

Development Framework for Distributed Agile Software Development

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Abstract—There is a growing interest in applying Agile development methods alongside global software development in order to reap the benefits of both approaches. With this said however, research has shown that software companies are encountering significant challenges when attempting this, due to the contradiction between Agile values and the global development environment. This paper focuses on the challenges encountered with this kind of development, and discusses several techniques via which these challenges can be addressed. It proposes a framework for distributed Agile development. Data has been collected from 85 participants from all around the world using both a self-completed questionnaire and face-to-face interviews. From this study it was found that communication barriers are the biggest development challenge. In order to ameliorate this, development teams and product owners need to work hard to improve the level of communication between them, by adopting a regimented communication schedule. The co-located development strategy “Scrum of Scrums”, where distributed isolated teams integrate together using one of the Agile methods, was found to be the most suitable strategy for distributed Agile development.

Keywords—distributed Agile; development framework; Scrum; Lean and Kanban methods.

I. INTRODUCTION

Increased globalization has led to greater competition between software development companies around the world. The software development industry is seeing a shift from co-located software development to Global Software Development (GSD), which involves multiple distributed development teams in different locations. GSD facilitates competitive software development prices by using teams from countries that have an abundance of IT developers available at relatively low cost [1]. In addition, research has shown that software companies are interested in applying Agile Software Development (ASD) to develop the software by global teams, in order to have the combined advantages of ASD and GSD [2][3]. The combination of Agile development methods and GSD is known as Distributed Agile Software Development (DASD). Venkatesh defines Distributed Agile Development as “a model in which projects execute an Agile Methodology with teams that are distributed across multiple geographies” [4]. This combination has shown signs of providing IT companies with the ability to meet the critical success factors of the software industry, such as quality, time, and cost. Sutherland et al. [5] detail their experience of applying a distributed Scrum approach and report several advantages, such as a high increase in team productivity, an increase in the transparency between team members, better building of trust,

and increased project visibility. However, although the potential advantages of GSD are clear, research has shown that software companies are encountering significant challenges by applying this approach. Developers are not always able to apply Agile practices successfully due to challenges introduced through the global development environment, including distance and time zone differences [6].

This paper presents the results of a mixed methodology study. The initial, quantitative part aims to study the impact that the projects’ settings make to the DASD. Inferential statistics will be used to investigate the differences between the development challenges, which have been reported by the study participants, with regards to the demographic information of their projects’ settings. The second, qualitative part involves one specific company, which employs the DASD approach. The study focuses on the challenges of adopting DASD and discusses some possible techniques to address and minimize those challenges. Finally, the results will be integrated to form a development framework to guide users towards a better adoption of DASD.

This paper is structured as follows: first, the related work will be reported. Following this, the research method will be discussed. The results and discussion will be presented in Sections IV and V. Section VI will then address the study validation. Section VI will report the proposed development framework, whilst the final section will contain the summary and conclusion.

II. RELATED WORK

Venkatesh [4] reports some results from surveys by the DH2A Institute. Their data shows that 30% of respondents are using distributed Agile, 40% use local Agile development, and about 85% of them have distributed teams. In addition, the 30% of respondents that stated they are using distributed Agile explained their use of this approach by the advantages and successes they achieved from this kind of development, such as reducing the development cost, accessing the talent pool and resources, increasing team productivity, and decreasing the cost of having high quality software.

However, Software companies are likely to encounter significant challenges and large obstacles when they adopt DASD. Developers may not be able to apply the Agile methods and practices successfully due to the global development environment. The lack of communication and differences in culture and time zones could create huge challenges for Agile methods [7], [8].

A systematic review studied the application of Scrum practices in global software development using 27 literature

studies, and analyzed the challenges into three categories: communication, coordination, and control [9].

The challenges of using Agile with distributed national teams can be categorized into three types of deficiency: communication, trust, and control [3].

Ensuring effective communication within DASD is a huge challenge. The reasons behind these communication challenges could be summarized into four categories: a lack of communication tools, time zone differences, a lack of English language, and a lack of teamwork. These barriers may limit and decrease communication levels in a distributed development [10].

There is a current need for more studies to improve our understanding of how best to adopt Agile methods within global software development. There is a lack of theoretical models of distributed Agile. More studies are needed to address the literature gap by investigating the geographical, cultural, and temporal challenges involved [11].

Previously, we conducted a systematic literature review focusing on the challenges of applying DASD [12]. One of the significant findings of that review was that most of the DASD studies cover the technical perspective of the development but lack coverage of the human perspective. The review also reported that: "The human perspective needs to immediately search to explore the effect of the cultural differences on the relationship between the stakeholders and the development process" [12]. This paper aims to address this issue by exploring the challenges and techniques of applying DASD from the developers' point of view (i.e., the human perspective). Moreover, the systematic literature review classified the development challenges under a four-dimensions model (Communication, Culture, Management, and Agile). This study will provide further investigation into this model and will aim to propose a development framework for this development approach.

III. RESEARCH METHOD

This paper presents a mixed methodology study including both quantitative and qualitative data. This study has been applied to a simple random sample from the study population. According to Kumar [13], the simple random sample is the most popular way to ensure randomization, as each element in the study population has an equal chance of selection. The questionnaire was distributed online to 45 online LinkedIn Agile groups from around the world and many IT organizations were invited to get involved in this investigation. Further collaboration came from two Agile conferences, who sent the questionnaire to their attendees: Lean Agile Scotland Conference 2012 and Agile Worlds - Distributed Agile Conference 2012. Moreover, some software companies agreed to distribute the questionnaire to their staff, although only one global IT development company agreed to let one of its teams be interviewed. All the team members have applied the distributed Agile development and have had a good experience with this kind of development approach.

The questionnaire was configured as a web-based online questionnaire because of the need to gather information from a large number of participants, from a sample study

distributed across a number of continents. In addition, the participants were all IT professionals, meaning they were not going to have any difficulties in completing an online questionnaire. The participants were invited to answer the questionnaire online. It ran for five months, from July 2012 to December 2012. Over 120 responses were collected by the end of the data collection stage, including the self-completed questionnaire and the face-to-face interviews; 85 of these were eligible and reliable enough to be investigated. The excluded responses included incomplete responses or responses with "fake" answers (e.g. putting the same answer for all the questionnaire points).

This section addresses the data collection and analysis procedures. It will report the quantitative part first, and then the qualitative one.

A. The quantitative data

The main content of the questionnaire can be classified into two groups of items:

1) *The demographic items – "Categorical variables"*: This section aims to collect information about the background of the participants, such as the number of developers involved and the Agile method applied. This section will contribute to a better understanding of the correct setting for the application of the DASD approach.

2) *The development challenges – Likert scales*: This section will use the four-dimensions model, in the form of Likert scales, to evaluate a list of challenges within each dimension. It aims to provide a better understanding of the level of expected issues with this development, by showing what the participants think about the listed points.

This paper will investigate the differences between these responses, with regards to differences between the participants' demographic information. Several null-hypotheses need to be formulated which assume no significant differences between the tested variables until the inferential statistics can prove significant differences. In this case, the alternative hypotheses will be accepted, otherwise the null-hypotheses will be accepted [14]. Estler et al. [15] used the null-hypotheses technique in similar work, in order to study the differences between Agile and structure development. This paper has 10 main null-hypotheses, based on the number of the demographic variables that will be investigated as follow:

H₁: There are no significant differences between the responses of the respondents to the development challenges scales due to the location of the Product owner.

H₂: There are no significant differences in the development challenges scales due to differences in the Number of Developers in the development teams.

H₃: There are no significant differences in the development challenges scales due to the Agile development method adopted.

H₄: There are no significant differences in the development challenges scales due to the Number of different time zone areas amongst development teams.

H₅: There are no significant differences in the development challenges scales due to the Number of distributed teams.

H₆: There are no significant differences in the development challenges scales due to differences in participants' Agile experience.

H₇: There are no significant differences in the development challenges scales due to having development participants from different cultures.

H_8 : There are no significant differences in the development challenges scales due to the Number of different time zone areas that the teams are placed into.

H_9 : There are no significant differences in the development challenges scales due to differences in the participants' Distributed Agile experience.

H_{10} : There are no significant differences in the development challenges scales due to differences in the applied Distributed development strategy.

Each one of these null-hypotheses has four sub null-hypotheses for each development scale. The development challenges scales data within this study are Likert scale data, so they need to be treated as nonparametric data [16], [17], [18], [19]. The Mann-Whitney U Test needs to be applied to test the differences for the variables with two groups, and the Kruskal Wallis Test for the variables with three groups [14]. Moreover, the median, mean rank and effect size need to be reported to show whether the differences are significant cases or not. Pallant [14] also reports Cohen's criteria [20] to describe the effect size: 0.1 is considered a small effect size, 0.3 a medium effect size and 0.5 a large effect size.

B. The qualitative data

The qualitative data was collected through structured interviews. The interviews were face-to-face and recorded with a voice recorder. Also, notes of the main ideas and answers were taken during the interviews. The data was transcribed from verbal form to textual form. The transferred documents were then compared to the notes from the interviews, to ensure the reliability of the data. Following this, a thematic analysis was applied, which is an approach to identify the themes and patterns from the collected qualitative data [21], [22]. In addition, the data-driven method was selected for the thematic analysis of this study. The data-driven method, regarding to Asnawi, can be summarized in five steps, as follows: "(i) reducing the raw information, (ii) identifying themes within subsamples, (iii) comparing themes across subsamples, (iv) creating a code, and (v) determining the reliability of the code" [23].

The interviews were carried out at a large, global IT development company. The company has 27 offices distributed through 11 countries around the world: Australia, Brazil, Canada, China, Germany, India, Singapore, South Africa, Uganda, the United Kingdom and the United States. The company provides software design and delivery services, as well as development consulting services. It also produces customized software products as tools to support distributed Agile software development, thus helping the development teams to communicate, share information and track progress. The company applies Agile methods in order to develop its global software projects and has been involved in the software industry for the past 20 years. The company requested to remain anonymous within this study.

Three interviewees with good experience of Agile methods and the distributed development approach agreed to participate in this study. Participant-1 had experience working with over 15 teams spanning the entire globe, both East and West, including teams from countries such as India, USA, the UK and Australia. Participant-2 had 4 years of experience, including a special course in Agile development during his master's degree, as well as significant experience when it came to working with stakeholders from different

cultures, including people from China, Europe, the UK, the USA and the Middle East. Participant-3 acquired a vast amount of experience before joining the company, since he developed a project while both the product owner and business analyst were away from the development team. He also had experience working with customers from different countries including New Zealand, Australia and the USA.

IV. QUANTITATIVE RESULTS AND DISCUSSION

This section presents the quantitative inferential analysis of the study's null-hypotheses that were reported earlier. The following subsections present the results of each null-hypothesis and its sub-hypotheses in detail, in those cases where there is a significant difference.

A. Product owner location

This demographic variable explores whether the product owner (key stakeholder) was located with one of the development team on-site. It has two answer groups: Yes (i.e. the product owner was located with one of the development teams), and No (i.e. the product owner was not located with one of the development teams).

TABLE I: THE RESULT OF THE MANN-WHITNEY U TEST WITH THE PRODUCT OWNER VARIABLE

	Communication scale	Culture scale	Management scale	Agile scale
Mann-Whitney U	685.000	715.500	772.000	515.000
Wilcoxon W	1813.000	1796.500	1900.000	1596.000
Z	-1.395	-0.781	-0.515	-2.797
Asymp. Sig. (2-tailed)	0.163	0.435	0.606	0.005

Table I above illustrates the U test results. It shows that the difference is highly significant within the Agile scale, with $p = 0.005$ (≤ 0.01) as a high significant level, so in this case the null-hypothesis for this scale will be rejected and the alternative hypothesis accepted. To investigate the significant differences further, the median and the mean rank are recorded in Table II. The first group has a higher mean rank value of 48.3 while the second group has a value of 34.7. The effect size in this case is $r = 0.31$. This would be considered a medium effect size, based on Choen's criteria [20].

TABLE II: RANKS FOR THE AGILE SCALE BASED ON THE PRODUCT OWNER

Product owner	N	Mean Rank	Median	Sum of Ranks
No	34	48.35	3	1644.00
Yes	46	34.70	3	1596.00
Total	80			

Table II shows the median and the mean rank. The first group has a higher mean rank value of 48.3 while the second group has a value of 34.7. The effect size in this case is $r = 0.31$. This would be considered a medium effect size. It is recommended that the product owner is placed onshore with one of the development teams. Having the product owner located on-site with one of the development teams

significantly reduces the risk of any Agile development problems, in terms of the distributed Agile approach. This ensures good levels of communication between the developers and the customers, as well as enabling the development teams to receive rapid feedback. The result shows that having the product owner (key stakeholder) located with one of the on-site development teams could reduce the challenges to the Agile dimension by 31%.

B. Number of developers

This demographic variable has two answer groups: 1) there were 15 developers or fewer within the development team, and 2) there were more than 15 developers within the development team. Table III illustrates the U test results. It shows that the difference is highly significant within the Agile scale, with $p = 0.006$ (≤ 0.01) as a significant level. In this case, the null-hypothesis for this scale will be rejected and the alternative hypothesis accepted.

TABLE III: THE RESULT OF THE MANN-WHITNEY U TEST WITH THE NUMBER OF DEVELOPERS VARIABLE

	Communication scale	Culture scale	Management scale	Agile scale
Mann-Whitney U	786.000	661.000	671.000	532.500
Wilcoxon W	1689.000	1441.000	1491.000	1312.500
Z	-.542	-1.608	-1.706	-2.766
Asymp. Sig. (2-tailed)	0.588	0.108	0.088	0.006

Table IV reports that the first group has a higher mean rank value of 47 while the second group has a value of 33.6. The effect size in this case is $r = 0.30$, which would be considered a medium effect size. This indicates that having a greater number of developers does not create more difficulties for the Agile practices. The group with 15 developers or fewer had more Agile dimension issues. 15 members or more had fewer challenges with regard to the Agile dimension – specifically, problems were reduced by 30%. This hypothesis shows that an increase in team members could reduce Agile issues. In other words, a larger number of development participants will help to improve communication and will provide a better environment for Agile adoption. For instance, regarding DASD challenges such as language barriers, members could help each other to communicate better with other team members when they experience communication difficulties. Agile philosophies and values support the idea of having more team members to provide a better environment for sharing information and collaboration as applied with XP programming practices.

TABLE IV: RANKS FOR THE AGILE SCALE BASED ON THE NUMBER OF DEVELOPERS

Number of developers	N	Mean Rank	Median	Sum of Ranks
15 developers or less	41	47.01	3	1927.50
More than 15 developers	39	33.65	3	1312.50
Total	80			

C. Agile methods

There are 7 variables representing the Agile methods, with each variable checking one of the applied development

methods (Agile approach in general, Scrum, eXtreme Programming (XP), Scrum/XP hybrid, Lean and Kanban, and Feature-Driven Development (FDD)). Some of the questionnaire participants chose more than one of the Agile methods so this section will investigate each Agile method separately in order to identify any significant differences between the respondents who used or did not use that particular Agile method. The U test results show several significant differences regarding the adopted Agile method. Firstly, the Scrum method has significant differences to the management scale, with $p = 0.006$ (≤ 0.05) as a significant level. Table V shows the U test results for applying the Scrum approach.

TABLE V: THE RESULT OF THE MANN-WHITNEY U TEST WITH USING SCRUM METHOD

	Communication scale	Culture scale	Management scale	Agile scale
Mann-Whitney U	625.000	655.500	516.500	671.500
Wilcoxon W	1900.000	1880.500	1791.500	1847.500
Z	-1.583	-0.965	-2.734	-0.786
Asymp. Sig. (2-tailed)	0.113	0.335	0.006	0.432

To investigate the significant differences further, the median and the mean rank are recorded in Table VI. The first group has a higher mean rank value of 49.3, while the second group has a value of 35.8. The effect size in this case is $r = 0.30$ (medium effect size). Applying the Scrum method within the DASD may decrease the risk of challenges arising, with regard to the management and control dimension, by 30%.

TABLE VI: RANKS FOR THE MANAGEMENT SCALE BASED ON USING SCRUM METHOD

Use Scrum method	N	Mean Rank	Median	Sum of Ranks
No	31	49.34	3	1529.50
Yes	50	35.83	2	1791.50
Total	81			

Secondly, the Scrum/XP hybrid method has significant differences to the communication scale, as shown within Table VII (with $p = 0.006$ (≤ 0.05) as a significant level), and also to the Agile scale (with $p = 0.03$ (≤ 0.05) as a significant level).

TABLE VII: THE RESULT OF THE MANN-WHITNEY U TEST WITH USING SCRUM/XP HYBRID METHOD

	Communication scale	Culture scale	Management scale	Agile scale
Mann-Whitney U	415.500	558.000	520.500	439.000
Wilcoxon W	2245.500	2269.000	2350.500	2209.000
Z	-2.770	-1.040	-1.588	-2.124
Asymp. Sig. (2-tailed)	0.006	0.298	0.112	0.034

To investigate the significant differences further, the median and the mean rank are recorded in Table VIII and Table IX. The effect size with regards to the communication scale is $r = 0.30$ (medium effect size), and to the Agile scale it is $r = 0.23$ (small effect size).

TABLE VIII: RANKS FOR THE COMMUNICATION SCALE BASED ON USING SCRUM/XP HYBRID METHOD

Use Scrum/XP hybrid method	N	Mean Rank	Median	Sum of Ranks
No	60	37.43	3	2245.50
Yes	22	52.61	3	1157.50
Total	82			

The research result suggests that applying the Scrum/XP hybrid method to DASD may increase the challenges faced, with regard to the communication and collaboration dimensions, by 30%. So it is therefore better not to adopt this development method in DASD.

TABLE IX: RANKS FOR THE AGILE SCALE BASED ON USING SCRUM/XP HYBRID METHOD

Use Scrum/XP hybrid method	N	Mean Rank	Median	Sum of Ranks
No	59	37.44	3	2209.00
Yes	21	49.10	3	1031.00
Total	80			

The research result shows that applying the Scrum/XP hybrid method with DASD may increase the challenges with regard to the Agile dimension by 23%. Applying this methodology within DASD is not sufficient where the setting of the distributed development is concerned, so it is therefore better not to adopt this development method with DASD.

Furthermore, Table X illustrates the U test results for the use of the Lean/Kanban method. This development method has significant differences to the culture scale (with $p = 0.016$ (≤ 0.05) as a significant level), and also to the Agile scale (with $p = 0.00$ (≤ 0.05) as a significant level).

TABLE X: THE RESULT OF THE MANN-WHITNEY U TEST WITH USING LEAN/KANBAN METHOD

	Communication scale	Culture scale	Management scale	Agile scale
Mann-Whitney U	702.000	529.500	601.500	305.500
Wilcoxon W	1108.000	935.500	1007.500	683.500
Z	-0.572	-2.415	-1.644	-4.490
Asymp. Sig. (2-tailed)	0.568	0.016	0.100	0.000

To investigate these significant differences further, the median and the mean rank are reported in Table XI and Table XII. The effect size with regards to the culture scale is $r = 0.26$ (small effect size), and to the Agile scale it is $r = 0.50$ (large effect size).

TABLE XI: RANKS FOR THE CULTURE SCALE BASED ON USING LEAN/KANBAN METHOD

Use Lean/Kanban method	N	Mean Rank	Median	Sum of Ranks
No	52	44.32	3	2304.50
Yes	28	33.41	2	935.50
Total	80			

TABLE XII: RANKS FOR THE AGILE SCALE BASED ON USING LEAN/KANBAN METHOD

Use Lean/Kanban method	N	Mean Rank	Median	Sum of Ranks
No	53	48.24	3	2556.50
Yes	27	25.31	2	683.50
Total	80			

The research result would suggest the use of the Lean/Kanban method to be highly recommended. Applying the Lean/Kanban method within DASD may decrease the challenges to both dimensions: the culture dimension by 26%, and the Agile dimension by 50%.

The U test results show no significant differences within the rest of the development methods, including the Agile approach in general, eXtreme Programming (XP), and Feature-Driven Development (FDD).

The result indicates that there are significant differences from the Agile methods variables for all four scales (communication, culture, management and Agile), so the null-hypotheses will be rejected and all of the alternative hypotheses accepted.

D. Number of time zone areas between development teams

This demographic variable has two answer groups: 1) there are no time zone “spaces” between teams (the “space” [gap] here represents one time zone that has no stakeholders placed in it), and 2) there are one or two time zone spaces between development teams. Table XIII illustrates the U test results. It shows that the difference is significant within the communication scale with $p = 0.031$ (≤ 0.05) as a significant level, so in this case the null-hypothesis for this scale will be rejected and the alternative hypothesis is accepted.

TABLE XIII: THE RESULT OF THE MANN-WHITNEY U TEST WITH THE NUMBER OF SPACES VARIABLE

	Communication scale	Culture scale	Management scale	Agile scale
Mann-Whitney U	527.500	669.000	692.500	630.000
Wilcoxon W	2123.500	1020.000	2288.500	2170.000
Z	-2.163	-0.409	-0.385	-0.642
Asymp. Sig. (2-tailed)	0.031	0.683	0.700	0.521

To investigate the significant differences further, the median and the mean rank need to be reported. Table XIV shows that the first group has a lower mean rank value of 37.9 while the second group has a value of 49.2. The effect size in this case is $r = 0.23$. This would be considered a small effect size.

TABLE XIV: RANKS FOR THE COMMUNICATION SCALE BASED ON THE NUMBER OF SPACES

Number of the space between time zones	N	Mean Rank	Median	Sum of Ranks
No space between teams	56	37.92	3	2123.50
There is a space 1 or 2 spaces	26	49.21	3	1279.50
Total	82			

Having no “space” means that there is less than 5 hours time difference between any given development team and

the next closest team, which would mean they have at least 3 overlapping working hours. Having one or two spaces could allow time differences of between 5 and 11 hours. Teams with these time differences could have no overlapping working hours between them, which could bring on many communication challenges to the development. It can increase the challenges with regard to the communication and collaboration dimensions by 23%. It is therefore recommended to maintain a time zone difference of less than 5 hours.

E. Number of distributed teams

This demographic variable has two answer groups presenting the number of distributed teams: 1) less than three distributed teams, and 2) three distributed teams or more.

TABLE XV: THE RESULT OF THE MANN-WHITNEY U TEST WITH THE NUMBER OF DISTRIBUTED TEAMS VARIABLE

	Communication scale	Culture scale	Management scale	Agile scale
Mann-Whitney U	832.500	728.500	749.500	745.500
Wilcoxon W	1693.500	1589.500	1610.500	1606.500
Z	-0.080	-0.824	-0.918	-0.559
Asymp. Sig. (2-tailed)	0.936	0.410	0.358	0.576

Table XV above illustrates the U test results. It shows that there are no significant differences with all the four scales (communication, culture, management and Agile), so the null-hypothesis will be accepted.

F. Agile years of experience

This demographic variable has two answer groups representing the years of experience with Agile: 1) four years of experience or less, and 2) more than four years of experience.

TABLE XVI: THE RESULT OF THE MANN-WHITNEY U TEST WITH THE AGILE YEARS OF EXPERIENCE VARIABLE

	Communication scale	Culture scale	Management scale	Agile scale
Mann-Whitney U	662.500	686.000	674.000	639.500
Wilcoxon W	1158.500	1961.000	2000.000	1914.500
Z	-1.325	-0.767	-1.212	-1.182
Asymp. Sig. (2-tailed)	0.185	0.443	0.225	0.237

Table XVI above illustrates the U test results. It shows that there are no significant differences with all the four scales (communication, culture, management and Agile), so the null-hypothesis will be accepted as below.

G. Multi cultures

This demographic variable has two answer groups: 1) the development teams include participants from different cultures, and 2) the development teams do not include participants from different cultures.

TABLE XVII: THE RESULT OF THE MANN-WHITNEY U TEST WITH THE MULTI-CULTURES VARIABLE

	Communication scale	Culture scale	Management scale	Agile scale
Mann-Whitney U	177.500	148.000	208.500	226.000
Wilcoxon W	205.500	169.000	236.500	254.000
Z	-1.527	-1.631	-0.975	-0.541
Asymp. Sig. (2-tailed)	0.127	0.103	0.330	0.589

Table XVII above illustrates the U test results. It shows that there are no significant differences with all the four scales (communication, culture, management and Agile), so the null-hypothesis will be accepted.

H. Number of time zone areas that the teams are placed into

This demographic variable has two answer groups: 1) all the development teams are placed into one time zone, and 2) the development teams are placed into more than one time zone (2-4).

TABLE XVIII: THE RESULT OF THE MANN-WHITNEY U TEST WITH THE NUMBER OF TIME ZONES VARIABLE

	Communication scale	Culture scale	Management scale	Agile scale
Mann-Whitney U	674.000	660.000	775.500	760.000
Wilcoxon W	1377.000	1695.000	1810.500	1750.000
Z	-1.599	-1.492	-0.0578	-0.333
Asymp. Sig. (2-tailed)	0.110	0.136	0.563	0.739

Table XVIII illustrates the U test results. It shows that there are no significant differences with all the four scales (communication, culture, management and Agile), so the null-hypothesis will be accepted.

I. Distributed Agile experience

This demographic variable has three answer groups, representing the level of distributed Agile experience: 1) less than one year of experience, 2) between one and four years' experience, and 3) more than four years of experience.

TABLE XIX: THE RESULT OF THE KRUSKAL WALLIS TEST WITH THE DISTRIBUTED AGILE EXPERIENCE VARIABLE

	Communication scale	Culture scale	Management scale	Agile scale
Chi-Square	5.222	3.519	3.916	0.927
Df	2	2	2	2
Asymp. Sig.	0.073	0.172	0.141	0.629

Table XIX illustrates the Kruskal Wallis test results. It shows that there are no significant differences with all the four scales (communication, culture, management and Agile), so the null-hypothesis will be accepted.

J. Distributed development strategies

This demographic variable has three answer groups exploring the development strategy: isolated development (teams are distributed geographically but are not cross-

functional), co-located development (distributed isolated teams integrate together using one of the Agile methods), and fully integrated development (teams are distributed geographically and work cross-functionally, using Agile development). Table XX illustrates the Kruskal Wallis test results. It shows that the difference is significant within the management scale, with $p = 0.038$ (≤ 0.05) as a significant level, so in this case the null-hypothesis for this scale will be rejected and the alternative hypothesis accepted.

TABLE XX: THE RESULT OF THE KRUSKAL WALLIS TEST WITH THE DEVELOPMENT STRATEGY VARIABLE

	Communication scale	Culture scale	Management scale	Agile scale
Chi-Square	0.128	2.623	6.562	0.317
Df	2	2	2	2
Asymp. Sig.	0.938	0.269	0.038	0.854

To investigate this result further, there is a need to apply the Mann-Whitney U test as a follow-up test to identify the differences between each pair groups. The table below shows that the significant differences are between the first and the second group based on the U test results.

TABLE XXI: THE RESULT OF THE MANN-WHITNEY U TEST THE DEVELOPMENT STRATEGY VARIABLE AND THE MANAGEMENT CHALLENGES SCALE

	Management scale
Mann-Whitney U	167.000
Wilcoxon W	728.000
Z	-2.199
Asymp. Sig. (2-tailed)	0.028

Table XXI shows that there are statistically significant differences between the isolated development strategy and the co-located development strategy on the management scale, with $p = 0.028$ (≤ 0.05) as a significant level which is less than the alpha level of .05. The effect size is considered as a medium effect, with $r = 0.31$ (medium effect size). Table XXII below shows that the isolated development strategy group has a higher mean rank value of 31, while the second group (co-located development) has 22.

TABLE XXII: RANKS FOR THE MANAGEMENT SCALE BASED ON THE DEVELOPMENT STRATEGY

Development strategy	N	Mean Rank	Median	Sum of Ranks
Isolated	16	31.06	3	497.00
co-located	33	22.06	2	728.00
Total	49			

Having the development teams isolated and not cross-functional may lead to a lack of management and control. Development teams may have problems when combining their developed functions. The study result shows that the isolated development strategy increases the challenges faced, with regard to the management and control dimension, by 31%. The co-located development "Scrum of Scrums" was found to be the most suitable strategy for DASD.

V. QUALITATIVE RESULTS AND DISCUSSION

This section presents the results of the qualitative data by investigating the challenges and the mitigation techniques under the four dimensions model: communications, cultural differences, management and control, and Agile skills

A. Communication and Collaboration Challenges

1) Lack of communication and losing the ability to make immediate decisions (A1): Agile methods require interactive, daily communication among stakeholders. This is difficult to provide within the global environment. The lack of communication and collaboration is a significant issue within the DASD approach [24]. Team members were not able to make immediate decisions, because of the distance between the participants and the lack of communication. As mentioned by Participant-3: "We lose the ability to have an immediate decision. If we were here at 11am and we wanted to know something straightaway the earliest we could hear from our product owner will be 3pm and that's only if he's got up very early."

2) Time zone differences (A2): The time zone differences is one of the main reasons that cause DASD's communication challenges [8]. The distance and time zone differences among stakeholders could reduce the available overlap of working hours of distributed teams. Participant-3 reported the issue of having no overlap of working hours by: "I think if you had two teams where their working days didn't overlap at all, so if you had the UK and the East Coast of Australia where there's something like a 10 hour difference, I don't think that would work".

3) The lack of English language skills (A3): In most cases, the English language is not the mother tongue of the offshore team members. The lack of proficiency in English could pose a major challenge for the development teams. The different levels of English among the stakeholders could create misunderstandings [25], in the event of people trying to express or indicate meaning by a hint and expecting the others to understand them. Participant-3 reported that: "If you're having a discussion and there's a thing that you don't say and you assume the other person knows and it's implied, that's where you get the chance for errors".

Participant-2, who is not a native English Language speaker, described his experience with communication with people with different level of English as hard. Participant-2 stated that: "The other thing which might be hard is that different people have different levels of English knowledge.". Also, Participant-2 mentioned some difficulties with understanding native speakers who are speaking with a difficult accent or speaking in a fast way: "Sometimes it's hard to understand people who are speaking English as their mother language, as well".

B. Communication and Collaboration Techniques

1) Find a time and a way for synchronised communication (B1): It is important to create an overlap of working hours among the distributed teams. The overlap hours will be used as available time for synchronised communication. Participant-3 reported there should be at least 2 hours of overlapping: *“If you have two teams in different time zones their working days have to have some overlap and if they don't have some overlap and if they don't have some overlap then you need to change the working hours of one of those teams so there is an overlap. I think there needs to be, I would say, at least two hours overlap between those two teams so they can talk face-to-face”*.

With some cases that require staying late, the project manager and the business analyst could stay late to communicate with the other stakeholders. Participant-1 stated that: *“PM or BA or whoever needs to showcase something to the client, they need to stay for a while.”*

2) Flexibility regarding working from home (B2): Working hours should be flexible; therefore, the team members should be able to work from home when necessary. This flexibility could help to create overlapping hours among teams. Participant-1 reported that: *“Yeah so the company gives you the opportunity and flexibility to work from home. They also provided the broadband.”*. Participant-2 stated as well: *“The people are free to do and people are getting flexible times to do work from home or work from somewhere else when they are away from the office”*.

3) The communication schedule should be regimented (B3): The development stakeholders should have a daily, regimented communication schedule (i.e., Communication Road Map CRM). Such a schedule would help to increase the communication level. Participant-3 reported that: *“I think you need to do what we're doing here at this company and have a very regimented communication schedule”*. The product owner should make himself available to communicate with the development team as Participant-3 said: *“I'd say from our product owner's point of view he's got to make sure that he's very involved and he keeps himself aware with what we're up to”*. Communication, as reported earlier, is the main issue with the DASD development, so it is necessary to increase the level of communication among the distributed teams. Participant-3 summarised that by: *“You've got to make sure that you communicate well with the stakeholders”*.

4) Ask people to speak clearly and be explicit (B4): Regarding the different levels of English skills among the stakeholders, there is a need to speak clearly and to be explicit about what is wanted. Participant-3 mentioned that: *“It's much better to be explicit and to really make clear what you want”*.

5) Apply multi-channels for communication (B5): There is a need to have multi-channels for communication. There

should be a choice of method and use of the one best suited, such as phone calls, video Skype calls, voice over IP and texting. Participant-2 reported that: *“We are using voice over IPs and the video services. We use Skype, we use GoToMeeting, we have an internal voice over IP device here”*, and reported as well: *“we use our own internal service for chatting”*. In addition, software to share the screen and knowledge helps teams to share information and increase the visibility of the development. Participant-2 mentioned that: *“So, I can say, tools are really important in distributed systems”*.

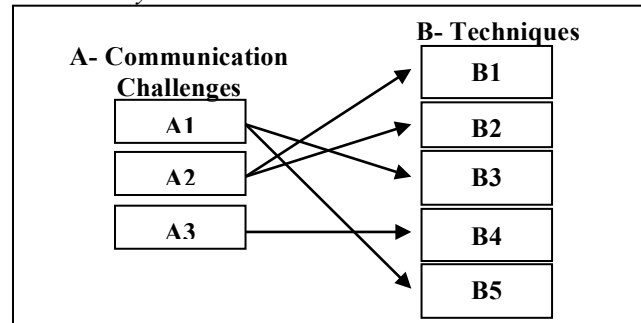


Fig. 1 Communication with DASD challenges and techniques

Fig. 1 illustrates the recommended techniques to address communication and collaboration challenges. It links the challenges with the techniques in order to provide better understanding of them. For example, to address challenge A1, techniques B3 and B5 can be employed. Finally, the CRM must identify a main communication channel that should be selected, based on the project setting and infrastructure. The communication costs with the selected channel need to be considered. The plan should report synchronous and asynchronous channels with an explanation of how to use them.

C. Cultural Differences Challenge

The cultural differences of the stakeholders could create certain misunderstandings [25]. Participant-2 reported that: *“There are a lot of different things in a culture. Like, in some countries, people really like to talk about politics”*. Cultural differences could limit the communication between development participants in order to avoid any misunderstandings. Participant-2 stated: *“I feel I know, if somebody from a different culture joins our team, how to behave and then how to find the limits on paid programming, how to speak to people, what sort of questions to ask, what sort of questions not to ask. So, these are the things which we learn”*.

D. Techniques to Address the Cultural Differences

1) Creating an open culture within the development teams (D1): There is need to promote an open culture among the project's stakeholders, encouraging people to be free, flexible and liberal. Team members should accept other cultures and try to understand them. Participant-1

mentioned that: “our culture rules are very liberal, free, there is no dress code. The people are free to do and people are getting flexible times to do work from home or work from somewhere else when are they away from the office. So this flexibility provides a lot of appreciation to the developers and all the people”. Participant-2 also stated that there is need to be flexible within the people from different cultures: “people who are working in a distributed team, I guess should be more flexible than people who are working on a one - centralised process”.

2) Move the developers between the teams (D2): Providing the team members with the opportunity to move between global offices could help them to discover and explore other cultures. Participant-1 mentioned that by: “there is a global assignment program which runs every year and it gives a chance to people to work round in any office in the world. So it's a very diverse culture in the company”.

3) A training course for new members (D3): New team members should have a special training course to provide them with the required Agile skills and make them aware of other cultures. The investigated company has a multi-cultural training centre in Bangalore, India. This could help new members to understand different cultures as reported by Participant-1: “Once you hire anyone, if it's a fresh then he's a graduate. We send them to a university. There is a university which runs in India, in the Bangalore office”. And Participant-1 mentioned as well: “All the students around the world gather with a different culture in India. They do works together on the same project for three months. After that we send them across different global assignments”.

4) Choose people who fit in with the distributed development culture (D4): Before hiring new people, they should be interviewed to ensure that they fit in with the open culture of the DASD. Participant-1 stated that: “Always choose the people who actually fit with the culture. We don't choose people who don't fit with the culture”.

In addition, new members should have a qualifying period of a few months, to make sure they fit in with the development culture and environment as reported by Participant-1: “Even after that, there is a probation of three months, okay. So in the three months itself it is enough time to know the person's attitude and whether - how he is behaving in all the steps. So if he doesn't fit in the culture then we don't extend their assignment”.

5) Flexible working hours and places (D5): This practice was mentioned when addressing communication issues and could also help to increase trust between the company and its employees, one of the cultural issues within the DASD. Participant-1 stated that: “They do - they know all right that the company the flexibilities providing to them it come with a trust. So the company's putting trust on

them so they, of course, need to do the work properly and they also need to put the trust in the company”.

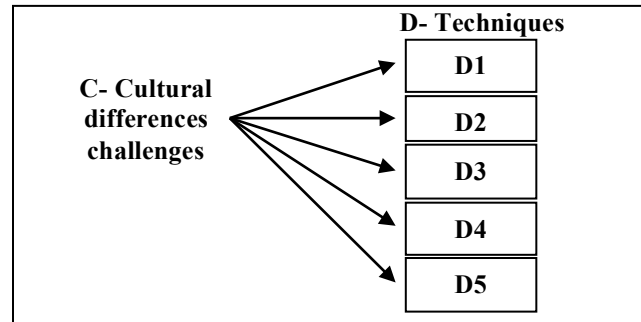


Fig. 2 Cultural differences with DASD challenges and techniques

Fig. 2 illustrates the recommended techniques to address the cultural differences challenges. Techniques D1 to D5 have been applied by the company to minimize the impact of the cultural differences to the development. The cultural differences could reduce the communication as reported early within this section and limit the collaboration between the team members.

E. Management and Control Challenges

1) Updating the developed story on the online wall (E1): Development participants with the DASD approach usually apply an online story wall to track progress. In some cases, they have issues with not updating the developed story on the online wall. This could lead to duplication when developing the required functions/stories. Participant-2 declared that: “So, sometimes, you - when you get into a story and then it finishes the phase and you start another story, you may forget to move it on the electronic wall”.

2) Estimation difficulties (E2): The second management challenge is with estimation. Large teams could have difficulties with estimating their stories. Participant-2 explained this issue by: “Estimation for example is one thing that it's hard. So when you have 20 people online and you have 20 people here and you want to estimate stories!!”.

F. Management and Control Techniques

1) Increase communication (F1): There is a need to increase the level of communication in order to manage the work and to resolve any misunderstandings. Participant-3 mentioned that the communication is required to better apply DASD: “If we do a lot of communication then we can apply all the practice of Agile globally”. Participant-2 reported that as well: “There should be a lot of communications between the teams as well”. In addition, Participant-1 stated the same thing to manage the distributed Agile development: “Any company you go there would be the challenge to manage such a vast distributed work, right? It requires a lot of communications; it requires a lot of coordinations between all the offices to work together right”.

2) Use software management tools (F2): Using software management tools is required to apply different Agile practices within the distributed development environment. Those tools support the development, make it more visible and easier to track. The tools usually have an online wall for the development stories, which is required to keep it coordinated with the normal story wall. Participant-3 declared that: *“So we have story wall, but that's all replicated in an online tool and we make sure that we keep those two in sync so that the product owner at any time can look at our entire story wall and see what's in progress”*. And Participant-2 mentioned the same as well: *“is really important and there are not - and you should be able to first of all, be responsible for updating the electronic wall”*.

3) Split large teams (F3): Having a large number of participants could make it difficult to apply some Agile practices, such as estimation. Therefore, splitting large teams could be a solution. However, this requires a lot of communication and coordination between the divided teams. Participant-2 agreed with that by: *“You split the team, you have two PM, you split the number of developers, you will add a new BA. But there should be a lot of communications between the teams as well”*.

4) Estimation cards (F4): This practice aims to address the estimation issue. The participants would have a card to estimate each story and they would then show their cards and discuss issues. Participant-2 mentioned that technique by: *“we talk about the story and we count to three and everybody should show a card, or show their hands”*.

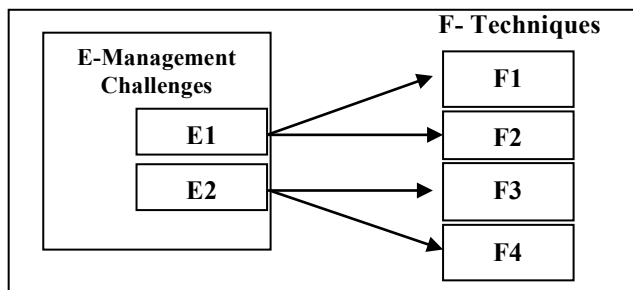


Fig. 3 Management with DASD challenges and techniques

Fig. 3 links the management challenges with the recommended techniques in order to provide better understanding of them.

G. Agile Level Challenges

1) Lack of a close relationship (G1): The distributed development could result in losing the main aspect of Agile, which is the close relationship between the development participants. Participant-3 mentioned that by: *“I think the main problem with global is - with Agile it's very important to maintain a close relationship to your customers”*.

2) Working with traditional organisations/ customers (G2): Traditional organisations/customers may not accept the Agile way of development. They may be used to

traditional development approaches, such as the waterfall model [5]. This could decrease the Agility level of the development. For instance, traditional organisations may take their time to allow the developers access to their database or to the necessary information. Participant-2 reported that: *“We speak a lot with tech team, with manager's team, with anyone who can - but they are traditional companies. They have a lot of paperwork for just getting one server, access to one server, or access to a database. But, in an agile company you just ask for something. In our company if you need to access anything...we just ask and we get it as soon as we can. But it's sometimes in other, in client side, in the companies which we are working for they have their own database team which we - a manager should give you permission”*. And Participant-2 stated that as well: *“There have been problems with those things. Like database is the obvious one that we can say, you don't get the access to them. You need to go through their process”*.

3) Difficulty in applying some Agile practices (G3): The global development setting could make it difficult to apply some Agile practices [22]. For example, the stand up daily meeting is difficult within the distributed Agile development, because of the large number of participants and the lack of visibility among the meeting attendees. Participant-2 reported that by: *“I guess the whole point of stand up is visibility so that you can see somebody and you can ask a question”*, and by: *“So imagine if 100 people want to talk for one minute each, it would be a bout two hours while people are standing”*.

Furthermore, applying the retrospective practice with the distributed development is difficult as well. Participant-2 stated that: *“Retrospectives are getting affected. Because retrospectives in an agile team are, I guess I feel it's the most physical thing happens because what we do is that we practice different type of RETROS. So what we do is that every iteration that we have RETROS we change them. So we try a lot - because we don't want to make it boring”*

H. Techniques for the Agility Level

1) Use software tools to enable some Agile practices (H1): Usually, development teams adopt various software tools to help them to apply Agile practices. Participant-3 reported that: *“We've done some remote pair programming with him. We use tmux which is a UNIX tool for sharing terminals and we used a VNC client called Chicken and we also use Skype and SSH to set up the connection. So with a combination of those we can have a live pair programming session and that worked quite well”*. In addition, Participant-2 stated that as well: *“Tools are really important., learning how to work with tools are taking time. You may need more efforts”*.

2) Dealing with the issues of traditional organisations (H2): Sometimes, IT development companies avoid working with a traditional product owner who is not able to

understand Agile values. Sometimes, they try to provide the traditional product owner with some training about the Agile approach before the project begins. Participant-2 mentioned that: “So the way that we work is that we try not to accept projects in our company that clients don't give us the chance of working in a way that we want. But some projects it happens that we try - so in some projects when the clients accept that we work for them, but they are not working in agile way. So usually we try to teach, teach the team which we are going to work with them. We communicate a lot, we talk a lot, we have lots of meetings in our team. So we try to settle these things before accepting a project”.

3) Practice for the stand up daily meeting (H3): Practice includes throwing a ball during the meeting. The member who has the ball is the one who is allowed to speak. This practice aims to manage the meeting by allowing one person to speak at a time. In addition, they hold computer tablets, such as iPads, during the meeting to see the distributed members. This practice reported by Participant-2 as: “we use iPad and we ask them to be online and they talk about it. So we have a ball as a token. We throw it to each other when someone is going to talk.”.

4) Apply simple documentation (H4): One of the techniques in the DASD approach is doing simple reports to share information from the meetings with participants who were not able to attend. Participant-2 declared that by: “Usually one person writes a simplify - a very simple report that this happens, this decision has been made. This is the reason that we make this decision. So we just read that email every night for example and we get updated about what's happening. If we don't like it, we can state it the day after, or we can send an email and discuss it”.

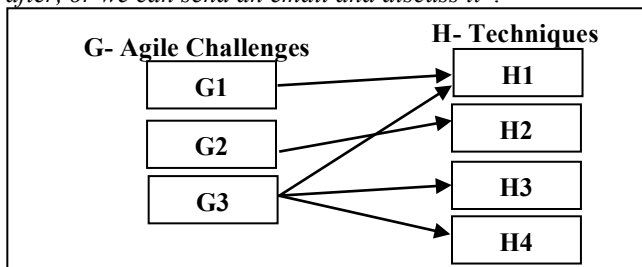


Fig. 4 Agile challenges and techniques with DASD

Fig. 4 reports the Agile challenges and links them with the recommended techniques to award better apply for Agile methods with the distributed development.

VI. VALIDATION

This section addresses the study validation, which could be classified into two categories: the validation of the qualitative data, and the validation of the quantitative data.

A. Validation of the qualitative data

To ensure the validity and the reliability of the study's qualitative analysis and to identify any elements of bias from the researcher, two procedures were applied. Firstly, after the final code was developed, it was tested by other researchers, who applied it to the raw data to ensure that the code and theme analyses were correct. The second procedure was to have the transcripts rigorously checked by other researchers, comparing them to the verbal records and the notes that had been taken. The aim of this was to identify any transcription errors or mistakes [23].

B. Validation of the quantitative data

To ensure the validity of the quantitative data, the questionnaire has been piloted by experts in the field of Agile software development. The aim of this was to check whether the questions are measuring what they aim to measure in an appropriate way. In addition, with multiple-item scales such as the Likert Scale, variables of internal reliability need to be tested. One robust method of achieving that is to apply Cronbach's alpha coefficient. This shows the correlation among all items in the scale. The ideal Cronbach's alpha level is above 0.7 [14]. Table XXIII shows the Cronbach's alpha values for the study scales.

TABLE XXIII: CRONBACH'S ALPHA FOR THE QUESTIONER SCALES

	Scale	Reliability	N of Items
1	The level of communication and collaboration barriers with Distributed Agile Software Development (DASD)	0.888	10
2	The cultural differences (organizational and region culture) barriers with Distributed Agile Software Development (DASD)	0.875	6
3	The lack of management and control within Distributed Agile Software Development (DASD)	0.700	5
4	The lack of Agile with skills within Distributed Agile Software Development (DASD)	0.748	5
5	Total for the challenges scales	0.765	26

Table XXIII shows the Cronbach's alpha values for each scale. The first four scales represent the challenges scales. The Cronbach's alpha values for those scales are all above 0.7. In addition, the alpha value for the all challenge scales is 0.765. That means the scales and their items are internally consistent.

VII. DEVELOPMENT FRAMEWORK FOR DASD

This section integrates the development strategy of the company under investigation with the study findings in order to provide a standard development framework for DASD. Fig. 5 and Fig. 6 illustrate the proposed framework and it can be organized into four development phases.

The earliest phase is the startup phase, which aims to ensure readiness for the DASD on the development teams' side, and on the product owner's side as well. The communication between product owner and development

teams will be established during this phase. A training course for new members is recommended, as reported within D3. D4 and H2 are also recommended techniques for this phase.

The next stage is the design phase, which includes the gathering of all participants in one place for a few days, to finalize the requirements and estimate the deadline of the project. One of the main techniques that need to be identified within this stage is the design of the CRM. The mitigation techniques for this stage include B1, B3 and B5

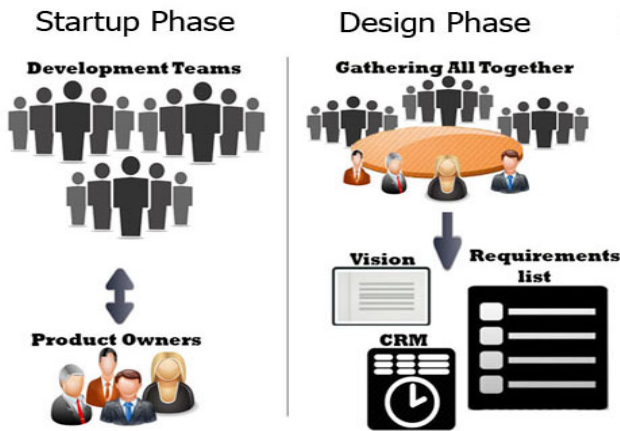


Fig. 5 Startup and Design phases of the development framework

The next phase is the inspection and analysis phase, which aims to break the requirement and development tasks into small development stories. These stories will then be organized and linked to each other. Applying an estimation card can help within this stage, as reported earlier.

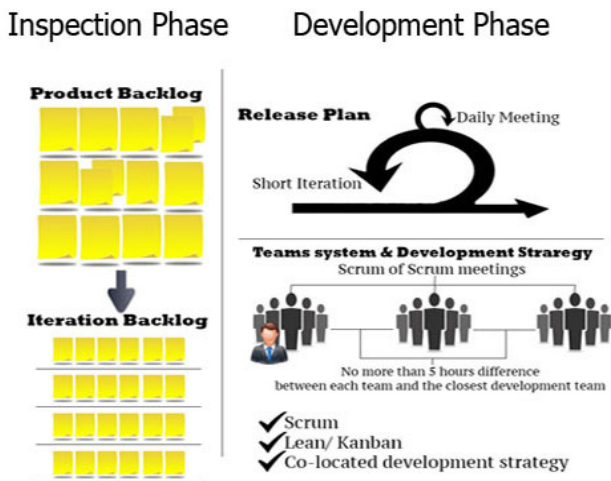


Fig. 6 Inspection and Development phases of the development framework

The final stage is the development phase. Most of the mitigation techniques and study recommendations are linked to this phase, including: D2, F1, F2, F3, F4, H1, H2, and H4.

Firstly, teams should have a daily meeting and weekly iteration to increase the level of communication. It is recommended that the product owner be located within one of the development teams. Teams need to have a local meeting and then Scrum of Scrum practice should be applied, to link teams together. In other words, the co-located strategy should be adopted to manage the development teams. In addition, it is recommended to use Scrum or Lean/ Kanban practices as an Agile development method to reduce the development challenges. To reduce the challenges presented by time zone differences, it is not recommended that teams have more than a 5-hour time difference between them and their next closest development team.

Other techniques, such as B2, B4, D1, and D5, are recommended during all the development phases.

VIII. SUMMARY AND CONCLUSION

This paper has presented a mixed methodology study. It has explored the significant differences between the demographic variables and the development challenges scales. The Kruskal Wallis test and the Mann-Whitney U test have been applied as inferential statistics to investigate 10 null-hypotheses. Five of these were rejected and their alternative hypotheses were accepted.

The reported results suggest that communication barriers are the biggest challenge faced when employing the DASD approach. A number of techniques were reported by the participants to address the known communication issues affecting this approach. Most of the issues related to the lack of communication between stakeholders. The development teams and product owners need to work hard to increase the level of the communication between them.

The other main issue encountered was the lack of Agile skills and knowledge from the developers and the product owners. A global setting makes this issue all the more pronounced, because of the distance between the stakeholders. In these cases, there is a need to improve knowledge of Agile by providing training courses and Agile coaching, to ensure the sufficient application of Agile practices.

The management issues are also related to the distance and the size of the development teams. Improving the communication level and Agile skills could reduce these management difficulties. Splitting teams may be with a solution for teams with a large number of developers.

The issue of cultural differences is the least important problem because most of the stakeholders are aware of each other's cultures and have the ability to work with different people. However, some misunderstanding could arise, particularly through a lack of communication. Thus, it is essential that the development participants are clear, flexible, and open with those from other cultures. The experience with DASD from the investigated company helped develop a clearer understanding of the challenges of cultural differences. The application of techniques such as training courses can help to minimize these cultural differences issues. Moving the team members between the various development teams throughout the world will also help them

to better understand other cultures and could address this issue.

In conclusion, this case study has highlighted some of the major challenges of applying DASD. It has also proposed a development framework that outlined several development practices to achieve a more effective application of this development approach. The discussion has shown that the study findings are in agreement with existing literature on most of the investigated points.

Future work will involve further investigation into the proposed framework in order to understand its impact on the DASD approach.

IX. ACKNOWLEDGMENT

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