23] studied traditional project efficiency and concluded that scope is important parameter in determining project success. Müller and Turner [26] used ten-dimensional method for project success. The project success is defined by Müller and Turner [26]; Pinto and Slevin [27]; Shenhar and Dvir [23], as meeting time, cost and scope goal.

III. Traditional Methodology and Agile Methodology

The waterfall methodology is a sequential and linear method of managing projects. It is often referred to as the basic approach or sequential approach. This approach is predicated on the notion that the project should advance in a succession of clear stages or phases, with each step being finished before going on to the next. This approach was created initially for manufacturing and construction projects, but it has since been used for a wide range of other tasks.

The waterfall methodology typically consists of the following phases:

- Requirement Gathering: The project team determines and records the project's needs and goals during this phase.
- Design: During this stage, the project team creates a comprehensive project plan, which includes a system architecture, design papers, and technical requirements.
- Implementation: In this stage, the project team constructs the project in accordance with the meticulous plan from the design phase.
- Testing: In this phase, the project team evaluates the work to make sure it adheres to the standards and specifications established in the earlier phases.
- Deployment: In this stage, the project team delivers the product to the client or final users, frequently along with instructions or training
- Maintenance: In this stage, the project team supports the project, makes any necessary updates or repairs, and takes care of any problems or errors that may develop.

The waterfall process often requires that each step be finished before going on to the next, leaving limited room for alterations or revisions once a phase has been finished. The customer's requirements and objectives are thought to be clearly specified and unlikely to change throughout the project, according to the waterfall technique. Because of this, projects where the requirements are clear and the project team has experience completing tasks identical to them in the past are best suited for the waterfall methodology.

The waterfall methodology has the benefit of giving project management a defined framework and structure, which is beneficial for big or complicated projects. The linear nature of the procedure may also make it simpler to manage time and money. The waterfall methodology does, however, have some drawbacks. It may be rigid, making it challenging to adapt to changes in needs or unanticipated problems that develop throughout the project. The waterfall process also requires a lot of planning up front, which may be time-consuming and expensive. Moreover, this process defers client or end-user involvement until later in the project, which may lead to a final product that falls short of their demands or expectations.

Agile methodology is an iterative and flexible software development technique that stresses cooperation, self-organization, and continuous improvement. The agile process is intended to be flexible and responsive to changing requirements, and it aims to provide working software frequently and rapidly. Each sprint normally lasts between two and four weeks, and at the end of each sprint, a working product increment is delivered. Agile teams prioritize features and needs based on business value and user input, and they collaborate to enhance the product continually. Agile methodology offers multiple benefits, including better flexibility and adaptation to changing requirements, a focus on delivering value to consumers, and a highly collaborative and responsive team atmosphere [15].

Agile methodology is an incremental and iterative approach to project management that places a strong emphasis on adaptability, teamwork, and providing value to the customer. Although it was first created for software development, it may be used for a wide range of applications.

Agile methodology is founded on the Agile Manifesto, which describes four values and twelve principles.

The four values are: Interactions and individuals preceding tools and procedures, collaboration with customers over contract negotiation, functioning software over extensive documentation, and adapting to change over sticking to a plan.

The twelve tenets are: Frequently delivering functional software and favoring the quickest turnover time, even late in the project. Accept shifting requirements, agile methodologies

leverage change for the customer's competitive advantage, and produce a functional product frequently while favoring a shortened time frame. Throughout the duration of the project, entrepreneurs and developers must collaborate daily, build initiatives around motivated individuals, entrust them to complete the task, and provide them with the necessary environment and resources. The most effective and efficient method of sharing information with a development team is face-to-face interaction. Usable software is the primary metric of progress. The promotion of sustainable development is facilitated by agile methods. Sponsors, developers, and consumers should be able to maintain the current rate indefinitely. Constant attention to technical excellence and intelligent design increases agility. Crucial is the art of simplicity, which maximizes the amount of labor avoided. Self-organizing teams generate the most effective designs, specifications, and architectures. The team frequently contemplates how to be more effective and then modifies its behavior accordingly.

Working in brief iterations (typically 2-4 weeks) and continuously refining the product based on feedback are the cornerstones of the agile methodology. Agile process involves following steps:

- Describe the project's vision and list the stakeholders
- Prioritize features according to their value to the client and the difficulty of implementing them
- Plan sprints, which are brief development intervals with a time limit
- Breaking the features down into smaller tasks
- Defining them in the order of priority
- Testing and assessment of the product, along with stakeholder feedback
- Based on the input, adapt and iterate, and change the project plan as appropriate.

Agile methodologies use self-organizing teams that are given the authority to decide and work closely together throughout the project. Moreover, the Agile method necessitates more continuous interaction and engagement with stakeholders, and it might not have a comprehensive project plan at the outset. Delivering value to the customer and reacting to changes in needs or the environment are prioritized by the agile methodology [6].

There are similarities between traditional and agile methodologies, such as the significance of project management, the requirement for testing and quality control, and the utilization of teamwork to achieve project objectives. Yet, there are substantial distinctions between the two approaches. Traditional technique, for instance, emphasizes a linear, sequential approach, whereas agile methodology is iterative and adaptable. The traditional methodology necessitates a detailed project plan and road map, but the agile methodology is meant to adapt to changing requirements. Traditional methodology places a premium on documentation and preparation, whereas agile methodology places a premium on working software and client input. The traditional methodology is optimal for projects with stable and unchanging requirements, whereas the agile methodology is optimal for projects with changing requirements and where the team can work cooperatively and flexibly [9].

IV. Research Method

The research method uses triple constraint success as the project success. Scope, time and budget are the triple constraints. The data are collected from the research paper published by Sajeev et al. [14]. The same project is worked with agile methodology and traditional methodology. The time taken for each project to complete is studied in detail. A survey is conducted from different users using the similar software. They were given a choice between more successful and less successful applications of the traditional and agile methodologies.

In this research method, the degree of effort needed for traditional and agile methodology as predictor is evaluated. The project complexity, quality, goals and team experience are selected as parameters. Outcomes are studied for stakeholder satisfaction, project efficiency and overall project success. Approach uses simplest relationship and analysis are conducted using progressive technique. The results are analyzed to study for linear regression and examined for dependent relationship.

The evaluation is performed using 5-point numerical scale developed by Cooper and Schindler [25]. Three questions needed for the success are measured in the project efficiency and for the project stakeholder satisfaction four parameters are measured. This assessment is needed for the project success. Questions like “How the project budget is meet in the success of the project?”, “How the project goals is meet in the success of the project?”, “How project success is assessed in requirement meeting scope?”, “How the project result influences the client satisfaction rated?”, “How to rate the end user’s satisfaction?”, “How to rate the success of the project” give effectiveness of agile and traditional methodology. While studying the agile methodology, special care is taken for analysis of execution and planning phase. A survey is conducted for 256 cases, with the above questions. The respondents have shown high attention to the questions. The primary analysis is to determine the efficiency factor. The efficiency was determined with the following questions: “Did the project meet budget goals?” and “Is project completed in time?” [25].

V. Result and Analysis

Sajeev et al. [28] developed best practices for project management in CFD. A survey is conducted among 256 respondent and with score ranging from 5 to 1. The effectiveness of the agile and traditional methodology for solving CFD projects is analyzed in detail. Score 5 is given to high effectiveness for the methodology and score 1 is given least effectiveness. The percentage of respondent for each score is studied in detail.

For the question “How the project budget is meet in the success of the project”, the respondent’s response is shown in Table I. The analysis of the respondent survey shows that agile methodology has slight advantage over traditional

methodology. The agile methodology has score of 32.67 and traditional methodology has score of 32. The agile methodology has shown a slight improvement of 2% over traditional methodology for the question "How the project budget is met in the success of the project".

TABLE I
ANALYSIS OF HOW THE PROJECT BUDGET IS MET IN THE SUCCESS OF THE PROJECT

Score	Agile Methodology	Traditional Methodology
5	90%	80%
4	10%	20%
3	0%	0%
2	0%	0%
1	0%	0%

For the analysis of the question "How the project goals are met in the success of the project?", the response analysis shows that both for traditional methodology and agile methodology, the project goals achievement remains the same. This shows that that the project goals are met with same effectiveness.

TABLE II
ANALYSIS OF HOW THE PROJECT GOALS ARE MET IN THE SUCCESS OF THE PROJECT

Score	Agile Methodology	Traditional Methodology
5	100%	100%
4	0%	0%
3	0%	0%
2	0%	0%
1	0%	0%

The respondent response for the question "How project success is assessed in requirement meeting scope?" is shown in Table III. The agile methodology gives a score of 32.67 and traditional methodology gives a score of 31.67. Clearly the agile methodology has a slight advantage over traditional methodology. For the question "How project success is assessed in requirement meeting scope?" agile methodology has an advantage of 3.06% over traditional methodology. Clearly for the project success in meeting the scope required agile methodology should be used.

TABLE III
ANALYSIS OF HOW PROJECT SUCCESS IS ASSESSED IN REQUIREMENT MEETING SCOPE

Score	Agile Methodology	Traditional Methodology
5	90%	75%
4	10%	25%
3	0%	0%
2	0%	0%
1	0%	0%

Responses for the question "How the project result influences the client satisfaction?" are shown in Table IV. The agile methodology and traditional methodology have shown same client satisfaction. The respondent survey shows that both agile and traditional methodology have the same influence on client satisfaction.

TABLE IV
ANALYSIS OF HOW THE PROJECT RESULT INFLUENCES THE CLIENT SATISFACTION

Score	Agile Methodology	Traditional Methodology
5	100%	100%
4	0%	0%
3	0%	0%
2	0%	0%
1	0%	0%

TABLE V
ANALYSIS OF HOW TO RATE THE END USER'S SATISFACTION

Score	Agile Methodology	Traditional Methodology
5	100%	50%
4	0%	30%
3	0%	20%
2	0%	0%
1	0%	0%

Responses for the question "How to rate the end user's satisfaction?" are shown in Table V. Analysis of the respondent survey for agile methodology and traditional methodology shows that end users' satisfaction is higher for the agile methodology. The agile methodology gives a score of 33.34 and traditional methodology gives a score of 28.67. Agile methodology has 14% advantage over traditional methodology. If the end user satisfaction is important then the agile methodology should be implemented.

Responses for the question "How to rate the success of the project using different methodology" are shown in Table VI. Analysis of the respondent shows that the agile methodology is more successful project management than traditional methodology. The agile methodology has a score of 32.67 while traditional methodology has a score of 27. The responses to the survey query "How to rate the success of the project using different methodology" indicate that agile methodology is superior to traditional methodology by 17.35%.

TABLE VI
ANALYSIS OF HOW TO RATE THE SUCCESS OF THE PROJECT USING DIFFERENT METHODOLOGIES

Score	Agile Methodology	Traditional Methodology
5	90%	50%
4	10%	20%
3	0%	20%
2	0%	5%
1	0%	5%

The efficiency question is analyzed for the agile methodology and traditional methodology for the question if the project meets the budget goals.

TABLE VII
ANALYSIS OF HOW THE PROJECT MET ITS BUDGET

Score	Agile Methodology	Traditional Methodology
5	86%	75%
4	8%	10%
3	4%	5%
2	1%	5%
1	1%	5%

The Agile methodology gives a score of 31.8 while traditional methodology gives a score of 29.67. Clearly Agile methodology has shown advantage in the project, meeting the budget goal. The responses to the survey query "Did the project meet its budget" indicate that agile methodology is superior to traditional methodology by 6.75%.

For the question if the project is completed in time, the respondent analysis based on 5-point method is shown in Table VIII.

TABLE VIII
ANALYSIS OF HOW PROJECT IS COMPLETED IN TIME

Score	Agile Methodology	Traditional Methodology
5	95%	60%
4	5%	15%
3	0%	15%
2	0%	5%
1	0%	5%

Respondent analysis shows that the agile methodology has clear advantage over traditional methodology regarding the time needed to complete the project. Based on the scores assigned, agile methodology has a score of 33 and traditional methodology has a score of 28. In other words, the agile methodology has an advantage of 15.15% over traditional methodology.

VI. CONCLUSION

Analysis of the result from "project meet budget" and "project completed in time" shows that the agile methodology has advantage over traditional methodology in the CFD project. The use of agile methodology is highly recommended in such CFD projects. Agile methodology was created to be flexible and adaptive to fluctuating needs. It helps the team to adjust rapidly to changes in consumer wants, market situations, or technological improvements, resulting in a superior product that fits the changing needs of customers. Agile methodology focuses on providing often and rapidly working software. This strategy enables the team to receive early user input and make any necessary adjustments, resulting in a shorter time to market for the product. Agile methodology prioritizes continuous testing, quality assurance, and software delivery. This strategy ensures that quality is incorporated into the product from the start, resulting in fewer defects, faster problem resolution, and increased overall quality. Agile methodology focuses on providing often and rapidly working software. This strategy helps the team to obtain early user input and make any necessary adjustments, resulting in a quicker time-to-market for the product. Ultimately, the agile methodology provides a more collaborative, flexible, and iterative approach to software development, resulting in higher-quality, customer-focused software with a shorter time-to-market.

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