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Does a Hybrid Approach of Agile and Plan-Driven Methods Work Better for IT System Development Projects?

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ABSTRACT
With a focus on large-scale IT system development projects in diverse enterprises, this research suggests that a hybrid approach combining agile and plan-driven management methods should fit in a wider context of specific project characteristics. Although the extant research illuminates the advantages of the hybrid approach, very few empirical studies actually suggested that the hybrid approach can improve the likelihood of project success. This research results show that the hybrid approach should be more scalable than the agile method, and that the hybrid approach can provide better cost-benefit ratios compared to the traditional plan-driven method. These quantitative and qualitative findings offer a practical recommendation for the project manager or the project management office to utilize the hybrid approach appropriately.

Keywords **-** Hybrid Approach, Agile, Plan-driven, Survey, Case Study, Project

I. INTRODUCTION

It is common in IT system development projects for project managers to deal with both project control issues and fast responses to changes in the project. The challenge in managing system development and IT projects comes from the fact that diverse stakeholders seek both predictability in the project scope and flexibility in the requirements due to uncertain and changing business circumstances. Furthermore, system development is often positioned as a critical subsystem in complex and large-scale hardware product development projects, wherein innovative outcomes are expected expeditiously while phase gates are applied to mitigate risks. In this case, agile methods alone may not be sufficient to produce desired results. Therefore, it is no surprise that research shows a trend of studies focusing a hybrid approach that uses plan-driven and agile-method together in enterprise level IT system development [1, 2, 3].

However, there are, to the authors' knowledge, very few empirical studies to support that the hybrid approach can improve to the likelihood of project success. To address this knowledge gap, this paper is intended to provide an integrative empirical study of the hybrid approach using statistical data analysis of survey respondents (n = 117) and two qualitative case studies in Japan.

The objective of this research is to provide quantitative and qualitative evidence through actual project result data to illustrate that the hybrid approach works better than traditional plan-driven or agile methods for improving specific project success indicators. The hybrid approach has been highlighted as an important area for future research in recent studies on system engineering and project management disciplines [2, 3, 4, 5]. The results presented herein contribute to estimating costs and benefits of the hybrid approach compared to those associated with the plan-driven method.

II. LITERATURE REVIEW

This section presents a review of the existing literature on plan-driven, agile, and hybrid variants, and defines the scope of the hybrid approach.

2.1 Plan-driven and Agile Method

Conventional IT system development organizations selectively utilize two techniques: the plan-driven method in which requirements are defined and base-lined in the initial phase of the project [6, 7], and the agile method which is based on iterative, incremental development of the project scope [8, 9, 10].

The plan-driven methods, also known as the Waterfall method, is an IT system development process that consists of sequential phases that are

linear. Phases in the plan-driven method typically include requirements analysis, design, implementation, testing and operation. These phases require a sign-off by the project manager to proceed to the subsequent phases. Requirements are baselined before design and implementation and implementation commences using an integrated change control process [7]. Thus, after finalizing the requirements in the initial phase, customer involvement is limited.

With the agile method, on the other hand, re-planning with customers is carried out iteratively even during the execution phase. Although high-level requirements can be collected early in the project, team should repeatedly prioritize detailed requirements. Agile methodologies include more than six frameworks and practices [11, 12, 13, 14]. The most popular variants are Scrum [9], Extreme Programming [15], Crystal [16], Dynamic Systems Development Method [16], Lean software development [17] and Feature Driven Development [18]. The Agile Manifesto [8] consists of four value statements:

- Individuals and interactions over processes and tools
- Working software over comprehensive documentation
- Customer collaboration over contract negotiation
- Responding to change over following a plan

Two of the main features of the agile method are iterative scope definition and development, and incremental delivery [1, 19, 20]. The purpose of agile project management is to deliver reliable and innovative products within the cost and schedule constraints and, to mitigate risks proactively by managing the uncertainties inherent in the iterative process [19]. The agile project team must cope with rapid changes in project plan and active involvement of customers [21]. Project members should be able to improve productivity through the iterative incremental process and the active involvement of key customer members in the process [5]. The agile approach should be suitable for small projects and not for large-scale projects, but less for large-scale projects. The recommended number of team members is between five and nine [22] to be self-managed, and it might be not feasible to create the self-managed team in large-scale projects.

Although there are a few empirical studies to support the conclusion that the agile method can improve the likelihood of project success [5], our preliminary study suggested that agile development has been applied in the project situations where novelty on market, system complexity and likelihood on large-scale rework (rate of changes [1]) are all relatively higher [23]. However, the contribution on the cost-benefits would have been very marginal [5, 23]. This paper will compare project size, rate of changes, and cost-benefits of hybrid approach, agile method and plan-driven method.

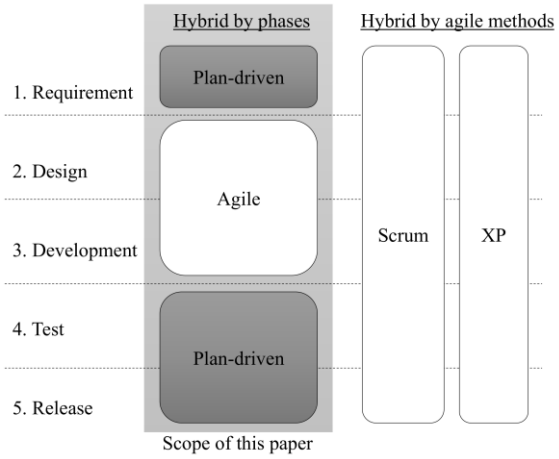

Fig 1. Hybrid approaches

2.2 Hybrid Approach

Recent research suggests an increasing tendency to use hybrid approach for enterprise level projects [2, 3, 4, 5]. Consequently, practitioners are faced with three options: plan-driven, agile methods and hybrid approaches [2, 3, 24]. For example, in the field of product development with a high level of novelty, flexible project management methods along with concurrent engineering, and spiral models with prototypes are often considered [25].

The literature review revealed two types of hybrid approach. The first approach is to use both traditional plan-driven and agile variants, depending on the project phase [1, 3, 4, 5, 26]; we denote this as "Hybrid by phases." The second alternative involves utilizing mixed methods, via Scrum or XP for example, or using a plan-driven estimation tool in an agile development [27, 28, 29, 30]. We refer to this as "Hybrid by methods."

Additionally, the hybrid approach can be applied to both IT and non-IT projects. The hybrid approach would be effective in a large system development project where organizational and contractual issues would hinder the iterative development process inherent to agile method [3]. On the other hand, the hybrid approach in a stage-gate model context is often used in hardware product development projects undertaken by small companies [2]. Due to the increasing number of practitioners' articles [3, 31, 32], this paper will focus on "Hybrid by phases" (Fig 1) for IT system development projects.

Although we could only identify few em-

pirical studies which support the idea that hybrid approaches can improve the likelihood of project success, we have proposed an integrated decision-making flow with 13 input parameters for project managers to comprehensively properly plan and execute such an approach [33]. Through the literature review, our decision tree suggests that the hybrid approach can be applicable in large-scale projects with higher requirement uncertainties. For our empirical study in this paper, it is hypothesized that:

(H1) The hybrid approach can be scalable for projects with high levels of requirement uncertainties.

(H2) The hybrid approach can improve project success rates.

III. STATISTICAL DATA ANALYSIS

This section documents our data collection methods and the statistical data analysis results in order to evaluate the two hypotheses stated above.

3.1 Data Collection

To investigate properties of projects that use hybrid approaches, we designed an online questionnaire in order to collect data from practitioners; specifically, project managers and project team members in Japan. The questionnaire was distributed to potential respondents between March and June in 2015; several project management and agile development communities were targeted, as well as the authors' professional networks. Similar approaches to data collection have been utilized in previous studies into agile methods [5, 34]. The questionnaire has several sections with 70 questions in total in order to enable integrative analysis: respondent attributes (demographics), project attributes, project characteristics, project results, and project management methods. The project characteristics, actual results, and project management methods were evaluated with ordinal 5-point Likert scales. The questionnaire and descriptive analysis are provided in Appendix A. In a previous study [23], the authors demonstrated the relationships between project success factors and agile methods with the same questionnaire; however, this paper focuses on the hybrid approach.

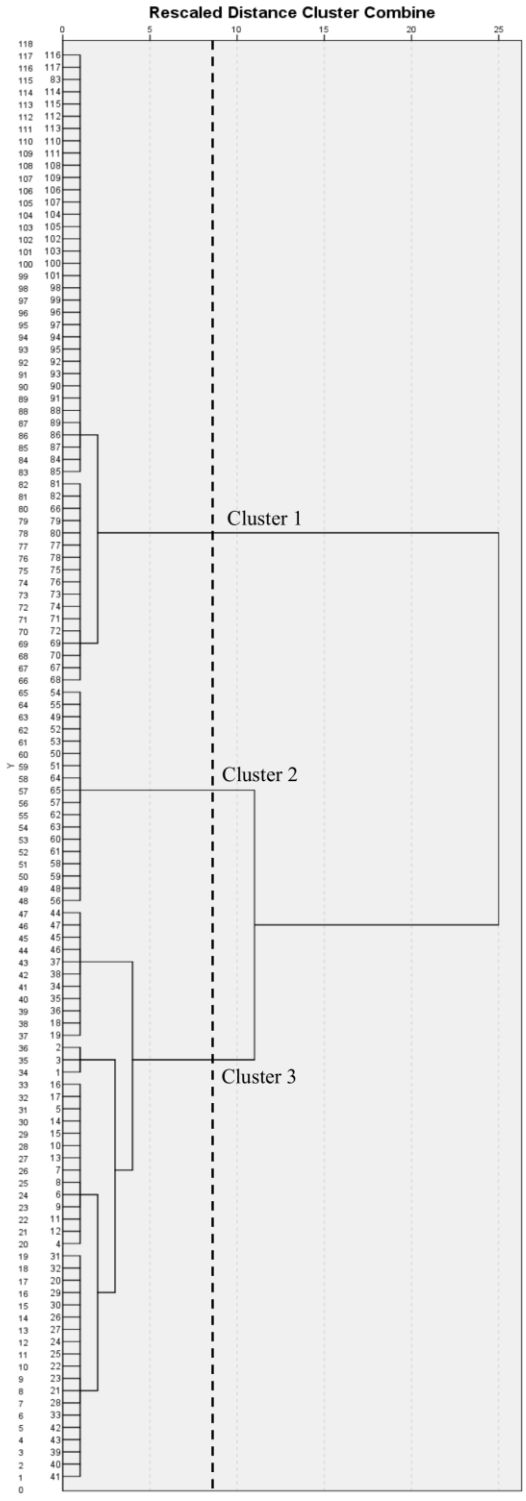

Fig 2. Dendrogram using Ward linkage
(Dashed line is to determine the number of clusters)

Table 1: Methods and project attributes: cluster and ANOVA analysis

Cluster	N	Means and ANOVA								
		Methods		Attributes		Methods in detail				
		Agile method rates	Plan-driven method rates	Project Size	Project Duration	Rate of requirement changes	Scoping in initial phase	Scheduling in single path	Phase gate review with document	Phase gate review with working system
		(Q15_12)	(Q15_11)	(Q8)	(Q9)	(Q10_9)	(Q15_1)	(Q15_2)	(Q15_3)	(Q15_8)
1 (Hybrid)	47	2.77	3.64	1.64	3.45	3.47	3.76	3.26	3.38	3.21
2 (Agile)	18	4.33	1.50	1.56	3.67	3.89	3.44	2.28	2.72	3.83
3 (Plan-driven)	52	1.00	4.67	2.21	3.73	3.10	4.10	4.44	3.92	2.87
All clusters	117	2.22	3.77	1.88	3.60	3.37	3.86	3.63	3.52	3.15
F		119.62	186.79	4.61	0.89	2.85	2.55	26.40	6.43	3.53
p(F)		0.000	0.000	0.012	0.413	0.062	0.083	0.000	0.002	0.032

We collected survey responses from 117 individuals, excluding 27 responses due to missing values. Respondents represented companies which were large (more than 10,000 employees, 27%), medium (500–10,000 employees, 40%), and small (less than 500 employees, 38%). In total 50% of the projects involved more than 20 team members, while the duration of 50% of projects exceeded 1 year. However, 70% of respondents were project managers and 70% of them had over 10 years' experience in project management.

3.2 Statistical Analysis Result

Our hierarchical cluster analysis and one-way analysis of variance (ANOVA) analysis indicated a cluster of hybrid approach which has responses from both agile and plan-driven methods (Fig 2 and Table 1). Using the rates of the agile and plan-driven methods (Q15_1 and Q15_2 in Appendix A), the cluster analysis with Ward methods suggests three cluster; a chi-squared test rejects the null hypothesis that the data are independent (χ^2=17.28, df=2, p<.001).

As is evident shown in Table 1, cluster 1 can be identified as hybrid approach since agile (Q15_12) and plan-driven (Q15_11) methods both feature to a relatively high extent (p<.000). In addition, the hybrid approach (cluster 1) were used in the projects where the rate of requirement changes (Q10_9) was higher as compared to the pure plan-driven methods (cluster 3), and where the project size of projects (Q8) was lager as compared to the pure agile method (cluster 2). These results support the first hypothesis (H1) in section II that the hybrid approach can be scalable for projects with high levels of requirement uncertainties.

In detail, cluster 1 (hybrid) used the plan-driven methods more than cluster 2 (pure agile) and leveraged agile method more than cluster 3 (pure plan-driven). As shown in Table 1, those results can be found in three plan-driven methods (scoping: Q15_1, scheduling: Q15_2, and gate review by document: Q15_3) and one agile method (gate review by the working system: Q15_8). In other responses about plan-driven or agile methods (Q15_# in the Appendix A), significant differences were not found among three clusters.

Furthermore, cluster 1 (hybrid) has a larger average rates of project success on cost (within budget, Q11_1 in Table 2). Cluster 2 (agile) has largest average rates on project quality (Q11_1) and project sponsor identification of the success (Q11_4). Cluster 3 (plan-driven) has a marginally larger average rates of project success on duration (on time, Q11_3). This finding can be extracted through a descriptive analysis in Table 2. Although one-way ANOVA F-test cannot provide support in a statistical sense, in descriptive terms Table 2 results marginally support the second hypothesis (H2) described in section II that the hybrid approach can improve project success rates, specifically in terms of cost.

Table 2: Project success rates for each cluster with descriptive analysis

Cluster		Means and Standard Deviation			
		Quality	Cost	Delivery	Sponsor satisfaction
		(Q11_1)	(Q11_2)	(Q11_3)	(Q11_4)
1 (Hybrid)	mean	4.04	**3.81**	3.96	4.19
	s.d	.908	1.262	3.96	.947
2 (Agile)	mean	**4.33**	3.78	3.78	**4.39**
	s.d	.594	1.114	3.78	.608
3 (Plan-driven)	mean	3.98	3.52	**4.00**	4.15
	s.d	1.229	1.421	4.00	1.161
All clusters	mean	4.06	3.68	3.95	4.21
	s.d	1.028	1.312	3.95	1.005

IV. CASE STUDIES

This section provides qualitative evidence through case studies that used hybrid approaches successfully with specific project properties, and further evaluates the two hypotheses in section II.

4.1 Data Collection

We selected two IT system development projects from two different business organizations that used hybrid approaches. Data were collected through interviews; their authenticity was then validated by accessing publicly available information such as conference proceedings and articles [3, 35]. Two project managers involved in projects that employed the hybrid approach were interviewed to collect information for case studies. Main interview questions aimed to understand (1) needs of key stakeholders, (2) project characteristics such as size and duration, (3) project management approach and its contextual background, (4) issues and measures, and (5) final results and lessons learned from the project. Interview scripts were sent to the project managers ahead of the interviews, followed by 90-minute face-to-face interviews. These interviews were held between March and July 2016. These interviews were held between March and July 2016. The recorded conversations were converted to MS Word documents and sent to interviewees for corroboration.

4.2 Project Alpha

The objective of this large-scale (multiple teams) global procurement system integration project in a leading IT technology company. The objective of that project is to deploy the using a common procurement process and across interfaces with major customers in six countries. Although the highest priority of the stakeholders was to complete the project within 9 months, approximately 50% of the requirements have not been well defined. The project exhibits technical risk in terms of data interfaces and cross-country design alignment which could result in escalated costs to implement the system.

To deal with uncertainties and mitigate risks, the project team adopted a hybrid approach of plan-driven and agile methods. The initial phase used the plan-driven method with 2.5 months included for defining requirements and high-level design. The core project team documented detailed requirements for efficient communication with other teams. The project leader in the core project team stated that "*the initial phase was important to officially reach agreement with all the teams about the documented architecture and review*." In the development phase, the core project team used the Scrum method to respond to changes efficiently. Iteration developments delivered not only functional requirements but also non-functional requirements that are usually managed by the plan-driven method. The development phase also incorporated plan-driven practices such as risk response planning along with multi-national stakeholders. The project team tried to manage the coordination with several teams with a defined architecture document and this plan-driven-like document contributed to effective iterative development and the success of the project. As the project manager revealed to us: *"Using Scrum with a light process of change control, we roughly estimated more than 15% cost (work effort) reduction. But if we did not agree with the architecture document in the initial phase, we could not have identified the source (problem) when they happened and it would have caused a delay with the release. The planning approach to avoid those risks was one of the success factors of this project."*

Table 3: Summary of case study results

	Project alpha	Project Beta
Scope	Procurement system integration project and global roll-out	Web-based human resource management system.
Size	Large (6 team)	Small (single team)
Requirement uncertainty	High (50% of all requirements)	Middle (20% of all requirements)
Agile method	Scrum method in the development phase	Three-week times three cycle of the iteration development with 20% cap of changes
Plan driven method	Documented detailed requirements for efficient communication with other teams. Risk response planning with the defined architecture document	In the initial phase and high-level design phase, quality management process adopted. The test phase has integration and acceptance test.
Results	Successfully completed on time	Successfully completed on time
Cost reduction rates as compared with plan-driven	>15% (estimated)	~8% (measured)

As summarized in Table 3, this case would support the two hypotheses (H1) and (H2) in section II. In a large-scale project alpha that used a hybrid approach with a plan-driven initial phase and a de-

fined architectural document, the project scope was a large-scale (multiple teams) global system integration project. Although approximately 50% of the requirements have not been well defined, the project was successfully completed with the Scrum method in the development phase to reduce change costs.

4.3 Project Beta

The objective of this small-scale (single team) project in a power supply company was to implement a web-based human resource management system. This project required high-level security and rigid authorization control. Further, the system interface is needed with other enterprise systems. Previously, the legacy system was used for many years, and the specification document of the legacy system had not been updated for its migration to the web-based application.

The project management team decided to use a hybrid approach to deal with the uncertainty associated with requirements and to ensure high-level quality assurance. In the initial phase and high-level design phase, the plan-driven method was adopted. With uncertainty cone analysis, the cap of the cost increase was estimated to be 20% of the total cost. In the detailed design and development phase, the agile method with three cycles of iterative development (Scrum) was used. The duration of each iteration was 3 weeks. The test phase was executed as a plan-driven method. Although 20 changes had to be incorporated, the project finished on-time and achieved about an 8% cost-reduction as compared with the plan-driven approach in all the phases. The project manager of the development vendor stated: "*In the plan-driven method, the cost would increase by 50% because the rework had to be done as phase-2 after the first release. In this hybrid approach, such rework did not happen, since the customer was requested to attend meetings after completion of each iteration to review the working of the system…. the customer's satisfaction level was higher in using the hybrid approach than the plan-driven approach. The users can interact with the system easily even without the detailed instruction manual since the detail development was done after listening to user opinions.*"

As summarized in Table 3, this case further supports the two hypothesis (H1) and (H2) stated in section II. In this small project with a high level of requirement uncertainty, the hybrid approach can be used. Using agile iterative development and the plan-driven test phase, the project was successfully completed on-time with a measured cost-reduction as compared with the plan-driven approach.

V. DISCUSSION

The objective of this research is to provide quantitative and qualitative integrative evidence that hybrid approaches work better than traditional plan-driven method or agile method. First, both survey data and the case studies supported the hypothesis that the hybrid approach can be scalable on project size (number of teams) for projects with high levels of requirement uncertainties (H1 in section II). Existing literature has asserted that pure agile methods are more common in small single team consisting of 6-10 members [19]. Our case studies were substantively heterogeneous in scale and scope, yet the hybrid approach worked well in both (Table 3). Second, both survey data and the case studies support the hypothesis that the hybrid approach can improve project success rates (H2 described in section II), specifically with respect to cost. Existing literature has posited that the pure agile approach tends to only offer marginal cost improvements [5, 23]. Our case studies showed that the hybrid approach is expected to provide bigger cost benefit as compared with the plan-driven method in larger-scale IT system development projects (Table 3).

These quantitative and qualitative findings can form the basis of practical recommendations for project managers or project management offices (PMO) to appropriately utilize hybrid approaches. In IT system projects with higher requirement uncertainties and larger numbers of teams, the hybrid approach combining agile development and plan-driven requirement definition and tests would increase the likelihood of improving the cost-benefit ratio by possibly 8–15% as compared with the pure plan-driven method.

VI. CONCLUSION

This paper presented an empirical study of the usage and benefits of hybrid approaches combining the agile and traditional plan-driven methods. Our statistical analysis and case studies provided quantitative and qualitative integrative evidence that hybrid approaches work better in larger-scale project contexts with higher levels of requirement uncertain-

ty. Further, the hybrid approach increases the likelihood of improving the cost-benefit ratio, compared to purely plan-driven methods.

Although these findings may provide practical insights to appropriately utilize hybrid approaches, our empirical study has limitations in that the results may not necessarily generalize beyond our survey sample and case-study interviewees. Our past research indicated that the pure agile method could be used in low-criticality projects and the agile team would need higher skill on agile iterative developments [23]. Further empirical research is certainly warranted to explore and understand the contexts and criteria against which these different methods are appropriate.

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Appendix A. Questionnaire (The responses of the underlined questions were analyzed in this paper.)

#	Questions		
Q1-6	Respondents attributes		
Q1. Industory, Q2. Size of organization, Q3.Annual revenue, Q4. Occupation, Q5. Number of PM experiences, Q6. PMP certification			
Q7-9	Project attributes		
Q7. Project scope and deliverables (text), Q8. Number of team mbers, Q9. Duration			
Q10_#	Project characteristics	Mean	S.D.
1. The project deliverables are new-to-the world products or solutions.		2.94	1.53
2. Reference market data for the products or solutions does not exist.		2.39	1.46
3. The project needs to use a wide range of new technology.		3.23	1.40
4. Necessary technologies do not exist at the project initiation stage.		4.33	1.05
5. The products or solutions contain a widely dispersed collection of systems with a common mission.		3.37	1.29
6. The products or solutions have a complex multi-layer hierarchy of systems and subsystems.		2.56	1.43
7. The project completion time is crucial for success.		3.06	1.40
8. The project have a high-level of project urgency and very much limited available timeframe.		3.08	1.34
9. A high probability of a significant amount effort of redoing a process or activity (rework) is expected due to requirement changes.		3.60	1.27
10. A high probability of a significant amount effort of redoing a process or activity (rework) is expected due to solution changes.		3.10	1.25
11. Project stakeholders including project team are made up of individuals from different countries.		2.83	1.69
12. Project activity locations are geographically dispersed in different countries.		2.91	1.75
13. Project needs and requirements are collected from different countries.		2.33	1.56
14. Project deliverable (products or solutions) are developed by foreign manufactures or service providers.		2.68	1.78
Q11_#	Project results	Mean	S.D.
1. Project completed within budget.		4.06	1.01
2. Project completed by due date.		3.64	1.32
3. The deliverable of the project met the quality specifications.		3.91	1.33
4. Project sponsors considered the project is successful overall.		4.18	1.03
5. Project team members were satisfied with the outcome.		3.82	1.18
6. End users considered that the project deliverable will provide a high level of business benefits.		3.99	0.99
7. A significant amount of efforts of redoing a process or activity (rework) was required due to incorrectly defined requirements.		2.81	1.45
8. A significant amount of efforts of redoing a process or activity (rework) was required due to incorrect solution design.		2.49	1.39
9. A significant amount of efforts of redoing a process or activity (rework) was required due to incorrect development.		2.29	1.32
10. Changes to functional requirements led a significant amount of rework.		2.38	1.38
11. Changes to solution design led a significant amount of rework.		2.21	1.29
12. Changes to stakeholder needs led a significant amount of rework.		2.56	1.40
Q15_#	Project management methods	Mean	S.D.
1. Project schedule with sequential phases was planned and executed.		2.87	1.52
2. Project scope, requirements and the priority were defined in the initiation phase.		3.86	1.14
3. Project phase gate reviews were based on documents and signed-off.		3.63	1.42
4. Customers of the project were mainly involved in the requirement and testing phases.		3.52	1.33
5. Project manager had a governance and control of that project.		3.70	1.19
6. Overlap of iterative phases of requirement definition, design, development and testing was planned.		3.45	1.27
7. Requirements were defined and prioritized in all the project phases.		3.52	1.19
8. Project phase gate reviews were conducted mainly based on working software.		3.15	1.37
9. Customers of the project were involved in all the project phases.		3.33	1.45
10. Team members had a right to make decisions on how to manage and control the project.		3.26	1.27
11. Overall, the project management practice of that project was based on traditional (such as Waterfall) approach.		3.77	1.32
12. Overall, the project management practice of that project was based on Agile one (such as Scrum approach).		2.22	1.39