Virtual Team Configurations that Promote Better Product Quality

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ABSTRACT

Managers need to decide on how they will configure their virtual teams each time a new project starts. So questions such as 'Which countries should be involved in the project?' and 'How large should the team size be?' need to be answered before hand. Project configurations are known to affect communication, coordination and collaboration aspects of a project, and as a consequence, its performance. Therefore, a challenge managers face is knowing which configurations promote better project outcomes when working with virtual software teams. This article reveals a set of configurations that have promoted the quality of software products developed by virtual teams to support the business of a Fortune 500 large IT multinational company. These configurations can be used as a guideline by managers to set up their own virtual teams. Recommendations on how to set up virtual teams based on the study are then suggested.

CCS Concepts

Software and its engineering → Collaboration in software development.

Software and its engineering → Software development process management.

Keywords

Global software engineering, virtual teams, product quality, team configurations.

1. INTRODUCTION

Suppose you're a project manager from a company that develops software in a distributed fashion and need to decide on how to organize your virtual team for the project that has just been approved with the customer. A virtual team is that in which its members are physically separated and they are forced to rely on technologies to mediate communication and to coordinate work [1]. The company expects you to guarantee that the project will attend the performance measures in place. These could be delivering the project on time, free of bugs, and within the estimated budget. How would you go about organizing the project and its virtual team? Would you assign a large team to deliver the project faster? Would you invite people based on expertise despite their physical location? Would you aim for a small time zone separation to facilitate coordination?

You are not alone. In software organizations, it is often the manager' responsibility to make such project configuration decisions aiming to attend whichever are the organization's performance goals. In software development, configuration refers to the set of factors that a manager has to account to put a project into place, such as the team size and the physical distribution of its members. We know from past work that project configurations affect communication, coordination and collaboration aspects of a project, and as a consequence, its performance (e.g., [2][3][4]).

ESEM '16, September 08-09, 2016, Ciudad Real, Spain

 ISBN 978-1-4503-4427-2/16/09…$15.00

DOI: http://dx.doi.org/10.1145/2961111.2962638

However, we still know little about it when considering virtual software teams [5]. In this article we present which project configurations better influenced the performance of over 1,000 virtual software teams of a Fortune 500 large IT multinational company. Our findings confirm anecdotal knowledge that the smaller the number of allocated team members, the fewer countries involved in, and the lesser the hours spent, the better the quality of the product developed. Also, that the lesser the days allocated, the less critical are the defects found by the customer in production. Surprisingly, we also found that the higher the time zone and the physical separation, the smaller the deviation from the planned effort estimation suggesting that distribution does not affect project performance of virtual teams. In addition, we identified a negative correlation between the hours spent, the number of team members, and the number of involved countries with the overall project performance. A closer look at the projects with better performance reinforced the results above. Our findings provide empirical evidence to support managerial decisions on project configuration. Based on the findings of our study, we present some recommendations on how managers can configure virtual teams to maximize the performance of their distributed projects.

2. STUDY OVERVIEW

We investigated a large IT multinational company headquartered in the USA. Software to support the business processes (e.g., online sales) and internal operations (e.g., employees' career development) is developed in-house. Projects range from new product development to the customization of software packages, the maintenance of legacy systems, and the integration of complex systems. Its development centers are located in the USA, Brazil, and India. There are also development operations in Canada, Ireland, Russia, Malaysia, Japan, and China. The organization has been previously recognized as a CMMI Level 3 company.

As it develops software for internal customers only, the organization's main concern is to attend the customer's expectations regarding the quality of the software applications. In the organization, quality is measured in terms of the adherence of the software to its business needs and how free of defects the product is. The IT department follows a matrix structure based on business areas (e.g., sales, manufacturing) and IT functions (e.g., developers, testers). Each project has a virtual team allocated to serve the project during its development and the team is dissolved when the project is over. The teams use a large set of standardized tools to support their collaborative and virtual work. Team members are either employees or contractors, and are globally distributed.

3. APPROACH

We collected data on all projects archived between September 2001 and December 2012. A total of 7,365 projects were identified. We eliminated the projects (i) that did not have defects logged in and (ii) that have less than 250 hours reported as actual spent hours, the minimum size in hours the organization considers to define development activities as "a project". Our final dataset is then comprised of 1,049 projects (14.3% of the original) ranging from 2006 to 2012. To identify which configurations promote better project performance, we first identified a set of configurational measures and a set of performance measures that are relevant within the organization's context. The former was pointed out by managers of the organization as relevant criteria that they consider when defining a virtual team for their distributed projects. The later is part of the organization's performance measurement program and was pointed out by the managers as the most used and important measure adopted worldwide by the company. The target scores for the performance measures were used as a reference to identify whether a project attended its expected performance. Next, we analyzed the data aiming to identify: (1) which were the projects that attended the performance measures and their respective configurations, (2) whether a configuration measure individually influences a certain performance measure, and (3) how the configuration measures combined influence the performance measures.

3.1 Introducing the Measures

To identify which virtual team configurations promote better product quality, we used the following measures as defined below.

Configurational Measures

- *Actual effort:* actual number of hours spent in the project. This data was extracted from the management repository, which records the hours worked by team member in a daily basis.
- *Total time:* number of days spent in the project. It was calculated by the difference between the actual finish and the start days. It includes weekends and holidays. It was also extracted from the management repository.
- *Team size:* number of members allocated to work in the project team. It includes members *directly allocated* in the project such as developers and testers, as well as those *indirectly allocated* such as environment configuration analysts and database administrators. This data was extracted from the human resources allocation repository.
- *Countries:* total number of countries involved in the development of a project. Each country has one single development center. This data was identified based on the physical location of the employee extracted from the country information indicated in the human resources repository.
- *Physical separation:* defined based on the spatial dispersion measure proposed by O' Leary and Cummigs [3]. It refers to the physical separation among project members allocated to a project and was calculated as follows: $\frac{\sum_{i-j}^{k}(Km_{i-j} * n_i * n_j)}{(N^2 - N)/2}$, where Km_{i-j} is the kilometers between countries i and j, k = the total number of countries represented in the team, n_i = the number of members in the i^{th} country, n_j = the number of members in the j^{th} country, and N = total number of members across all countries. The number of countries was calculated based on physical location. This data was identified based on the physical location of the employee extracted from the country information indicated in the human resources repository.
- *Time zone separation:* measure defined by O' Leary and Cummigs [3]. It refers to the time zone differences (in hours) among project members allocated to a project and was calculated as follows: $\frac{\sum_{i-j}^{k}(TimeZones_{i-j} * n_i * n_j)}{(N^2 - N)/2}$, where $TimeZones_{i-j}$ are the number of time zones between countries i and j, k = the total number of countries represented in the team, n_i = the number of members in the i^{th} country, n_j = the number of members in the j^{th} country, and N = total number of members across all countries. The total number of countries has been calculated as previously described.

Performance Measures

Performance is mainly defined at the investigated organization in terms of the adherence of the software to its business needs as identified during the validation-testing phase conducted by the end-user and how free of defects the product is in relation to its specifications as identified by the testing team. The company also keeps track of how well the development team is performing by measuring the number of defects produced by developers. Therefore, performance is defined as the quality of the product measured by the number of defects as indicated in literature [6] and categorized as follows:

- *Developer-detected defects (DIT):* percentage of reported defects categorized as 'DIT' over the total of reported defects. DIT defects identified by the Development team during the Unit Testing phase. The organizational measurement target for this measure is >= 70%.
- *Testing team-detected defects (SIT):* percentage of reported defects categorized as 'DIT' or 'SIT' over the total of reported defects. SIT defects are reported by the Testing team when verifying the quality of functionalities, usability, performance, and integration among modules. Target is of >= 95%. Note that this is a cumulative measure.
- *End user-detected defects (UAT):* percentage of reported defects categorized as 'DIT', 'SIT', or 'UAT' over the total of reported defects. UAT defects are reported by the End User during its assessment of the product to be delivered. Target is of >= 98%. This is also a cumulative measure.

Although these measures and values are what is used in the studied organization, we developed an *overall score for product quality* named *quality index* aiming to group the projects by size to facilitate analysis. To generate the index, which is a proxy for size, we normalized the total number of defects by the hours spent per day in the project (the total hours spent in the project divided by the total time of it in days). The formula applied to the quality index is as follows: 1 – (total number of defects / ln(actual effort) / ln(total time)). Using the result of the quality index, we categorized the projects in three groups: Best, Medium, and Worst.

4. STUDY RESULTS

We first identified which projects achieved or failed the target scores for the performance measures and then their respective configurations. Table 1 presents the average value of the configuration measures for each performance measure. Cells highlighted in grey indicate that the averages of failed and of achieved projects are statistically different ($p<0.05$), i.e., this difference did not happened by chance. In sum, results indicate that the projects that have achieved the target for each one of the performance measures are those that have reported, on average, *smaller actual effort* in comparison to those that have failed the target for these measures (e.g., 4,008.16 against 7,866.16 hours for the DIT measure). These projects have also *smaller teams*, on average, than those that have failed. Moreover, team members are distributed in a *smaller number of countries*.

Table 1. Configuration results for the projects that achieved and that failed each of the performance measures

		Product Quality								
		DIT			SIT			UAT		
Variable	**Status**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**
Actuals effort	Failed	998	7866.16	13172.48	686	9145.10	14658.87	589	9179.06	13845.93
	Achieved	51	4008.16	5008.92	363	4907.16	8059.23	460	5757.34	11358.77
Total time	Failed	998	309.76	160.17	686	316.40	170.81	589	314.81	171.04
	Achieved	51	342.82	196.63	363	301.84	144.20	460	306.95	150.14
Team size	Failed	998	25.74	29.17	686	27.45	23.82	589	27.72	24.02
	Achieved	51	17.22	10.57	363	21.30	35.64	460	22.25	33.35
Countries	Failed	998	3.07	1.38	686	3.20	1.39	589	2.88	1.39
	Achieved	51	2.71	1.17	363	2.75	1.28	460	3.18	1.33
Physical separation	Failed	998	4069.50	1823.03	686	4064.29	1777.99	589	4186.44	1746.84
	Achieved	51	4135.04	1848.13	363	4088.55	1908.74	460	3927.03	1909.06
Time zone	Failed	998	3.09	1.73	686	3.02	1.68	589	3.18	1.66
	Achieved	51	3.21	1.67	363	3.24	1.80	460	2.99	1.79

Second, to identify whether a configurational measure influences a performance measure, we tested if there are differences on the values of each configurational measure for the projects grouped into the three categories identified by the quality index. Table 2 presents the mean and standard deviation for the configurational measures in each group. Results indicate that there is a significant difference between the groups in two of the measures: team size and number of countries. In general, group of projects with 'best' scores for the quality index presents lesser average of team size and number of countries involved in the project. This indicates that the smaller the number of team members allocated to the project and the smaller the number of countries involved in it, the higher is the quality of the project. We also checked the correlation between the configurational measures (Table 3) and found that there is significant correlation among the actual effort and total time (in days), team size, and number of countries measures. Moreover, that there is also a positive correlation between the team size, number of countries, physical separation, and time zone separation measures. However, our results corroborate more recent previous findings that time zone and physical separation do not affect product quality. Third and last, we investigated how much the configurational measures influence the performance measures when all of them are taking into consideration all together. Table 4 shows that the quality index is negatively affected by the team size and by the number of countries comprised in the project, being the team size relationship stronger (-.327) than the number of countries (-.088).

Table 2. Influence of configurational measures on performance as per the Quality index

	Best		Medium		Worst	
	Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
Team size	20.03	36.50	22.56	13.60	33.36	29.04
Countries	2.72	1.25	3.02	1.26	3.40	1.50
Time zone	3.06	1.89	3.09	1.68	3.14	1.59
Physical separation	4063.39	1996.47	4092.84	1750.43	4061.80	1716.11
Nr. Deffects	27.93	12.48	95.87	39.26	565.49	635.77
Sample Size	349		350		350	

Note: Quality Index is multiplied by 1,000. $F_{Team\ size}$=22.277, p<001. $F_{Countries}$=22.845, p<001.

Table 3. Correlation between the configuration measures

	Actual effort	Total time	Team size	Countries	Physical separation
Actual effort					
Total time	.480**				
Team size	.825**	.368**			
Countries	.547**	.298**	.616**		
Physical separation	.051	.035	.064	.261**	
Time zone	.071	.015	.095**	.183**	.866**

** p < .01

Table 4. Results from regression analysis for the impact of configurational choices on performance

	Quality Index
Team size	-.327**
Countries	-.088**
Time zone	-.025
Physical separation	.067

Note: values represent the Standardized Coefficients
* p < .05; ** p < .01

5. PRACTICAL IMPLICATIONS AND RECOMMENDATIONS FOR THE MANAGEMENT OF VIRTUAL TEAMS

In sum, our findings indicate that for achieving higher product quality performance, it is better to configure the project in a way that it *spends a smaller number of actual hours*, has a *smaller number of team members* assigned to it, and is distributed in a *smaller number of countries*. Physical and time zone separation did not influence the quality of the product. We discuss implications of such configurations and provide some recommendations to the configuration of virtual teams based on these findings.

Recommendation #1: Aim for less effort in hours to maximize the project performance

Results indicate that projects that achieved each and every of the quality performance measures were those that spent from 4,008.16 (for SIT) to 5,757.34 (for UAT) actual hours. Therefore, we suggest that you aim for having projects with as less hours assigned to it as possible and no larger than about 6 thousand hours to maximize the chances of ensuring quality. It is known that the faster software is put in production the more likely it is to be aligned with current business processes and, therefore, to attend the customer expectations [7].

Recommendation #2: Define smaller virtual teams

Results also indicate that projects that achieved the quality performance measures were those that had from 17.22 (for SIT) to 22.25 (for UAT) team members assigned to it. So, we recommend that you form virtual teams of up 22 members to promote increasing the quality of the product to be delivered.

Recommendation #3: Involve fewer countries when composing virtual teams

In addition, results also show that projects that achieved the performance measures were those that had team members located in 2.71 (for SIT) to 3.18 (for UAT) countries. We advise you to try to involve at most 3 countries when working with virtual teams.

Recommendation #4: Do not concern about physical and time zone separation

Over a decade ago distance was reported as a critical issue in distributed software development (e.g., [8][9]). However, our results corroborate more recent previous findings that time zone and physical separation do not affect product quality (e.g., [10][11]) when working with virtual teams. Therefore, you can build virtual teams that are located in distinct locations and time zones without being afraid of jeopardizing the quality of the software product you will delivered to your customer. This distribution might help you to overcome the challenge of hiring talented people within your neighborhood. However, we call attention that the team size and the number of countries involved in the project have a correlation with these distributions indicating that there is a limit to the number of members a manager can assign to compose the team and to the number of countries the project can be distributed to to avoid that these configurational measures negatively influence the product quality. It is important you watch out for this.

Recommendation #5: Be aware that increasing one configurational measure might request you to increase others as a consequence to guarantee that you will achieve the expected quality

Results demonstrate that there is a positive correlation among the actual effort in hours, total time in days, team size, and number of countries measures suggesting that if you have to increase any of these configurations you might have to increase one or more of the others to comply to the expected quality goal requested.

Recommendation #6: If you have to choose, prefer to reduce team size over the number of countries involved in the project to improve product quality

Our findings indicate that there is a stronger relationship between team size and quality than of the number of countries with quality. This suggests that, if you have to choose between one configuration or another, you rather reduce the number of team members assigned to your project than the number of countries to increase the expected quality.

Our study reveals that the smaller the effort spent, the smaller the team size, and the lesser the number of countries involved in a virtual software team, the more likely it is to have its performance goals meet. It also shows that physical and time zone separation do not affect performance as it used to in the past. Moreover, it also indicates that configurational measures influence each other and as such they cannot be considered isolated. Last but not least, it pointed out that team size has more influence on the quality of a product produced by a virtual team than the number of countries the project is distributed to. Managers can use the recommendations provided to guide their decisions when configuring their virtual teams. Although we have investigated one single organization, our dataset is composed of projects from several business departments promoting an interesting variety of project configuration scenarios. IT companies can organize themselves to also investigate how configurational measures impact performance and then promote discussion among projects teams to propose ways to maximize performance. We understand that other configurations such as organizational structure, team maturity, language proficiency, etc can also have an impact on performance. Our long-term goal is to study them and understand their impact in the performance of virtual software teams. We also would like to investigate other performance measures such as schedule adherence and requirements stability in order to broader our view on project performance.

6. FINAL CONSIDERATIONS

Generalization of our findings has to be considered with caution. Although we have investigated one single organization, our dataset is composed of projects from several business departments promoting an interesting variety of development processes. We understand that other variables such as organizational structure, managerial style, team maturity, programming language, language proficiency, among others, can have an impact to a certain extent on project performance. Therefore, managers must consider these limitations when making use of our findings. Our long-term goal is to study these variables and other factors such as the adoption of collaborative tools, and understand their impact in the performance of virtual teams. We also would like to investigate other performance measures such as schedule adherence and requirements stability in order to broad the way to consider how projects are evaluated in a software organization. Our findings not only corroborate to current evidence (e.g., [10][11]) but also add to knowledge by broadening how quality is defined—we consider quality metrics evaluated by the end user, and by considering additional configurational parameters—actual effort and total time.

7. ACKNOWLEDGMENTS

The authors acknowledge financial support in this research from CNPq (projects 312127/2015-4 and 406692/2013-0), FAPERGS (project 2062-2551/13-7) and the PDTI Program, financed by Dell Computers of Brazil Ltd. (Law 8.248/91).

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