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Agile principles and achievement of success in software development: A quantitative study in Brazilian organizations

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Abstract

The principles of agile development emerge as potential solutions to numerous design problems of software development. In this context, this paper aims to identify and analyze the profile of Brazilian software producers regarding the use of agile principles and their potential to achieve success in producing software. This is a quantitative study made with professionals from the software industry. Data were collected through structured questionnaires and analyzed using technical descriptive analysis, factor analysis and cluster analysis. Based on the categorization of factors, three software organizations profiles have been obtained regarding the use of agile principles and the scope of success in producing software. The implications of this study are that organizations with the highest success rates in software are the same as those that have higher rates for capacity in terms of team, culture, communication with the client, environmental configuration and relationships with external partners. Organizations that used agile software development principles achieved success in software development, but it cannot be said that the use of agile principles alone can guarantee the achievement of such success in software development. Additionally, relationships with external partners, although not contemplated in the related studies investigated, was shown to be a critical factor for success in software development and, therefore, relevant to the agile software development field. In conclusion, this study is relevant because it helps to improve our understanding of the use of agile principles in the development of software and whether these principles are associated with obtaining success in software production; therefore, it explores a new factor that has not been observed previously.

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Keywords: Agile methodologies; Agile principles; Success in software; Software development; Information systems management.

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1. Introduction

Software development projects involve high failure rates, which are part of a large set of challenges that software development companies face [1]. Given such challenges, researchers and practitioners have opened discussions about the most appropriate approaches to develop software products with greater efficiency and effectiveness. In a dynamic and very complex process, such as software development, studies have pointed to methods with more iterative natures, which provide greater flexibility, improved interaction with customers and better results [2].

Given this scenario, in the 2000s, *The Agile Manifesto*, developed by a group of 17 specialists, arose. The principles of the Manifesto called for agile software development to direct its focus on: effective communication among team members and between the team and its clients and users; variable scope, in which changes in requirements during the project are accepted as intrinsic to software development; rapid delivery of software to the client; and team self-management, to provide flexibility and efficiency in the development [3].

In fact, there are growing reports of achieved improvements in the adoption of agile development methodologies [4]. However, some gaps in our understanding of this issue still persist and need to be understood. Currently, research on agile methodologies is in itsearlier stages, especially with regard to the results obtained by companies applying agile methodologies [5].

Dybå and Dingsøyr [5], in making a systematic review of works associated with agile methodologies, highlighted a poorly understood issue regarding the application of agile methodologies in organizations: What are the results produced by agile methodologies in software companies?

Although the work of Livermore [6] approached the principles of agile XP (Extreme Programming) that are being adopted by software industry professionals, there exists a lack of studies that focus on a broader set of agile principles.

This work is fundamental. Dybå and Dingsøyr [5] and Hasnain [7], in recent works, published excellent systematic reviews of the literature, in which all previously conducted empirical studies on agile methodologies were revised. However, neither of these studies found work that was similar in nature and scope to the study reported in this presented work. The profile identification of organizations is quite a neglected subject.

Given this context, in order to deepen the understanding of agile principles usage in Brazilian organizations that produce software, this paper presents the following research question: What are the profiles of Brazilian organizations that produce software regarding the use of agile principles and success achievement in software production? To address the research question, this study aims to identify and analyse the profiles of Brazilian organizations that produce software using agile principles and to examine their success achievement in software production. This paper is structured as follows: this introduction section, the literature review, the methodology, the results, the discussion and the conclusion.

2. Success in software development

In the literature, there is a wide variety of interpretations for the meaning of success in software development [8], leading to a diversity of descriptive variables for this phenomenon. Among the different perspectives from which success in software development can be assessed, those that characterize success in software development, in general, are associated with (1) time [9, 8, 10-13]; (2) scope [8, 10, 12, 14]; (3) cost [9, 8, 10-12]; and (4) quality [9, 8, 10, 11, 15, 12]. These are considered essential [16]. However, other factors have also been considered for the description of the results obtained and of success initiatives in software development, such as (5) customer satisfaction [8, 17, 12]. In terms of success attributes, which depict the full perception of project success, Cohn and Ford [18], Lindvall and Muthig [19] and Lee and Xia [20], suggest that quality is delivering a good work product, scope is project alignment according to the specified requirements, time is on-time software delivery and attending to deadlines and cost is cost adequacy regarding developed budgets and efforts. Moreover, according to Agarwal and Rathod [8], Misra and Kumar [17] and Paiva and Varajão [12], customer satisfaction is meeting customers' expectations.

3. Exploring the principles for success in agile software development

The literature review presents factors associated with agile principles that influence success in software development. These factors will be described below.

3.1. Team capacity

People are considered key to the success of software [21, 10, 17]. It has been argued that getting the right people with the right skills and empowering them in decision making is fundamental to agile development success [10]. As a result, the ability of the team is also considered a critical success factor in software projects. The presence of trained staff is a primary requirement for achieving successful software projects. In this sense, different characteristics of teams have been identified as essential for both the adoption of agile methodologies and the achievement of success in software development.

According to Lindvall and Basili [21], teams formed by competent persons in technologies that are essential for software projects can meet deadlines, attend to scopes and promote customer interaction. In this sense, note that, in agile projects, it is preferable to have teams with a few competent, reliable and experienced people, rather than many people without these qualities. Wan and Luo [22] and Wan and Wang [23] emphasize that software success depends largely on the leadership of team members, the recognition and respect of leaders, and the self-discipline to work in an organized way. Leadership is pointed out by Wolff, Fagundes and Cabral [24] as being responsible for the effectiveness for motivating job performance.

3.2. Communication with customers

Communication is also a factor considered relevant for understanding the results of agile methodologies, and it is critical to success in software development [21, 25, 26]. Recurring problems are caused by miscommunication with customers [21].

Interaction and communication with the customer have also been shown to be important agile principles [21, 25, 26]. Close and frequent interactions with clients are a critical factor for the success of agile methodologies [21]. Given this premise, studies have sought to understand the factors that bring about such interaction.

For Lindvall and Basili [21], motivation corresponds to the key point that allows an organization to establish close ties with a client. Another important factor related to customer communication is documentation. In the context of agile development, the quality and usefulness of documentation represent a key point for development teams that can explain solutions that meet customer problems. Thus, documents produced during the project need to be useful, ensuring adequate support in interactions with client representatives [21].

3.3. Environmental configuration

The interaction among development team members constitutes an important factor for success in software development [3, 21, 17, 27]. In the search for an understanding of how to develop environments and approaches that facilitate interaction between team members, studies have focused on different variables.

One factor that influences team interaction is the quantity of members comprising the staff [21, 17]. Nevertheless, organizations that wish to be agile need to have mechanisms like environmental configuration [5], which means that they need to be organized in order to facilitate engagement among the members, regardless of the number of members in the team. Mechanisms are often recognized as important vehicles for achieving successful projects.

3.4. Culture

Another factor considered relevant is organizational culture. Organizational culture represents the idea of identity and distinction: those features that particularize and distinguish one organization from another [28]. It can be described as a group building its environment and developing discernable behavior patterns among its members [29].

Organizational culture is conceptualized from its constituent elements, which include values, myths, symbols, rituals and rites [30, 31, 28]. Values are defining elements and identify human social groups [28]. Myths play an important role in shaping culture, and they are quickly created and easily perceived by organization members [31]. Symbols are the major manifestations of culture because they are references, objects, actions, events, qualities or relationships that encourage people to act [30]. Rites and rituals are expressed in a dramatic form, and they are the basic values that give meaning, significance, identity and belonging to any group [28].

Culture represents an essential foundation for agile methodologies to be utilized appropriately [32] and to deliver results in organizations [17].

According to Lindvall and Basili [21], the openness of company culture to negotiations between employees is a factor of great importance to the use of agile methodologies. In accordance with [17], in environments characterized

by agile development, agility in decision making depends on the degree of autonomy for planning and control given to development teams.

Thus, agile methodologies should be used within an "agile culture" characterized by extensive support for negotiations, a capacity for change, collaboration and continuous sharing of experiences and knowledge [21, 17].

3.5. Relationships with external partners

The relationships among partners establish themselves in dynamic processes that cover contradictions, paradoxes and conflicts of interest. They require familiarity with ambiguities and respect for singularities in order to identify the convergences and intentions of multiple authors who originate a project and the others who participate in the progress of the project activities [33].

But, despite the conflicts that can happen between partners, cultivating partners to assist in the development of software to cover internal deficiencies in development and to reduce risks from risk sharing is considered relevant to achieving success in software development[21].

According to Dybå and Dingsøyr [5], in order for fast and efficient customer relationships to occur, it is important that there is adequate training in these agile processes. For Lindvall and Basili [21], this training is required to obtain rapid feedback from stakeholders, contributing to agility in the development process and quality in the final products delivered.

4. Research methodology

4.1. Data collection for research

A survey was designed in order to explore agile principles usage relating to success in software production. The survey's first version was pre-tested by two software development companies. Using the results of the pre-test, some modifications were made in order to facilitate the understanding of questions.

The questionnaire, in its final release version, was sent to about 5,000 professionals in the software industry, chosen randomly from available databases. The survey cover letter was sent as the body of the email to briefly describe the questionnaire's purpose. Data were collected between June and July of 2012. The survey was sent to CEOs, CIOs, project managers, business analysts, and software architects. From the total number of sent surveys, approximately 958 were returned, resulting in a rate of return of about 19.16%. Of these, only 409 were considered valid for statistical analysis.

4.2. Analysis steps

The analyses performed on the obtained data are summarized in the following steps. First, to provide an overview of the sample in the surveyed organizations, a descriptive analysis was performed, based on questions 1 through 8 in the questionnaire. Then, in order to identify and analyse the profiles of Brazilian organizations that produce software in relation to the use of agile principles, a factor analysis and a cluster analysis were made performed on responses to questions 9 through 13 in the phase 2 of the questionnaire. The results were interpreted by examining the main differences between the factors in the clusters.

To perform the exploratory factor analysis, a main axes extraction PAF (*Principal Axis Factoring*) was used. Of the many possible types of applications of revolutions, the *Varimax* rotation method was used in this work. The method used to realise the cluster analysis was the hierarchical of Ward, which always aims to minimize the internal variability within clusters. In the end, the standard deviation and the variable averages comprising each factor were calculated, and the means of all factors were determined for the three identified groups in the cluster analysis.

All analyses were performed using the Statistical Package for Social Science (SPSS for Windows, Version 14, SPSS Inc., Chicago, IL, EUA).

5. Results

5.1. Instrument for the assessment of Brazilian organizations regarding the use of agile principles and success in software development

The survey contained a total of 16 questions, divided into two phases: a demographic profile and an analysis of the usage of principles of software development by the organization. In the first part, the description of demographics, respondents reported their areas of professional practice, their positions held within the organization, the number of employees in their companies, their organization's administrative classification, the types of product developed in their organizations and whether agile methodologies are used.

The second part of the analysis comprised the usage of the principles of software development by the organization. Respondents indicated, on a Likert scale of six points, their degree of agreement regarding the use of agile principles by the organizations in which they worked. The scale had the values: (1) strongly disagree (always disagree), (2) disagree (disagree most of the time), (3) partially disagree (somewhat disagree), (4) partially agree (somewhat agree), (5) agree (agree most of the time) and (6) strongly agree (always agree). Additionally, the option *NI* (do not know or do not wish to respond) was included for cases in which the respondents did not know or did not want to answer the question.

5.2. Sample description

All five regions of Brazil are represented in the sample. The sample consists of 68.7% respondents working in organizations located in the Brazilian Southeast region; 14.7% respondents working in the South region of the country; 8.0% and 5.6% respondents located in the North and Midwest regions, respectively; and 2.4% respondents working in the Northeast region of the country.

Regarding the number of employees of the organizations, the sample consists of 37.2% of organizations having more than 500 employees, 22.0% of organizations having between 50 and 249 employees, 12.0% of organizations having between 250 and 499 employees, 11.5% of organizations having between 5 and 19 employees, 9.3% of organizations having between 20 and 49 employees, and 7.3% of organizations having fewer than 5 employees.

As to the administrative classifications of the interviewed organizations, the sample consists of 89.2% private organizations, 6.4% mixed-capital organizations and 4.4% public organizations.

Products or services that stood out in the sample were: IT services, with 208 of the respondents; customized software, with 151 of the respondents; mobile applications, with 145 of the respondents; business intelligence solutions, with 145 of the respondents; software administration, with 126 of the respondents; ERP systems, with 118 of the respondents; and e-commerce, with 114 of the respondents.

Regarding the agile methodologies usage time, responses showed that 26.7% of organizations adopt agile methodologies for two years, 22.2% of organizations adopt agile methodologies for one year, 15.4% of organizations adopt agile methodologies for three years, 11.7% of organizations adopt agile methodologies for five years and 11.0% of organizations adopt agile methodologies for four years.

Regarding the stage of maturity regarding the use of agile methodologies, according to the respondents' perceptions, the sample consists of 22.2% organizations in the maturity stage of using agile practices in repeatable processes, 21.8% organizations in the maturity stage of using agile practices ad hoc, 21.0% organizations that are in the maturity stage of using agile practices defined, 20.0% organizations in the maturity stage of the managed use of agile practices and 14.9% organizations in the maturity stage of the optimized use of agile practices.

5.3. Factorial Analysis

To identify which agile principles were correlated, a factorial analysis was used. The goal of factor analysis is to reduce the number of original variables (i.e., the principles) into dimensions that can be explained by the existence of correlation between the original variables. These new dimensions are called Factors.

The first step of the analysis was to verify whether the selected sample could be analyzed using the factorial analysis technique. Through this technique, the variability in the survey responses that originated the discovered factors is explained.

The validation of the data generated by the analysis can be tested using the KMO (Kaiser-Meyer-Olkin) method.

Measure of sampling adequacy	*Kaiser-Meyer-Olkin*	0.912
Sphericity Test	Q^2 Approximation	5961.318
Bartlett	DF	300
	Sig.	0.000

Fig. 1. KMO coefficient of exploratory factor analysis and Bartlett's sphericity test for sample

Fig. 1 summarizes the information regarding the factor analysis validation. The first index, the KMO, is equal to 0.912, which, according to Hair and Tatham [34], is admirable because it is greater than 0.800.

Bartlett's test shows a significance value of 0.000, which, according to Hair and Tatham [34], indicates that there are sufficient correlations between variables. Since Bartlett's sphericity test was less than 0.05, exploratory factorial analysis is appropriate [35].

Regarding the number of factors, the exploratory factorial analysis showed a structure of six factors that explain 60.197% of the variance of the survey responses, considering greater-than or equal-to-one eigenvalues, as recommended by the latent root criterion [34, 36].

Table 1. illustrates the variables corresponding to each of the six factors extracted.

Table 1. Solution of the sample factorial analysis

	F1	F2	F3	F4	F5	F6
Agility in team communication	**0.556**	0.086	0.077	0.215	0.255	0.433
People collaboration capabilities	**0.785**	0.057	0.099	0.106	0.108	0.080
Team communication capabilities	**0.639**	0.065	0.112	0.238	0.260	0.356
Competence of persons	**0.597**	0.068	0.085	0.167	0.123	0.127
Confidence among team members	**0.674**	0.127	0.159	0.195	0.291	0.285
Participation of leaders	**0.528**	0.292	0.138	0.200	0.215	0.149
Leader recognition	**0.633**	0.202	0.120	0.254	0.101	0.122
Project scope	0.066	**0.756**	0.014	0.010	0.066	-0.052
Quality of projects	0.150	**0.841**	0.000	0.096	0.121	0.038
Term projects	0.124	**0.754**	0.045	0.071	0.022	0.031
Customer satisfaction with the projects	0.087	**0.836**	0.055	0.103	0.085	0.093
Interaction with partners in software development	0.097	0.068	**0.655**	0.170	0.224	0.132
Interaction with external partners	0.187	0.003	**0.808**	0.229	0.105	0.048
Risk reduction with external partners	0.119	-0.009	**0.823**	0.092	0.119	0.039
Customer training	0.085	0.096	**0.453**	0.133	0.401	0.156
Organizational openness to talks	0.263	0.071	0.189	**0.596**	0.157	0.124
Agility in design decisions	0.388	0.194	0.222	**0.498**	0.217	0.162
Team autonomy in projects	0.255	0.080	0.209	**0.784**	0.166	0.088
Flexibility to changes	0.318	0.130	0.219	**0.528**	0.268	0.156
Useful documentation for the team	0.384	0.129	0.290	0.178	**0.425**	0.165
Useful documentation for the customer	0.380	0.076	0.248	0.218	**0.468**	0.076
Frequency of interactions with customers	0.317	0.105	0.201	0.258	**0.674**	0.138
Customers' motivations	0.267	0.150	0.239	0.175	**0.678**	0.169
Environmental configuration	0.261	0.102	0.131	0.156	0.117	**0.756**

The six factors extracted from the factorial analysis are described in detail in Table .

Table 2 Factors identified to characterize agile software development

Factor	Description
F1 - Team capacity	This first factor presents significantly high factor weights for agile principles related to people involved in software development and organization and communication teams. The biggest factor weights justify the agreement of respondents regarding the principles that compose and characterize the factor (*i.e.*, agile team communication, the collaboration capabilities of individuals, team communication capability, confidence among team members, the competence of persons, the participation of leaders and the recognition of leaders).
F2 - Success in software development	This second factor presents significantly high factor weights for agile principles related to success in software development. The biggest factor weights justify the agreement of respondents regarding the principles that compose and characterize the factor (*i.e.*, scope, time, quality and customer satisfaction with the project).
F3 - Relationship with	This third factor presents significantly high factor weights for agile principles relating to external development

external partners	partners. The biggest factor weights justify the agreement of respondents regarding the principles that compose and characterize the factor (*i.e.*, interaction with external partners, interaction with partners in software development, risk reduction with external partners and customer training).
F4 - Culture	This fourth factor presents significantly high factor weights for agile principles related to the culture of organizations. The biggest factor weights justify the agreement of respondents regarding the principles that compose and characterize the factor (*i.e.*, the opening of negotiations for organizations, agility in design decisions, autonomy in team projects and flexibility to changes).
F5 - Communication with the customer	This fifth factor presents significantly high factor weights for agile principles communication during software development. The biggest factor weights justify the agreement of respondents regarding the principles that compose and characterize the factor (*i.e.*, useful of documentation for the team and the client, frequency of interactions with the customer, customer motivation and customer training).
F6 - Environmental configuration	This sixth factor presents significantly high factor weights for agile principles related to communication and team organization. The biggest factor weights justify the agreement of respondents regarding the principles that compose and characterize the factor (*i.e.*, configuration settings).

5.4. Cluster Analysis

Usage analysis of agile software development principles by the organization and by respondents constituted the key step in the construction of the factors justifying the correlation of the studied variables, which refers to the correlation between agile principles in relation to success factors in the production of software.

To contribute to a better understanding of the found factors, a cluster analysis was performed, which verified similarities and characteristics among the profiles of the organizations in relation to their success in software development, team capacity, relationships with external partners, customer communication, culture and environmental configuration.

From the cluster analysis, three clusters were obtained. The number of clusters was given thorough analysis in order to identify how different groupings are from one another, and with three clusters, the distinction of the groups was evident. The first group contains 132 cases, the second group contains 129 cases, and the third group contains 148 cases.

The variables presented inIn the **following**, we explain each cluster, comparing its factor numbers (from F1 up to F6) with the overall cluster numbers. — the average and the standard deviation (S.D) for each factor in the cluster— help to explain the inclusion of the factors in their respective clusters.

In the following, we explain each cluster, comparing its factor numbers (from F1 up to F6) with the overall cluster numbers. The first cluster comprises 32.27% of the cases in the sample and is characterized by high assessments for staff capacity (4.9762 > 4.8648), relationships with external partners (4.3617 > 3.8875), culture (4.7519 > 4.5379), communication with customers (4.6515 > 4.3399) and environmental configuration (4.9356 > 4.7164), and with a low evaluation for success in software development (2.7178 < 3.5293). This first cluster gathers cases characterized by high rates of agile principles usage and by low success rates in software development.

Table 3. Cluster Analysis

	Cluster 1 n = 132		Cluster 2 n = 129		Cluster 3 n = 148		Overall n = 409	
	Average	S.D	Average	S.D	Average	S.D	Average	S.D
F1- Team capacity	4.9762	0.4835	5.5105	0.3895	4.2027	0.9432	4.8648	0.8591
F2 - Success in software development	2.7178	0.8734	4.7578	0.6987	3.1824	1.2388	3.5293	1.298
F3 - Relationship with external partners	4.3617	0.8439	4.593	0.9897	2.8497	1.0276	3.8875	1.2399
F4 – Culture	4.7519	0.6841	5.345	0.5137	3.6436	1.0244	4.5379	1.0593
F5 - Communication with customers	4.6515	0.6314	5.1027	0.6371	3.397	1.0059	4.3399	1.076
F6 - Environmental configuration	4.9356	0.7677	5.2946	0.8674	4,0169	1.4456	4.7164	1.2153

The second cluster comprises 31.54% of the cases in the sample and is characterized by high evaluations for team capacity (5.5105 > 4.8648), success in software development (4.7578 > 3.5293), relationships with external partners (4.5930 > 3.8875), culture (5.3450 > 4.5379), communication with customers (5.1027 > 4.3399) and environmental configuration (5.2946 > 4.7164). This second cluster gathers the cases characterized by high rates of agile principles usage and high success rates in software development.

The third cluster comprises 36.18% of the cases in the sample and is characterized by low evaluations for team capacity (4.2027 < 4.8648), success in software development (3.1824 < 3.5293), relationships with external partners

(2.8497 < 3.8875), culture (3.6436 < 4.5379), customer communication (3.3970 < 4.3399) and environmental configuration (4.0169 <4.7164). This third grouping gathers the cases characterized by low rates of agile principles usage and low success rates in software development.

6. Discussion

The categorization of agile principles into factors was performed in order to facilitate the identification of profiles of Brazilian organizations that produce software using of agile principles and to explore success achievement in software development. This categorization of factors was achieved through the Factorial Analysis.

The purpose of identifying the profiles of Brazilian organizations that produce software using agile principles and of exploring success achievement in software development is to contribute to the improvement of our understanding regarding how agile principles are part of organizations that produce software and that achieve success in software development, thus allowing new software production organizations to adopt agile principles that can drive success in software development.

Through cluster analysis, three profiles were identified. The first profile is characterized by organizations that have high rates of agile principles usage and low success rates in software development. The second profile is characterized by organizations with high rates of agile principles usage and high success rates in software development. The third profile is characterized by organizations with low rates of agile principles usage and low success rates in software development. After each profile was defined, a comparison between the profiles was performed.

The difference between the first and the second profiles is that organizations in the second profile have much higher assessment rates for agile principles.

The difference between the first and the third profiles relates to success in software development, in that the third profile of organizations that produce software has higher rates of success.

The second profile totally differs from the third profile because the two deal with profiles of organizations that use the principles of software development and succeed in software development and those of organizations that do not utilize agile principles and not succeed in software development. The success assessment is much higher for the second profile than for the third profile.

As can be observed through the second profile, organizations that used agile software development principles achieved success in software development; however, it cannot be said that the use of agile principles alone guarantees the achievement of such success in software development. This is made clear because the first profile, which comprises organizations that used the principles described in the research, did not achieve success in software development.

At this point, the second profile, which comprises organizations that used agile principles and also achieved success in software development, will be evaluated. This profile can be evaluated based on critical success factors for agile development, based on theoretical contributions from Petersen and Wohlin [37], Dybå and Dingsøyr [5], Wan and Wang [23], Lindvall and Basili [21], Wan and Luo [22], Misra and Kumar [17], Chow and Cao [10] and Vijayasarathy and Turk [16].

The results obtained in this research show that the organizations with the highest success rates in software are the same as those that have higher rates of capacity in terms of team, culture, communication with the client, environmental configuration and relationships with external partners.

Thus, the results of this research regarding the team abilities corroborate previous findings obtained by Lindvall and Basili [21], Dybå and Dingsøyr [5], and Wan and Luo [22]. In these works, as well as in the results obtained in the research, agility in team communication [21], people's collaboration capabilities [21], team communication capabilities [21] and [17], confidence among team members [5], competence of persons, participative leaders [22] and [23] and leader recognition [22] and [23], are connected to successful software development.

Thus, the results regarding culture corroborate the previous findings of Lindvall and Basili [21] and Misra and Kumar [17]. In these works, as well as in the results obtained in the research, openness to trading [21], agility in decision making [17], team autonomy in projects [17] and flexibility to changes [17] are related to successful software development.

Given its findings regarding communication with customers, this work corroborates the previous findings of [21]. In this work, as well as in the results obtained in this research, the usefulness of documentation to the team and to the client, the frequency of interactions with the customers and customer training [21] were all connected with success in software development.

Environmental configuration was also confirmed as being important for success in software development by Lindvall and Basili [21], Dybå and Dingsøyr [5] and Chow and Cao [10]. In these works, as well as in the results

obtained in this research, environmental configuration [5] is connected with software development success.

Regarding the factor of relationships with external partners, the related work explored in this paper did not confirm this factor as a critical factor for success in software development. Thus, this factor is a new factor found in this study to be relevant to agile software development.

However, it is observed that the second highest rates for team capacity, culture, customer communication, environmental configuration, and relationships with external partners do not follow the second highest rate for software development success, suggesting that other factors can influence success in software development.

These variables positively influence the success of projects that adopt agile methodologies [17] and represent critical success factors for agile software development [21].

7. Conclusion

The aim of this study was to identify and analyse the profiles of Brazilian organizations that produce software, using the empirical experiences of respondents regarding the use of agile principles and success achievement in software development. This was achieved, since, from the literature review, it was possible to identify the principles that were laid down in theory. Subsequently, a verification of the 409 respondent organizations was held.

The results achieved supported subsequent identification and analysis of profiles of Brazilian organizations that produce software, with respect to their use of agile principles and their success in producing software.

In sum, this study contributes to a better understanding of the use of agile principles in the context of development associated with obtaining success in producing software. Research in this area is highly relevant for developing a better understanding and driving organizations to increase investments in resources, efforts and agile principles to achieve excellence in processes and software products. This paper also contributes to research in software engineering and to agile methodologies practitioners because it may assist in the identification of agile principles related to achieving success in software development. In the area of statistics, this study confirms that research in software engineering can be certified and validated by multivariate analysis. Moreover, the work contributes encouraging quantitative research regarding whether organizations using agile principles in the development of software can achieve success in producing software.

The implications of this study are that organizations with the highest success rates in software are the same as those that have higher rates for capacity in terms of team, culture, communication with clients, environmental configuration and relationships with external partners. Organizations that used agile software development principles achieved success in software development, but it cannot be said that the use of agile principles alone guarantees the achievement of such success in software development. Additionally, relationships with external partners, although not included in the related studies investigated in this paper, manifested as a critical factor for success in software development and, thus, agile software development.

A limitation of this study is the fact that evaluating only respondents that use agile methodologies may influence the research, since respondents who use agile methodologies are likely to like such methodologies more than respondents who do not use them. Since the sample of this study consists only of Brazilian organizations, it would be interesting to include in the sample respondents from other countries, to prevent the results from being influenced by a particular culture, for example. With this, it is suggested that this study be conducted in other samples (e.g., countries with greater maturity in software development, such as the United States and India), and in qualitative studies seeking to further investigate how these principles contribute to the achievement of success in producing software. Average comparison tests between clusters can be realized. New variables, such as revenue, number of projects and certifications, among others, may be included in the survey. Thus, the authors also suggest, as future work, a confirmatory analysis of these factors using structural equation modelling.

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