BM_Virtual Enterprise Architecture Reference Model for Concurrent Engineering and product improvement: 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 reqired task. The principal objective of the experiment is to show that the three organization models of the CE teams work effectively and analyse the performance of each one according to previously defined criteria. In this paper the results 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, Broker, BM_Virtual Enterprise Architecture Reference Model, product quality improvement

1. Introduction[1]

To support the requirements for the new organizational forms of enterprises, the cooperative work and work groups approach has appeared. Cooperative work may be defined as one where a group of people, physically separated or not, articulate the accomplishment of a common task in a synchronous or asynchronous form. In order to cooperate, a previous agreement should be considered. All should be committed to work to reach a common objective [1].

It is supposed that the agility, i.e. dynamics, with which these work groups may be created and reconfigurated, makes it possible to use the best "resources", i.e. the (best) individuals capable to add value to one defined task, independently of their (the individuals') (geographic) location and, consequently, contributes to the product and process quality. In that sense, it is supposed that application of Virtual Enterprise (VE) organizational principles contributes to the agility of the work teams, i.e. to the Concurrent Engineering (CE) work teams, or team work, organization.

[1] This paper is a continuation of the one [2], presented in the 1st I*PROMS International Conference in 2005 where the results on development lead time were presented. To make this paper auto-sufficient some of the text from [2] is repeated, namely the part that presents the BM_VEARM application for the CE team organization.

With the objective to test the potential of Enterprise (VE) organizational principles, in accordance with the BM_Virtual Enterprise Architecture Reference Model (BM_VEARM), for Concurrent Engineering (CE) team work organization, three different work groups had been created, i.e. organized: 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), and to each group were equally attributed the same project: to create a site[2] called "Virtual University", making use of information technology to support the education organization and process [3]. This task, i.e. experiment, was carried out by computer sciences students in their last year and undertaken in the period of October 27th to the 30th, 2003.

The experience has not been published in Brazil or in Portugal. It simultaneously involved three work groups, specially the agile and virtual groups of the BM_VEARM model, with the application of diverse software. The only asynchronous communication tool used among the members of the groups was e-mail.

This paper is organized in three parts. In the first part, we present the basic principles of CE as well as the organizational model for CE work groups. In the second part, we present the concept of Virtual Enterprise in accordance with the BM_VEARM model and also present the integration of the CE work groups in the BM_VEARM model. In the last part, we present the CE concrete work group models that were tested in the exercise, as well as the experiment results.

2. Concurrent Engineering

The concept of CE defines that various activities are developed in parallel, interactively, involving professionals from different specialties, covering the entire cycle of product development, in opposition to the traditional method of sequencing stages. Therefore, there is feed-back among the activities. This new form of working is very beneficial, since it avoids the possibility of wasting time and resources, originated from a lack of complete involvement of the different sectors in all the stages of the project. Besides improving the quality of the development process itself it also improves the quality of product. On the contrary, the time and resources wasted in the execution of tasks, that later would have to be redone, will never be recovered [4].

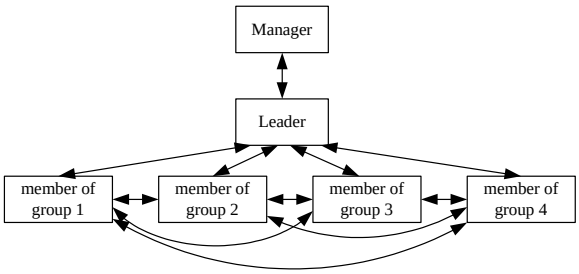

Figure 1 - Management Model of Concurrent Engineering Teams

The model that is being developed in this study is guided by work groups, also designated as the "task force" (Figure 1), which has the group leader as: 1) a linking element between the members of the group and the company higher level management, and 2) the group, i.e. the CE process, management (or manager).

3. BM_VEARM Model of Virtual Enterprise

A VE in accordance with BM_VEARM (Figure 2) is defined as a hierarchical model of multiple levels of the enterprise, with the broker inserted between two consecutive control, or management, levels (principal/broker/agent) of the enterprise, or manufacturing, process control system, which ensures *integrability, distributivity, agility* and *virtuality* [5].

Integrability is considered the capacity of an enterprise to access (interconnect) existing heterogeneous resources[3] inside and outside the organization. The integration of heterogeneous resources should occur at low cost. This is a characteristic of *open system* architectures.

In the context of virtual enterprises, *distributivity* is considered as the capacity the enterprise has of integrating and operating needed resources at a distance, remotely. The concept of a competitive enterprise 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

[2] A page or website that adds several links and services. It is an entrance gate, or starting point, for navigation.

[3] A resource is (from an enterprise point of view) an object that is used to conduct or support the execution of one or more processes (e.g. materials, machines, tools, computers, human operators, time, money, software, etc.). An enterprise is also a resource if it is contracted by another enterprise to render a service. In this work, a member of the group is a resource.

functions, *independently of distance*, using Wide Area Network (WAN) technologies and corresponding protocols, e.g. Internet. Therefore, the distributed manufacture/enterprise system is defined as a system in which performance does not depend on the physical distance between the elements of the enterprise.

It is necessary for an (virtual) enterprise be *agile*, i.e. to have a capacity of rapid *adaptability* or rapid *re-configurability* between two operations *(off- line)*, in order to quickly respond and/or pro-actively act upon dynamic market changes.

Virtuality is introduced with the objective of further improvement of the performance of an agile enterprise, i.e. virtuality should provide the system with the capacity of *re-configurability* during the undergoing operation *(on-line reconfigurability)* without the interruption of the operation, and in this way improving the "response" time.

Virtuality, combined with agility, distributivity and integrability provides the enterprise with highest level of flexibility and pro-activity.

The main agent of agility and virtuality is the broker and his role is to reconfigure the (VE) organizational structure during an operation in real time or between two operations. The broker acts as an interface between two hierarchical control layers, in a way that one layer is hidden from the other, and with the capability to reconfigure the VE architecture without interruption of the operation on the other control level, in order to avoid any loss of time due to the reconfiguration. The broker action between two operations, which obviously implies interruption of the process, is permitted by BM_VEARM but it is a relaxed case in terms of the VE by BM_VEARM.

To resume the above, we can now better define what we think a virtual enterprise [5] is: "The Virtual Enterprise (VE) is an optimized and synthesized enterprise on a universal set of resources[4] with its physical structure substituted in real time. The project and control of the system is executed in an abstract or virtual environment".

The expression "its physical structure which can be substituted in real time" combined with "in a virtual environment" provides the high level of flexibility and agility that the enterprise requires. The specific architecture of the BM_VEARM, through the specific role of the broker, should provide the highest level of the VE reconfigurability dynamics (and, consequently, of the CE teams organization based on BM_VEARM).

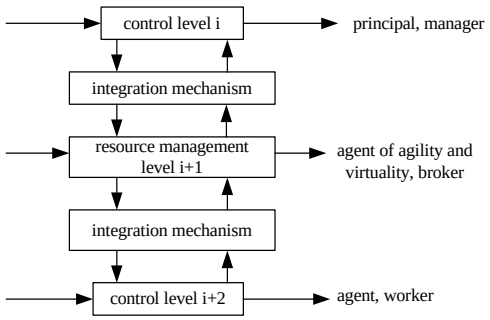

Figure 2 - Elementary hierarchical structure of Virtual Enterprise by BM_VEARM

In Figure 1 we can see the CE group members and their relationship as VE partners applying to the VE organization model in conformance with the BM_VEARM reference model. In Figure 2, we can obtain an organizational structure of the CE group as in Figure 3. The new element is/are broker(s) whose role is to manage the CE team organization dynamic reconfiguration in order to keep the maximum performance of the CE team.

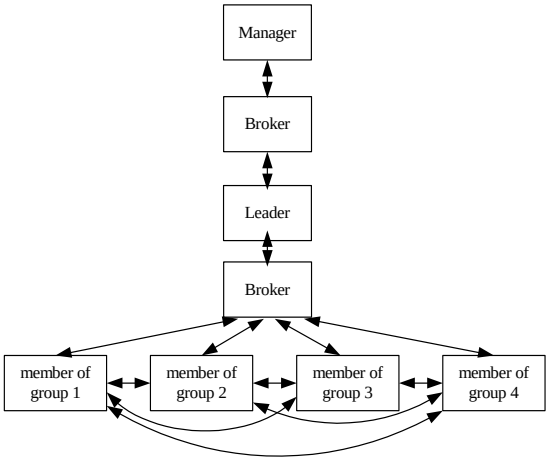

Figure 3 - BM_VEARM Model for CE Group

4. The Experiment Plan

The experiment was carried out by the three CE teams described above. Thus, the main objective of this exercise is to observe and analyze the three CE teams working in the practical situation and to evaluate the performance of each group by following the predefined

[4] A set of "universal resources" is understood to be any type of resource, primitive or complex, that can be distributed globally and can be located both inside and outside the frontiers of the enterprise. This implies VE as a network, or consortium, of enterprises, i.e. networked enterprise over globally distributed independent enterprises, i.e. partners, in the VE.

criteria (described in section 4.2).

The members of the CE teams didn't have any face-to-face meeting. To manage the work flow (simple or complex) and the communication among the team members, the broker was introduced. NetOffice software was used in addition to e-mails. The advantage of using NetOffice is that it is accessible from the conventional browsers (Internet Explorer, Netscape and Opera).

4.1. Distributed CE team organization (virtual)

The distributed CE team (Figure 4) was composed by the manager, leader, reviser, projector, designer, programmer/specialist in animation and the customer representative, i.e. students and professors. The only difference between this group and the traditional group of CE is that the traditional group of CE works in the face-to-face form and the distributed one works through the Web [6].

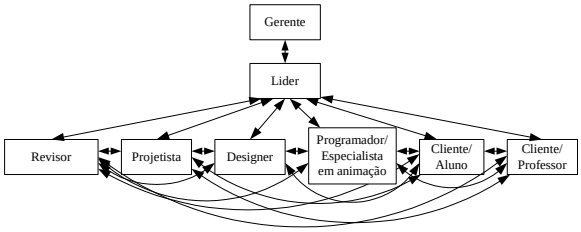

Figure 4 – Distributed CE team organization ("virtual")

4.2. Agile CE team organization by BM_VEARM

The main characteristic of this group is the insertion of the *broker* (element chosen by the manager or the leader in order to catch the necessary resources for the execution of the task, e.g. to enlist the members of the group) as the new member of CE team, to act as the agent of the reconfigurability of the CE, now agile, teams. In this way, the reconfigurability will be done *off-line*, i.e. when it will be the necessity to substitute a member of the group with another one, the broker will interrupt the execution of the task and perform the substitution. The members of the team that are "waiting" to substitute an acting member of the group, i.e. that will participate in the process of team reconfigurability, presented in the lower part of Fig. 5.

This team also has as the main characteristic the insertion of the broker as the agent of reconfigurability in the CE virtual teams (Figure 6). In this case, the performance of the broker is different. To reconfigure a member of the group into another one, it is not necessary to interrupt the activity that is on course. The reconfiguration will be performed *on-line*, i.e. the potential of this model consists of the substitution of a team member with another one, without that, this substitution affects the task and is not perceived by other members of the team or by another hierarchical superior level. The Broker in this model possesses the same attribution as the one defined for the agile model above. Since the reconfiguration is "hidden", we say that the group works with a "virtual" underlying organizational architecture.

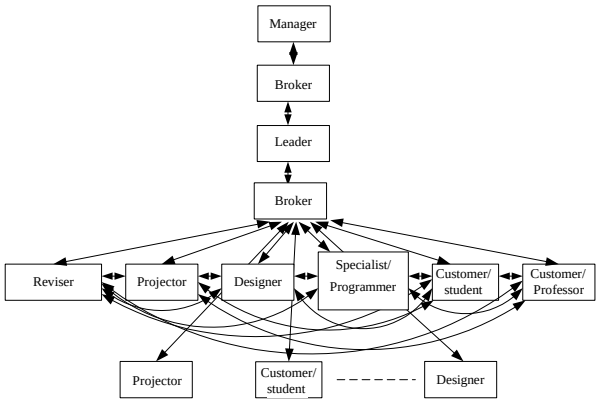

Figure 5 – Agile CE team organization

4.3. Virtual CE team organization in BM_VEARM

This team also has as the main characteristic the insertion of the broker as the agent of the reconfigurability of the CE virtual teams (Figure 6). The performance of broker in this case is different. To reconfigure a member of the group for another one, it does not need to interrupt the activity that is on course. The reconfiguration will be performed *on-line*, i.e. the potential of this model consists of the substitution of a team member for another one without that this substitution affects the task and neither perceived by other members of the team or by another hierarchical superior level. Broker in this model possess the same attribution that was defined for the agile model above. As the reconfiguration is "hidden" we say that the group works with a "virtual" underlying organizational architecture.

5. Evaluation Criteria

In the experiment, the following metrics,

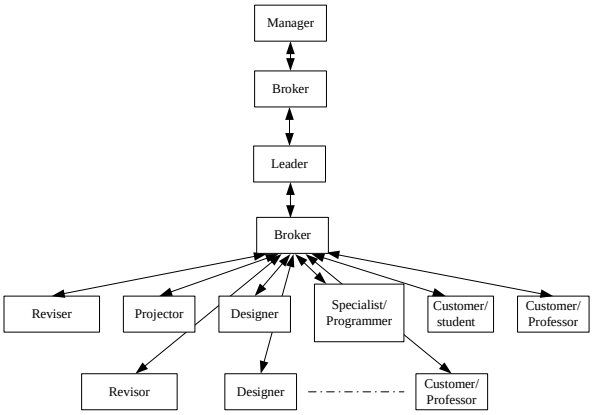

Figure 6. CE Virtual Team work According to BM_VEARM

concerning the quality of the product (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 the standard for the tests, a connection of 56Kbps was used (dial-up or dialed) and the calculation of this test was carried through Microsoft FrontPage 2000 software.

2 – *Quality of the code*: It is the evaluation of the conformity of the written code, based on international standards and agencies (ISO/OSI, W3C, PHP.NET). It verifies the syntax, straightness and skill in writing the code of the site, perfect use of the programming language, use of commentaries, identification and heading, as well as the optimizer demanded for item 1[7].

6. Results

To obtain more data, the site was divided into six screens/sub-pages (homepage, institutional, classroom, coffee, secretariat and library) and for 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.

6.1. Partial results of the Distributed CE team

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

Table 1 – Load time for CE distributed model

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

Table 2 – Quality of code for CE distributed model

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

6.2 Partial results of Agile CE team by BM_VEARM

The two basic differences of this model against the "distributed team" model are: 1) the insertion of the broker between the manager and the members of the group, 2) the dynamic substitution of a member of the team with another one.

This substitution causes an interruption of the task that was being carried out and, because of this interruption, the time of the project needed to be extended, in that way, the same could be executed. However, the reason for the existence of the broker within the CE team is to make this interruption as short as possible. The broker is an expert in organizational "reconfiguration" and he has access to the "market of resources", i.e. to the market of experts/professionals that can efficiently join the EC 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 market of specialized resources 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 3 and 4.

Table 3 – Load time for CE agile model

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

Table 4 – Quality of code for CE agile model

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

6.3. 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 substitutions in this model can be made in a shorter time, the alignment with the CE process objectives is even 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 Tables 5 and 6.

6.4. Total results of each one tested team

Finally, in Table 7 we present the total values (the total values of Table 1 and Table 6) obtained for the load time and the quality of code of the three CE team organizational models that were tested.

Table 5 – Load time for CE virtual model

Screens/pages of the site	Load time (seg.)
Homepage	29
Institutional	10
Classroon	12
Coffee	14
Secretary	10
Library	12
Total time	**87**

Table 6 – Quality of code for CE virtual model

Screens/pages of the site	Quality of code
Homepage	29
Institutional	10
Classroon	12
Coffee	14
Secretary	10
Library	12
Total	**87**

Table 7 – Total values obtained from the three models with metric load time and code quality

Total	Load time (s)	Quality of code
Distributed	**122**	**142**
Agile by BM	**111**	**163**
Virtual by BM	**87**	**170**

7. Conclusion

Based on the experimental results, we can conclude that the application of the VE organizational principles brings benefits to the CE objectives. This is realized not only for the project (CE process) lead time, already presented in [2], but for the product quality as well.

The authors believe that the realized experiment is important as it confirms the theoretical expectations of the VE concept.

Surely, it is necessary to perform more experiments in the industrial environment, as well as for different types of products, in order to make a positive and valid conclusion of the benefits of application of VE organizational principles. This work is under course. Also, it is necessary to refine the CE process management models in the environment of a VE.

References

[1] Borges, M.R.S. Suporte por Computador ao Trabalho Cooperativo. Jornada de Atualização em Informática: Congresso Nacional da SBC. Canela, 1995.

[2] Pithon A.J.C., Putnik G.D. (2005) BM_Virtual Enterprise Architecture Reference Model for Concurrent Engineering processes performance improvement: An experiment, in Pham D. T., Eldukhri E. E., Soroks A. J. (Eds.) *Intelligent Production Machines and Systems (Proceedings of the 1st I*PROMS Virtual International Conference)*, Elsevier, Amsterdam, pp: 61-66,

[3] Pithon, A., Putnik, G. Concurrent Engineering based in BM_VEARM for Development of Infrastructure (Portal) for Distance Learning. 10th ISPE International Conference on Concurrent Engineering: The Vision for the Future Generation in Research and Applications. R. Jardin Gonçalves, J. Cha, A. Steiger-Garção (Ed.), A Balkema Publisher, V.2, 2003, pp 931-936.

[4] Pithon. A., Putnik, G. Team Work for Concurrent Engineering in agili/Virtual Enterprise by BM_Virtual Enterprise Architecture Reference Model. Collaborative Business Ecosystem and Virtual Enterprise. Third Working Conference on Infrastructure for Virtual Enterprise (PRO-VE'02). L.M. Camarinha-Matos (ed), Kluwer Academic Publishers, 2002.

[5] Putnik, G. BM_Virtual Enterprise Architecture Reference Model, In A. Gunasekaran (Ed) Agile Manufacturing: 21st Century Manufacturing Strategy, Elsevier Science Publ,. 2000, pp 73-93.

[6] Pithon, A. Projecto Organizacional para a Engenharia Concorrente no Âmbito das Empresas Virtuais, PhD Tesis, University of Minho, Guimarães, Portugal, 2004, 225p.

[7] Staa, A.V. Programação modular: desenvolvendo programas complexos de forma organizada e segura, Rio de Janeiro, Editora Campus, 2000.