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EFFECTIVITY IMPROVEMENT OF HYBRID PROJECT MANAGEMENT WATER-SCRUM-FALL WITH SIX SIGMA IMPLEMENTATION

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Abstract— *In software development projects there is continuous development aimed at increasing the efficiency and effectiveness of the team in providing software quality and customer satisfaction. The problem is that many projects are planned using a waterfall approach by clients, therefore some tools are needed to balance this situation. This research aims to evaluate the effectiveness of hybrid methodologies in software development by uncovering the use of a combination of Waterfall and Agile Scrum methodologies with the application of Six Sigma. This hybrid methodology was deemed suitable for combining the plan- and contract-based characteristics of Waterfall with the flexibility and rapid iteration of Agile Scrum. The use of Six Sigma is used to focus on change, assist in systematically identifying and correcting process problems, and process improvement. In research methods, sample teams run different methodologies on similar software projects. Hybrid project management is carried out by applying the Waterfall approach in planning and contracts. At the same time, each phase in Waterfall is iterated using Agile Scrum to ensure flexibility and adaptability. The research results found that this hybrid method can increase team efficiency, reduce development cycle time, detect higher defects in each sprint, increase the final quality of the software, and finally increase the Sigma Index with a team comparison of σ=3.22 and σ= 3.11 and higher compared to teams that only use Agile-Scrum. In conclusion, the integration of Waterfall, Agile Scrum, and Six Sigma can be an effective strategy to face the challenges of modern software development.*

Keywords: *effectivity, project management, scrum, six sigma, waterfall.*

Intisari— *Dalam suatu proyek pengembangan perangkat lunak, terdapat pengembangan berkelanjutan yang bertujuan untuk meningkatkan efisiensi dan efektivitas tim dalam menyediakan kualitas perangkat lunak dan kepuasan pelanggan. Permasalahannya adalah banyak proyek yang direncanakan menggunakan pendekatan waterfall oleh klien, oleh karena itu diperlukan beberapa alat untuk menyeimbangkan situasi ini. Penelitian ini bertujuan untuk mengevaluasi efektivitas metodologi hybrid dalam pengembangan perangkat lunak dengan mengungkap penggunaan kombinasi metodologi Waterfall dan Agile Scrum dengan penerapan Six Sigma. Metodologi hybrid ini dianggap cocok untuk menggabungkan karakteristik Waterfall berbasis rencana dan kontrak dengan fleksibilitas dan iterasi cepat dari Agile Scrum. Penggunaan Six Sigma digunakan untuk fokus pada perubahan, membantu mengidentifikasi dan memperbaiki masalah proses secara sistematis, dan perbaikan proses. Dalam metode penelitian, tim sampel menjalankan metodologi berbeda pada proyek perangkat lunak serupa. Manajemen proyek hybrid dilakukan dengan menerapkan pendekatan Waterfall dalam perencanaan dan kontrak dan ada saat yang sama, setiap fase dalam Waterfall di iterasi menggunakan Agile Scrum untuk memastikan fleksibilitas dan kemampuan beradaptasi. Hasil penelitian menemukan bahwa metode hybrid ini dapat meningkatkan efisiensi tim, mengurangi waktu siklus pengembangan, mendeteksi cacat yang lebih tinggi di setiap sprint, meningkatkan kualitas akhir perangkat lunak, dan terakhir meningkatkan Indeks Sigma dengan perbandingan tim σ=3.22 dan σ= 3.11 hasil ini lebih tinggi dibandingkan*

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tim yang hanya menggunakan Agile-Scrum. Kesimpulannya, integrasi Waterfall, Agile Scrum, dan Six Sigma dapat menjadi strategi yang efektif untuk menghadapi tantangan pengembangan perangkat lunak modern.

***Kata Kunci**: efektifitas, manajemen proyek, scrum, six sigma, waterfall*

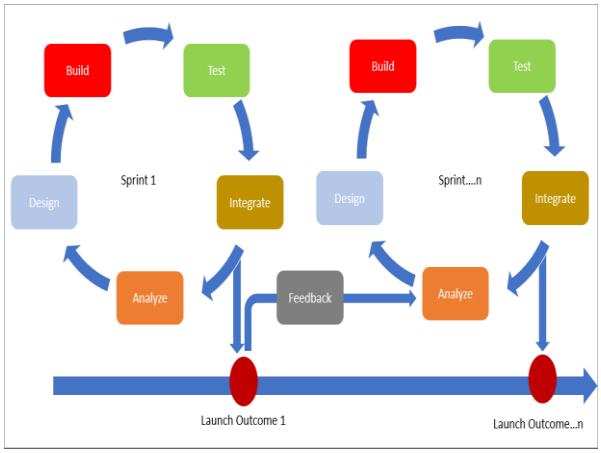
INTRODUCTION

In this decade, when the Industrial Revolution 4.0 is transitioning to 5.0, the development of software utilizing AI, IoT, and Machine Learning has become a part of the rapid, customer-oriented project cycle. In this case study at one of the software development companies in Indonesia, it was found that 30% of projects had bugs discovered after the system was delivered to customers, and 40% of projects had delays in delivery to customers, which resulted in customer satisfaction for each project only having an average of 67 out of 100 for customer satisfaction ratings. Based on this fact, software developers are continually seeking solutions and methods to enhance quality, efficiency, and performance in software development, infrastructure, and appropriate hardware. The context is the use of the right methodologies with new solutions and emerging technologies and also using the right tools is crucial [1]. Project performance indicators and forecasting the performance of a project are what most organizations need especially project managers to monitor their project activities [2].

Adopting and using agile methodologies in organizations that build software as their main core business, has become some value point and preferred choice for companies and software teams in executing software projects. Emphasizing values like attending to customers and their evolving requirements, fostering human interaction and individual contributions, minimizing undue development burdens, and ensuring regular and prompt delivery of developed software components, this methodology aims to enhance performance, quality, and also productivity in software development projects [2].

Agile methodology in software development encompasses a series of methods, and a series considers the process of delivering minimum product incrementally. The most well-known agile methodologies are Scrum, XP (Extreme Programming), Kanban, Crystal, Rapid Application Development (RAD), and Test-Driven Development (TDD) [3]. Some methodologies are mixed-use agile, for example, Scrum can be combined with other methodologies, such as Kanban and it will be scrum-ban [2], [3], but some traditional methodologies are also used to mix with agile like water-fall has been the most popular over decades in project teams.

Agile Software Development offers several benefits, including improved product quality, team productivity, and customer satisfaction. This approach allows teams to adapt to changes more quickly and reduce project risk through shorter iterations[4] , as visually on how Agile Project Cycle is in Figure 1.



Source: (Bott [5], 2020)

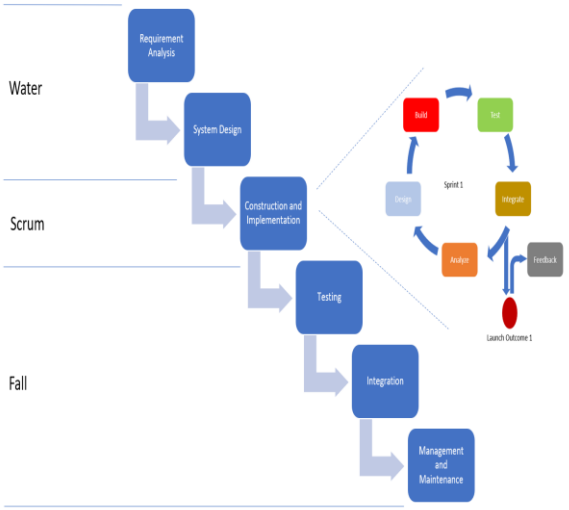
Figure1. Agile Project Cycle

Literature reviews in the software development life cycle indicate that combining these methodologies, in most cases, has frequently assisted software teams in reaching particular objectives. Teams often merge different methodologies to capitalize on their respective advantages and derive collective benefits [6]. Occasionally, Software methodologies integrate standards and perspectives on productivity and management [3], [6], leading to enhanced team productivity, satisfaction of the customer, and refined software development procedures [7], [8].

Dave West, in a technical report published by Forrester in 2011, explored this concept [6]. His study, which involved interviews with over 300 companies in 2009 and 2010, aimed to demonstrate the growing popularity of agile methods among organizations, while also highlighting that hybrid methods were becoming a more common reality. The data revealed that in 2010, 38.6% of companies used agile methods, compared to only 13% using traditional methods [6]. The study posited that hybrid methods, such as the "Water-Scrum-Fall" model, are the future of project management.

This model combines upfront work (the 'water' part, including tasks like requirement analysis and

resource planning) with the agile development phase (the 'scrum' part) and a controlled release process (the 'fall' part). This hypothesis has been further researched and tested, with results supporting the claim, showing that almost half of the respondents used scrum, and nearly one-third used the waterfall/traditional based model, indicating hybrid approach like Water-Scrum-Fall is used in reality in many organizations [9]-[13].



Source : (Reiff [13],2022)
Figure 2. Water-scrum-fall Project Cycle

Six Sigma is a management tool that is widely used in the industry, focusing specifically on achieving certain goals for improvement in performance, quality, productivity, reduction of defect and cost, and increased customer satisfaction [14]. Six Sigma is considered a tool of strategy that is used by an organization to gain maximum development of methods used by managers in the organization [15]. Six Sigma strategy uses measuring and evaluating the level of enhancement is essential for helping managers make decisions for process improvement, for the last several years, the Six Sigma approach has been used in the implementation of software development projects [16]. The principles identified in Six Sigma seem to align with the principles and objectives of Agile in the Agile manifesto [17]. However, it may impose burdens on agile development that partially detract from the ideal agile process [14]-[18].

In this paper, the Six Sigma methodology is utilized to analyze the effectiveness of using a Hybrid mindset and strategies in the execution of projects in software development. In contrast, the traditional waterfall method is still used in the nations and mandatorily uses traditional plan-based projects for their commercial interests in contracts and pricing which are unavoidable. However, many have already converted to using Agile Scrum in their development [9], and Six Sigma is the most common tool for increasing quality and is already well-known worldwide [14]-[16]. Therefore, given the existing conditions, this research was conducted using Six Sigma for effectivity improvement in hybrid methodologies Waterfall and Agile Scrum in software development [12], [16], [17].

MATERIALS AND METHODS

This research uses a seven-step process to ensure the accuracy of findings of the results with exploratory, this steps include identifying the problem, conducting a literature review, determining the research design, developing research instruments, collecting data, processing and analyzing data, and developing conclusions.

Instruments were developed by using interviews, observation, and performance metrics. Variables are used and deployed to assess the effectiveness of the development using a hybrid methodology, from teams as a sample during the Sprint [15], [16] as follows:

a. The total defects identified in Sprint, represent defects in function points.
b. The rework required volume, indicated by the user stories carried over from the current Sprint to the next one.
c. Performance Team, as determined by the number of user stories selected in a Sprint.
d. The level of customer satisfaction, as reported by customers during the Sprint review meetings.
e. Measuring Sigma index values, as represented in scoring for the improvement in quality are achieved.

Data collection in this research was conducted from software development project data and data observation that was carried out by the company between July 2023 and December 2023. The sample data is from Jira project management and Trello that are used in the company was extracted to MS Excel and performance calculations conducted to obtain Function point, Story point and Solved tickets, the average of defects and production, and Customer Satisfaction from the form collected by Scrum Master.

Teams have been determined based on management decisions within the organization to carry out project execution within the organizational scope. In this research, we collected data from 4 teams, and 2 teams were measured using Six Sigma in every quality aspect of each sprint conducted by Team 1 and Team 2, while other teams continued to use quality measurements

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based on existing agile methods. Early before the project started, 2 volunteer teams that use Six Sigma were trained to have familiarity and capability with the tools of Six Sigma and this requires adapting the principles of Six Sigma to align with the Scrum framework [12], [16], [17]. To accomplish that we used the following strategy to implement Six Sigma DMAIC in the Water-Scrum-Falls cycle [15], [16], [18] :

a. Using the DMAIC method in each Sprint iterated in the Scrum and the Fall cycle.
b. Utilizing process maps and diagrams to refine the Sprint backlogs in the sprint planning.
c. Identifying defects with cause-and-effect analysis during review and retrospective sessions.
d. Prioritizing product backlogs in alignment with customer-centric improvements.
e. The sigma value index is measured from the processes carried out by the Scrum team in retrospective sessions.

Six Sigma will be used within the Scrum and Fall phases for software development and presents a tactical method to leverage the benefits of both methodologies [18]-[20]. The primary challenge is effectively embedding Six Sigma within a Water-Scrum-fall-based environment [12] in the project cycle specifically Team 1 and Team 2 that use this methodology. As Six Sigma DMAIC is centered on measurable metrics and data-driven improvement, these elements must be mixed and blended into the Scrum methodology [16], [17].

a. Define the phase of Six Sigma, which involves setting explicit project goals, financial evaluations, and team performance metrics, which should be integrated at the project's commencement. This stage also includes defining clear productivity metrics and analytical data to outline the project's scope.
b. Measure phase of Six Sigma, which will quantify the project data such as user stories, daily sprints, sprint reviews, and velocity will be utilized and also include the problem when it arises. It is crucial to document every aspect of each Sprint, including inputs, outputs, assigned tasks, responsible individuals, and time requirements. Cause-and-effect analysis plays a significant role in addressing challenges encountered during Sprints, daily Scrums, reviews, and retrospectives.
c. The analysis phase employs methods such as cause-and-effect analysis to identify the primary causes of issues. 5W1H analysis is useful for modeling the interdependencies between process inputs and outputs, aiding in detecting and resolving defects. In this stage
d. Improve phase, a detailed solution and improvement plan is formulated, specifying actions for daily Scrum, review meetings, and retrospectives. Revising initial process maps based on these plans is highly beneficial. The impact of these improvement actions should be thoroughly assessed.
e. The control phase involves developing a monitoring and control plan based on an improvement plan and defect documentation to track the current process with new processes that have been adopted, including the development testing to detect any change in the process to take corrective actions immediately.

The Sigma Index value should be measured to ensure all the processes are aligned and have an impact on the quality that has been set. Using survey methods to examine the use and impact of two project management approaches (agile and hybrid) on project performance, Overall, the use of the Six Sigma method in measuring the effectiveness of application development can be expected to result in significant qualitative improvements and support the achievement of Scrum's objectives in terms of quality control within the conducted sprints. [19]

RESULTS AND DISCUSSION

This research utilizes data obtained from the company in executing an application development project consisting of teams as outlined in the following table.

Table 1. Project team profile

Team	Total Persons	Working Experience Avg (yrs)	Base Function Point	Estimate Customize Function Point
T1	5	5	5000	2100
T2	5	4.9	5000	2050
T3	6	4.7	5000	2000
T4	5	5.1	5000	2100

Source: (Research Results, 2024)

In the sprints utilized by the organization, the Sprints for these projects were set at two weeks. The product backlog remained consistent throughout the project, allowing each team to select user stories according to customer requirements. Consequently, the type and the size of the project were the same across all teams. Subsequent sections will detail the findings from the data collection related to the research variables.

1. Defect Detected

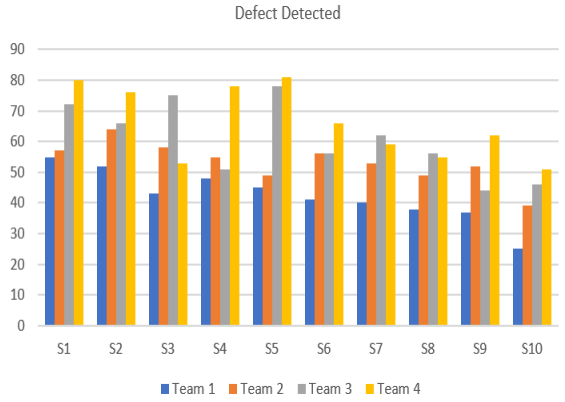
From a certain perspective, the number of defects identified in a Sprint reflects the team's precision decision in executing its responsibilities in terms of ensuring the product increment's alignment with customer expectations. A higher degree of operational quality, characterized by fewer detected defects, signifies an enhanced quality in the development process. Figure 3 illustrates the defects identified throughout the project's Sprints. The observation data in Figure 3 presents the statistics related to the defects identified across all four teams. It represents the total number of defects found in Team 1 is comparatively lower than the other three teams. Additionally, a decreasing trend in the number of defects in function points has been shown in Team 1, indicating its superior performance compared to the other teams.

Table 2. Defects detected in sprint

Team	T1	T2	T3	T4
Sprint 1	55	57	72	80
Sprint 2	52	64	66	76
Sprint 3	43	58	75	53
Sprint 4	48	55	51	78
Sprint 5	45	49	78	81
Sprint 6	41	56	56	66
Sprint 7	40	53	62	59
Sprint 8	38	49	56	55
Sprint 9	37	52	44	62
Sprint 10	25	39	46	51
TOTAL	424	532	606	661

Source: (Research Result, 2024)

We can see this in the visualization chart in Figure 3 below.



Source: (Research Result, 2024)

Figure 3. Defects detected in sprint chart

2. Reworks

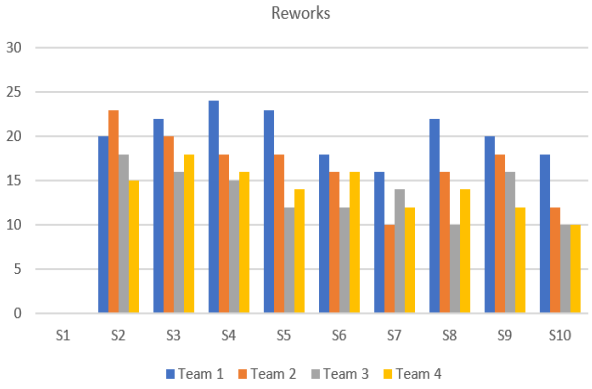
This criterion illustrates the level of need for the team to perform revisions or rework. This often occurs as a result of the inspection and evaluation process based on established criteria. In this research, rework is calculated based on the number of user stories that need to be repeated and carried over in the next Sprint. A lower number of user stories indicates a higher level of precision by the team in completing its tasks. Statistics related to this criterion are presented in Figure 4 below.

From the available data, it is apparent that the amount of rework performed by Team 1 is more than that of the other three teams. This may occur due to the application of strict measurement and evaluation standards following the Six Sigma methodology applied to the team that is being observed as in Table 3 below.

Table 3. Rework in sprint

Team	T1	T2	T3	T4
Sprint 1	0	0	0	0
Sprint 2	20	23	18	15
Sprint 3	22	20	16	18
Sprint 4	24	18	15	16
Sprint 5	23	18	12	14
Sprint 6	18	16	12	16
Sprint 7	16	10	14	12
Sprint 8	22	16	10	14
Sprint 9	20	18	16	12
Sprint 10	18	12	10	10
TOTAL	183	151	123	127

Source: (Research Result, 2024)



Source: (Research Result, 2024)

Figure 4. Reworks in sprint chart

To meet Six Sigma standards, teams may sometimes feel the need to make more efforts and undertake more revisions or adjustments based on feedback from sprint review activities conducted with customers. The use of cause-and-effect analysis to identify defects will be carried out by the team in reworking tasks that fall into the defect category and require rework.

3. *Team Performance*

Another criterion used for comparison in the research is team performance, this study utilizes a comparison between the volume of work completed (based on reports from end-user reviews at the end of each Sprint) and the work that was promised. The related data is presented in Table 4 below.

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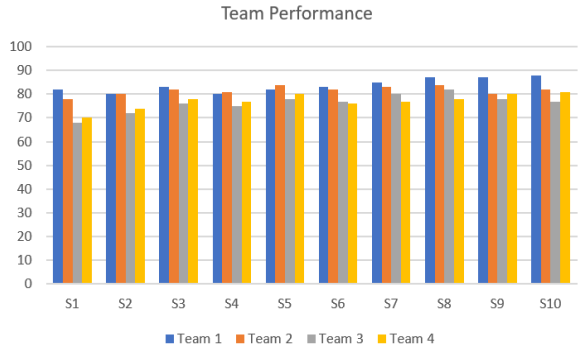
Table 4. Team Performance

Team	T1	T2	T3	T4
Sprint 1	82	78	68	70
Sprint 2	80	80	72	74
Sprint 3	83	82	76	78
Sprint 4	80	81	75	77
Sprint 5	82	84	78	80
Sprint 6	83	82	77	76
Sprint 7	85	83	80	77
Sprint 8	87	84	82	78
Sprint 9	87	80	78	80
Sprint 10	88	82	77	81
TOTAL	837	816	763	771

Source: (Research Result, 2024)

From the available observed data, it is apparent that the performance of Team 1 and Team 2 is superior compared to Team 3 and Team 4. This increase represents the implementation and using Six Sigma measurements within the Water-Scrum-Fall methodology has successfully enhanced team performance. Additionally, the collaboration between these two methods has proven to be efficient and supportive of achieving the set objectives. Figure 5 displays a visual of the related statistics.



Source: (Research Result, 2024)
Figure 5. Team Performance Chart

4. Customer Satisfaction

In this study, customers were invited to provide feedback on their level of satisfaction, which is a key target of the Water-Scrum-Fall and Six Sigma implementation, through a series of questions in a self-administered survey. Customers were asked to rate their total satisfaction level in the form of a percentage for each user story and product increment produced.

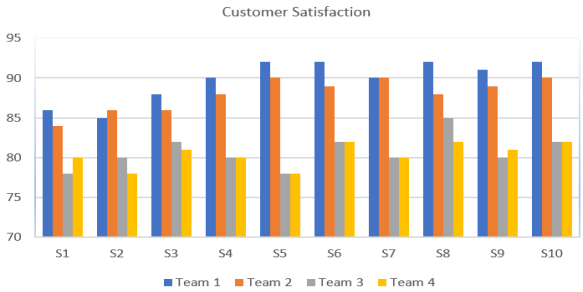
Based on observations, in nearly every Sprint, the satisfaction levels perceived and reported by customers for Team 1 and Team 2 tend to be higher compared to Team 3 and Team 4. This represents the effectiveness of using the hybrid approach in gaining increased customer satisfaction as one of its primary objectives as data collection in Table 5 below.

Table 5. Customer Satisfaction

Team	T1	T2	T3	T4
Sprint 1	86	84	78	80
Sprint 2	85	86	80	78
Sprint 3	88	86	82	81
Sprint 4	90	88	80	80
Sprint 5	92	90	78	78
Sprint 6	92	89	82	82
Sprint 7	90	90	80	80
Sprint 8	92	88	85	82
Sprint 9	91	89	80	81
Sprint 10	92	90	82	82
TOTAL	898	880	807	804

Source: (Research Result, 2024)

The trend of the customer satisfaction visualization chart is presented in Figure 6 below.



Source: (Research Result, 2024)
Figure 6. Customer Satisfaction Chart.

5. Sigma Index Value

The use of the Sigma index value is conducted at the end of each Waterfall-Scrum-Fall phase to determine the capability index and measure the Sigma value. This measurement is carried out to determine which team is undertaking the project to measure how well the team maintains quality standards in reaching the expectations outlined in the customer's user story. The higher the Sigma index value, the better a team is at executing and maintaining the quality of the software development itself.

Table 6. Sigma Index

Team	Capability Process	DPO	DPMO	Sigma Index
T1	0,0848	0,0424	42400	3,22349
T2	0,1064	0,0532	53200	3,11459
T3	0,1212	0,0606	60600	3,04976
T4	0,1322	0,0661	66100	3,00548

Source: (Research Result, 2024)

CONCLUSION

The hybrid method used in this research combines methodology, approach, measurement, quality, best practices, and standards, with Agile Scrum as a standard in development teams and Water-Scrum-Fall with Six Sigma as a tool for

measuring quality and process capability. The results of the research carried out involved four sample teams, where Teams T1 and T2 used Hybrid Water-Scrum-Fall with Six Sigma, while Teams T3 and T4 only used Agile-Scrum. The teams that used hybrid Six Sigma experienced a greater increment in bugs in each sprint, which was caused by a defect detection mechanism using the 5W+1H tool, root-cause analysis, and process improvement. The tools worked well when used in the software development process and they explored bug detection at the early and at every stage of development so the defect detected is lower with the teams that use hybrid Six Sigma.

The increase in defects in projects carried out in each sprint influences the rework after the sprint is closing and carried over to the next sprint or even after the product is delivered experienced by teams not using hybrid and Six Sigma, compared to other teams in each sprint. Even though defect findings are low, rework is higher due to quality process and code improvements in each sprint and this will affect the team's workload level in maintaining the project schedule and also maintaining the minimum viable quality of each product that has been mutually agreed upon. Team performance is seen increasing in teams that use hybrid and Six Sigma compared to teams that do not use hybrid, this is due to collaboration between team members in using the Six Sigma modeling tool resulting in the completion of more "user stories" with minimum bugs at the end of each sprint iteration during the sprint review.

Customer satisfaction shows differences between the sample teams that run hybrid and Six Sigma. In this study, the customer satisfaction index was achieved more by teams that used hybrid and Six Sigma methods, where every time they tested and reviewed the minimum viable product in each sprint iteration, customers were quite satisfied with the results of the questionnaire given. Water-Scrum-Fall and Six Sigma as hybrid methodologies in software development in this research were proven to be effective solutions for increasing the competitiveness and quality of software products in companies. However, this can also be a concern for managers, as the high workload and additional responsibilities require further study to understand the impact on the development team. Implementing Six Sigma can cause additional complexity that requires careful project implementation, but this would not happen if the organization had implemented quality achievement measurements using Six Sigma. Nevertheless, the use of Six Sigma in this hybrid methodology improves the process in production capabilities, productivity, and team effectiveness and improves the quality of the final product and customer satisfaction of the project in software development.

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