BM_Virtual Enterprise Architecture Reference Model for Concurrent Engineering: An experiment

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ABSTRACT

In order to test the potential of Virtual Enterprise (VE) organizational principles for Concurrent Engineering (CE) team work organization, an experiment applying the BM_Virtual Enterprise Architecture Reference Model (BM_VEARM) is organized. Three CE teams are asked to create a web site. The teams have been organized as follows: 1) CE distributed team (virtual team according to literature); 2) CE agile team (agile organization according to BM_VEARM) and 3) CE virtual team (virtual organization according to BM_VEARM), in order to complete the required task. The main objective of the experiment is to show that the three organization models of CE teams work effectively, and analyse the performance according to previously defined criteria. In this paper the results in terms of product quality are presented. The experiment has shown that better product quality, for the product quality aspects analysed, is achieved in cases when VE organization is applied.

Keywords: Concurrent Engineering. Virtual Enterprise. BM_Virtual Enterprise Architecture Reference Model.

1 INTRODUÇÃO

Concurrent Engineering (CE) and related concepts of teamwork and/or cooperative work has emerged as knowledge management and organizational tools with the aim to radically cut product development time as and improve product quality in order to better meet client's requirements.

To support the cooperative work, and especially the Concurrent Engineering (CE) processes, different organizational models may be applied. These models may be characterized by (physical) distribution of team members, agility and virtuality, among other characteristics.

The agility together with distributivity with which these groups can be created and reconfigured make possible the use of individuals capable to add value to one defined task, independently of the place where they are located.

With the objective of comparing the performance of distributed CE teams (or as traditionally defined “virtual” CE teams) with the performance of CE teams organized in accordance with the Virtual Enterprise (VE) concept (in this particular case in accordance to the BM_Virtual Enterprise Architecture Reference Model BM_VEARM), an experiment is planned and carried out in the Federal Center of Technological Education (CEFET-RJ) in Rio de Janeiro, Brazil. Participants were students registered in the last year of the Informatics Course.

The task was the development of a Website, consisting of several Website pages, adding several links and services, that should serve as a Portal for a Virtual University or as a starting point for navigating the Internet community (Borges, 1995).

The experiment was carried out in the period from October 27th to 30th 2003, involving three teams working simultaneously. To support the interaction between groups, NetOffice software (Pithon and Putnik, 2005) was used. As open source software, it was customized in order to handle of the necessities of the task, that is, to allow the broker’s function (Pithon and Putnik, 2003).

Initially the experiment was planned to be applied in the industry. However, due to technical problems and time constraints, it was applied in an environment where the work of diverse teams could be evaluated. Consequently, the experiment presented here contemplates services, rather than manufacturing. For each group, i.e. EC team, the same project was give: to create a Website entitled “Virtual University”, to be used as an education environment. Thus the, website should be conceived as an Education Portal, to make limitless use of the services and resources offered.

In such context, this paper is organized into three parts: in the first part the basic concepts of CE are presented, as well as the operational model for team work; in the second part, the concept of VE according to BM_VEARM is presented, as well as how BM_VEARM is applied to organize agile EC teams (work groups) and virtual organizational model of CE teams. Finally, in the third part, the experiment plan is presented as well as some results.

2 CONCURRENT ENGINEERING CONCEPT

The concept of CE defines that many activities are simultaneously and interactively developed, involving professionals from different specialties, covering the entire life-cycle of product development, despite the traditional method of sequencing product development life-cycles’ phases. Therefore, it becomes possible to “re-feed” an activity by other activities (the feed-back relation among processes). This new work pattern is very beneficial, since it minimizes waste time and resources, which arises from lack of complete involvement of different sectors, or functions, in all project phases. The new approach also improves quality of the product and quality of the development process (Pithon and Putnik, 2002).

The model for CE processes' organization, which has been developed in this study, is based on teamwork, also known as "task force" (Figure 1), in which the (team) leader is the linking element between team members (group) and company management.

Figure 1 - Management Model of Concurrent Engineering Teams

3 BM_VEARM

The BM_VEARM (Figure 2) is defined as a multi-levelled hierarchical structure of inter-enterprise processes' control and execution, in which the broker is inserted between two consecutive levels (main level/broker/agent) of the enterprise/manufacturing process control systems, which ensures integrability, distributivity, agility and virtuality (Putnik, 2000).

Integrability (interoperability) is e a company's capacity to access (interconnect, integrate) existing heterogeneous resources inside and outside the organization. The integration of heterogeneous resources must occur at low cost, which is an open system architecture's characteristic.

Figure 2 - Elementary hierarchical structure of Virtual Enterprise by BM_VEARM

In the context of virtual enterprises, distributivity can be perceived as the company's capacity to integrate and operate needed resources remotely, i.e. at a distance. The concept of a competitive company implies the ability to access the best resources: simply seeking the cooperation of other enterprises, purchasing components, sub-contracting other companies or creating consortiums, as well as the capacity to manage all business and manufacturing functions, independent of distance, using Wide Area Network (WAN) technologies and corresponding protocols, e.g. Internet.

In the same context (of VE), in order to become agile and answer the market's

abrupt changes, it is necessary that the enterprise has the capability to adapt or reconfigure itself rapidly between two operations (off-line operation).

The virtuality has the purpose of further improving an agile company's performance, that is, it must provide the system the reconfiguration capacity throughout the intended operation (on-line operation) without interruption. The combination of virtuality, agility, distributivity and integrability makes a flexible company with a higher performance level capable to achieve the needed competitiveness on the global market.

In this model, the broker is the main element of agility and virtuality, thus being able to reconfigure the company's organizational structure during a real-time operation (on-line) and/or between two operations (off-line).

Aiming at integration of the Concurrent Engineering concept (Figure 1) with the concept of Virtual Enterprise by the BM_VEARM model (Figure 2), the model of CE teams based on BM_VEARM is conceived (Figure 3).

Figure 3 - BM_VEARM Model for CE Group

4 THE EXPERIMENT

The experiment was carried out by three CE work groups, or teams:

- 1) distributed CE team (usually designated 'virtual teams' in literature);
- 2) agile CE team according to BM_VEARM, and
- 3) virtual CE team according to BM_VEARM.

Thus, the specific objective of this experiment was to observe the behavior and interaction of three team types, i.e. three organizational models for CE teams, and, then, evaluate the performance of each group/team by the criteria defined in section 4.2. Each group had a certain number of members and these didn't participate in any other group. All of the tested teams executed the same tasks.

In order to make the experiment closer to the real-life conditions, the group members did not have direct face-to-face contacts or meetings. The communication management and work flow among the group members, broker and leader processes

were carried out using open-source software NetOffice, which is advantageous for being accessible from conventional browsers (Internet Explorer, Netscape and Opera), without necessity of other tools.

4.1 Team work Description

This section describes the profile of the three CE teams that participated in the experiment, as well as the functions/roles of each team member and, still, the concrete model of team organization according to BM_VEARM.

4.1.1 Distributed CE Team

The distributed CE team (Figure 4) is formed by the manager, leader, revisors, projector, graphic designer, programmer and clients: student and professor. The only difference between this group and the traditional CE group is that the CE traditional group works face-to-face and the distributed one works using the Web. The job assignment to each one of them is (Pithon and Putnik, 2003):

- manager: elaborates the Portal strategy, i.e. defines together with the leader which are the Portal's functional requirements;
- leader: executes the tasks with details that had been attributed to him by the manager and co-ordinates the other group members group;
- revisor: creates and revises texts for the Portal; posts texts on the site;
- projector: projects the Portal, delineating the objectives, target audience, sections that the Portal must possess, and defines which type of human resources and technology are needed for each task;
- designer: creates and implements the Portal's graphic standards , according to the specifications defined by the projector;
- programmer: implements the technical/ logical code that defines operations and functionalities of Portal's pages; promotes integration of diverse individual elements that compose each section;
- client/student: represents the target audience, or others, to whom the Portal is destined. The role of this member is to verify if developed software takes care of students' necessities such as: easy visualization of the pages and the bulletin boards, easy access to subjects destined to the target audience, etc;
- client/professor: analyzes and reviews the implemented pedagogical content of the project; verifies the accessibility to the Portal: contents' localization, navigation on the pages, etc.

Figure 4- CE Distributed Team Work.

4.1.2 Agile CE Team According to BM_VEARM

The main characteristic of this group is the broker figure 5. It competes to the broker, which is an element chosen by the manager, to select necessary resources for tasks' execution (e.g. to enlist the group members). This broker acts as an agent of agile CE team reconfiguration. In this way, the reconfiguration will be implemented in the 'off-line' way, i.e. when it's necessary to replace some group member by another one, the broker will interrupt the task execution, or wait the interval between switching from one operation to another to implement the substitution. The alternative "resources" for reconfiguration of group structure (i.e. replacement of the group members) are presented in the lower part of Figure 5.

Figure 5- CE Agile Team work according to BM_VEARM

4.1.3 Virtual CE Team According to BM_VEARM

This group also has as a main characteristic the broker acting as the agent of virtual CE team reconfiguration (Figure 6). The broker performance in this case is different. To reconfigure the group structure, i.e. to replace a group member by another one, activity interruption is not necessary. This reconfiguration is performed on-line. This model's potential is the fact that a group member exchange doesn't affect current tasks' execution, and it's not perceived by other group members or immediate superiors. In this model, not only the broker has basically the same attributions that were defined for the agile model stated above, but also possesses more 'power' in decisions on reconfigurations. This 'power' is authorized by the Leader or Manager.

Figure 6. CE Virtual Team work According to BM_VEARM

4.2 Evaluation Criteria

In the experiment, the following metrics, concerning the product quality (web site), were used:

1 – Load time: It is the time that each section of the site takes to be loaded on the customer's terminal (the anonymous user that accesses the site through the Internet) from the server. As a standard for the tests, a connection of 56Kbps was used (dial-up) and this test's calculus was carried through Microsoft FrontPage 2000 software;

2 – Source code Quality: It is the written code's conformity evaluation, based on international standards and agencies (ISO/OSI, W3C, and PHP.NET). It verifies the syntax, straightness and skill in writing the source code, perfect use of the programming language, use of commentaries, identification and heading, as well as the optimizer demanded for item 1 (Staa, 2000);

3 – Product Development Lead Time (development efficiency criteria): The lead time is the time spent by each team in construction of each one of the six screens/pages that compose the Site. The constructed screens/pages had been: Homepage, Institution, Classroom, Café, Secretariat and Library.

5 RESULTS

To obtain more data, the site was divided into six screens/sub-pages (homepage, institutional, classroom, coffee, secretariat and library) and to each one of these screens/sub-pages, the defined metrics above were applied. These tasks and metrics' organization were applied in each of the tested teams. In the following sections, the obtained results, for each of the CE teams, are presented.

5.1 Partial results of the Distributed CE team

The tasks were distributed by the leader to each group member. As this model does not have a resources market, i.e. available experts/professionals by whom the changes in the team can be made, the replacement of a member by another one can delay the same project for days or even weeks. In this experiment, the communication mechanism used by group member (with the leader) was electronic –mail (a.k.a. e-mail). The experimental results, according to the metrics and defined task structure are presented in Tables 1, 2 and 3.

Table 1- Load time for CE distributed Model

Screens/pages of the site	Load time (s)
Homepage	41
Institutional	20
Classroom	15
Coffee	18
Secretary	14
Library	14
Total time	122

Table 2– Source code Quality for CE distributed model

Screens/pages of the site	Quality
Homepage	19
Institutional	19
Clasroom	27
Coffee	30
Secretary	22
Library	25
Total	142

Table 3- Lead time of code for CE distributed model

Screens/pages of the site	Lead time (h)
Homepage	10,42
Institutional	8,92
Clasroom	20,92
Coffee	19,67
Secretary	25,50
Library	49
Total	134,43

5.2 Partial results of Agile CE team by BM_VEARM

The two basic differences between this model and the “distributed team” model are: 1) the insertion of broker figure between the manager and group members; 2) the dynamic replacement of a team member by another one.

This replacement implies in an interruption of a current task, and due to this, project time is extended. However, the broker’s main reason of existing within the CE team is to make this interruption as short as possible. The broker is an expert in organizational “reconfiguration” and has access to the “resources market”, i.e., the market of experts/professionals that can efficiently join the CE team. Therefore, it is supposed to have a better “alignment” with the CE process’ objectives, including the project lead time as well as the product quality – because there is a specialized resources market and a selection of the best available resources available. The experimental results for this CE team, according with the metrics and task structure defined, are presented in Tables 4, 5 and 6.

Table 4 - Load time for CE agile model

Screens/pages of the site	Load time (s)
Homepage	35
Institutional	14
Classroom	19
Coffee	16
Secretary	13
Library	14
Total time	111

Table 5 - Source code quality for CE agile model

Screens/pages of the site	Quality
Homepage	26
Institutional	22
Classroom	30
Coffee	30
Secretary	28
Library	27
Total	163

Table 6 - Lead time of code for CE agile model

Screens/pages of the site	Lead time (h)
Homepage	9
Institutional	5,50
Clasroom	10,92
Coffee	19,67
Secretary	23,17
Library	43,33
Total	111,59

5.3 Partial results of the Virtual CE team with BM VEARM

This CE team organizational model uses the same mechanisms as the “agile” CE team model, but since the replacements in this model can be performed in a shorter time, the alignment with the CE process objectives is better (including the project lead time as well as the product quality). In reality, the CE team reconfiguration does not affect the total time of the task, due to the organizational architecture that implies virtuality.

The experimental results for this CE team, according with the metrics and task structure defined, are presented in Table 7, Table 8 and Table 9.

Table 7 - Load time for CE virtual model

Screens/pages of the site	Load time (s)
Homepage	29
Institutional	10
Classroom	12
Coffee	14
Secretary	10
Library	12
Total time	87

Table 8 – Source code quality for CE virtual model

Screens/pages of the site	Quality
Homepage	30
Institutional	28
Classroom	27
Coffee	30
Secretary	28
Library	27
Total	170

Table 9 – Lead time of code for CE virtual model

Screens/pages of the site	Lead time (h)
Homepage	7,67
Institutional	6,42
Classroom	32,50
Coffee	7,92
Secretary	13,17
Library	30,33
Total	98,01

5.4 Total results of each one tested team

Finally, in Table 10 are presented the total values (the total values of Tables 1 to Table 9) obtained for the load time and source code quality of the three CE team organizational models that were tested.

Table 10 – Total values obtained from the three models with metric load time, code quality and lead time

Total	Load time (s)	Quality	Lead time (h)
Distributed	122	142	134,43
Agile by BM	111	163	111,59
Virtual by BM	87	170	98,01

6 CONCLUSION

The purpose of this work was to demonstrate the performance of Virtual and Agile CE teams according to BM_VEARM against the traditional model of CE teams' organization.

By the experiment results, it can be concluded that the CE Virtual team, with the BM_VEARM based organization, had a better performance, i.e. it was faster, more efficient, and had better partial results partially (for partial tasks, i.e. for component web pages of the Portal) and global results (for the total, complete task), when compared with the CE Agile team, with the BM_VEARM based organization, and CE Agile team, with the BM_VEARM based organization, performed better, i.e. it was faster, more efficient, and had better partial and global results, when compared with 'traditional' CE Distributed (commonly called 'virtual') team.

The same type of results were obtained for repeated other two criteria; that is, the BM_VEARM based CE teams had the best product (Portal) quality in terms of Load Times and Source code Quality..

The experiment showed that BE_VEARM model improves performance of CE teams as theoretically expected. The CE Virtual team work based on BM_VEARM model can be feasible, provided that adequate group management software as well as teamwork and brokering training are developed in the model application.

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