Implementing Collaborative Engineering Environments Through Reference Model-Based Assessment

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Abstract. This paper presents an assessment methodology based on enterprise reference models that consider next generation manufacturing principles. Because is becoming ever more frequent for companies to design products and work collaboratively within the framework of the Extended Enterprise, the need arises for a methodology for the successful implementation of collaborative practices. The main contribution of this research work lies in the definition of the reengineering process that allows the transition to a collaborative engineering environment and relies heavily on the use of PLM tools, and the definition of the metrics for change management. The proposal includes a readiness assessment procedure that analyzes the development process from a point of view that considers five levels of maturity with the aim of favoring the management of the collaboration process. The development of this collaborative assessment model is important because, on the one hand, the literature on this particular subject is scarce and, on the other, it can provide us with a deeper understanding of the activities associated to product development by defining the collaboration processes.

Introduction

If collaborative engineering processes are to be efficient the extended enterprise must have a good Supply Chain Management and this requires improvements in the planning and management of complex interrelated systems in order to increase productivity. Information Technologies have allowed integrated systems (MRP, MRPII, ERP, PDMs, PLMs) for decision-making to be used in all its areas. These tools increase the benefits to be gained from the collaborative undertaking and allow instant access to information and coordination of the workflow [1]. One of these solutions, the web-based Product LifeCycle Management tools (PLM), allows management of the life cycle of products and processes by integrating expert

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applications that require the exchange of information between Databases, which are the basis on which information models [2] must be built and applied. PLM systems remove barriers between organizations but they cannot be implemented without descriptive models and a collaborative engineering focused implementation process that allow us to understand the functional relationships in the firm itself and among the firms that go to make up the Supply Chain [3].

On the one hand, these descriptive models require a reference architecture for the organization, examples of which include different points of view such as ARIS, CIM-OSA, GERAM, GRAI-GIM, NGM, PERA or SCOR. The problem lies in how to apply the modeling and analysis techniques while integrating the different points of view in order to implement a PLM system within a development framework that attempts to promote the activities of the Extended Enterprise.

On the other hand, we need a readiness assessment model that is oriented by these reference frameworks and can evaluate the current practices in order to achieve a Collaborative Engineering environment. The Next Generation Manufacturing Model [4] is a specific approach that enables the company to be evaluated from four different perspectives and, with the fundamentals of process reengineering, has allowed us to propose an assessment model.

Collaborative Engineering Assessment Models

Implementation of the Concurrent Engineering philosophy, and consequently Collaborative Engineering, implies a great cultural change within the company and should be carried out with caution [5]. The maturity of Collaborative Engineering practices is unlikely to be efficient if they are not preceded by correctly planned implementation, which involves aligning the objectives of the improvements in the product development process with the strategic objectives.

All the above ideas bring us to a newer concept of Collaborative Engineering that that goes beyond those carried out initially and that seeks to highlight the improvement in the innovation of products and of processes that can be achieved with the adoption of this new philosophy:

"Collaborative Engineering supposes the Integration of the Product Development Process through Teamwork with all the areas involved in its Life Cycle. With this aim, product Design Methodologies and Tools are used to allow the regular exchange of the product-related information that is generated and to allow internal and external collaboration to take place. They are also employed to ensure that decision making is carried out in a synchronized way with general agreement, which thus allows firms to achieve the improvement of terms, quality and innovation required by the Client."

It is important to define a series of elements that could constitute Collaborative Engineering basic mainstays. The correct development of these elements, customized for each company, will provide an appropriate Collaborative Engineering environment through which we will ensure the success of this new work philosophy.

In order to achieve this aim, processes and activities modeling is fundamental because it can provide a common working framework with which to begin to implement Concurrent Engineering. Drawing a model of company processes forces us to reach an agreement about the objectives, facilitates communication and constitutes a tool for the analysis and design of new processes.

However, product development process modeling alone is not enough; we also need to evaluate certain characteristic activities to be able to manage the innovation process and to control and track the new process, thus allowing us to determine the improvements that are obtained. This means that it is necessary to define an entire performance measurement system that will help us to control the new process and to qualify and quantify the improvements in the process.

As teams are the core of Collaborative Engineering, they must be defined and adapted to the new design process, while taking into account all the activities that influence the product life cycle, since they constitute the second basic mainstay. The other mainstays are product design methodologies, computer support for collaborative work tools (CSCW) and Information Technology infrastructures.

The appearance of Concurrent Engineering (CE) was a milestone in the development of this field as it simultaneously lowered product cost, increased product quality and reduced time to market. Several readiness assessment methodologies for Concurrent Engineering implementation were developed over the last two decades. These include RACE from the DARPA Initiative in Concurrent Engineering (DICE) [7], RACE II, Carter and Baker [8], FAST CE and a number of European projects.

Nevertheless, as the concept of Concurrent Engineering has progressed to Collaborative Engineering it seems that implementation processes and methodologies considering the new scenario have not been researched as far as the new methodologies and technologies require.

Research Approach

Our proposal for implementing Collaborative Engineering (CoE) Environments adopts the classic methodology of business process reengineering and has five stages (Fig. 1). Within each of them we distinguish different phases that we are obliged to go through if we want to achieve successful implementation.

It is important to distinguish between two different teams that must participate during the change process. On the one hand, we have the Change Management Committee which has the capacity to make decisions about strategic topics and will participate in the first and last stages. This teamwork will bring about changes by incorporating product and process development experts with an operative level capacity to make decisions. On the other hand, in the redesign stage a Collaborative Engineering Team will be formed in order to complete it and to participate in the pilot project.

The first step to be carried out in the implementing process consists in studying whether the company is suitable for adopting a CoE environment. The business unit must therefore be analyzed to ensure that, in a preliminary approximation, the company can take advantage of CoE because it is aligned with the corporate strategy.

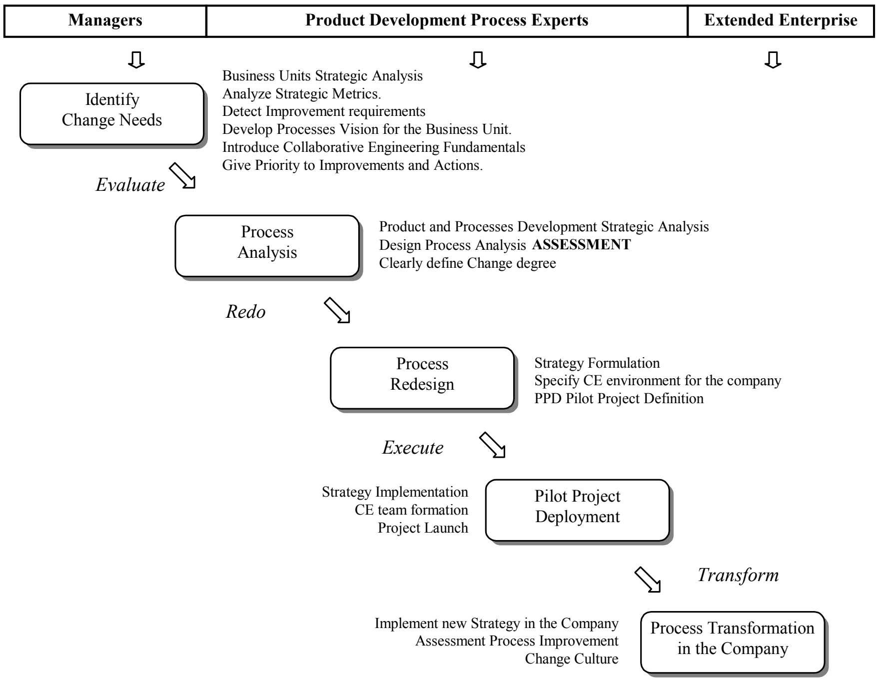

Fig. 1. Reengineering Process for Collaborative Engineering Deployment.

The Company and its products portfolio must be analyzed as well as the product development process (complexity, degree of innovation, markets, etc.) in order to establish the degree of change needed and demanded by the global markets.

Once an improvement in the product development process has been detected, the company has to evaluate the results of performance measurements. In order to understand these performance measurements and their relationships, a Process Vision will have to be adopted and the benefits of CoE must be explained to managers.

The Implementation Management Team must make a decision on whether CoE can be a solution or make a valid contribution. The process we seek to improve by innovation within each business unit must also be identified. To do so, a SWOT analysis can help find out the critical information about the company in order to decide which processes to improve and which operative strategy to develop.

The second stage requires a new Implementation Management Team made up of experts from different areas of the product development process. Here, a modeling methodology is needed and the IDEF family can be used to model each aspect of the Zachman framework for the company.

This analysis is oriented not only toward knowing how the process works but also to gaining a more precise understanding of what mechanisms are involved in producing delays and can be improved, as well as the interrelationships and dependencies between activities. We found that the proposal of Mentor Graphics introduced an excellent metric from the communication point of view and we have developed an assessment model in accordance with NGM. Once the assessment has been elaborated we will obtain the information of the current state (As-Is) and the desired state (To-Be). This assessment is the main core of our research and the results are presented in this paper.

The third stage involves redesigning the current process and driving the new one to perform parallel activities with CSCW tools, while considering not only the Product LifeCycle but also processes and facilities. Methodologies and techniques for the team must be well defined and the tasks and functions have to be clearly established.

Additionally, some goals must be set and a series of metrics for the product development process need to be considered in order to quantify the improvements of the process, and to know whether the partially achieved objectives really match the strategy of the firm. Another important item is to identify the organizational (cultural) and technical barriers so as to prevent possible failures. To obtain an appropriate atmosphere that facilitates the success of the project, it is also important to develop an entire system of incentives. At the end of this stage the first alternative leads us to define a pilot project and a decision must be made about what product to implement and the extension of the project.

The fourth stage involves carrying out the CoE practices through a team that has been trained in the selected methodologies and design tools as well as in the new communications and procedure environments. Once it has finished, the results must be analyzed in order to make a critical decision that will probably change the culture of the company, that is, the transformation of all the processes into collaborative ones. Therefore, the analysis should include the qualitative achievements (teamwork, technological and communication improvement, knowledge sharing, transparency, etc.) and the quantitative results, which involves adding up both tangible and intangible achievements. The report must clearly show successful and unsuccessful results and achievement of the goals proposed in the objectives that were outlined in the evaluation and in the change plan.

The decision to completely transform the integrated product, process and facilities development procedure is conditioned by the success of the pilot project. The new CoE environment is an improvement and the reengineering process should result in changes that depend on the experience acquired. The CoE team must promote the successful results of the Pilot Project. This stage involves a great deal of work, since a detailed audit of all the activities taking place in the product development processes has to be carried out, and how to transfer the knowledge from the previous experience to each of the departments has to be determined. Finally, it is crucial to adapt the culture of the firm since people are definitely the most valuable mainstay in any collaboration venture.

Findings

Our proposal for CoE assessment, as well as the reengineering framework described, was developed within the Research Project entitled Collaborative Engineering in the Ceramic Tile Supply Chain (CE-Tile). The proposal has four fundamental elements: a *questionnaire* to evaluate the Current Situation, a *matrix* to evaluate the Desired State (collaborative engineering scenarios), a *Change Diagram* (a graphical representation of shortages) and *Innovation Guidelines* (actions to be carried out in order to improve the process). The evaluation system is based on Carter and Baker's proposal but it has been developed bearing in mind the Next Generation Manufacturing Reference Model. It therefore analyzes its four Dimensions by evaluating a series of Key Factors according to different Maturity Levels.

Dimensions. These allow us to understand each of the broad areas of interest of an extended manufacturing enterprise. *Human Resources* identifies how managers empower people or teams to speed up the IPPD process, team training in use of techniques and tools, and what systems of incentives are used. *Processes* identifies the factors that are directly related to the procedures of product development that satisfy client requirements. *Technology* allows us to evaluate communications among the team member or personal skills. The *Integration* dimension allows us to analyze not only the integration between team members but also with clients and suppliers.

Key Factors. These will allow us to identify the way the company works, the levels of communication that exist and the use of technological resources. These are Key Factors that we consider fundamental in determining the CoE environment and on which we will base our implementing strategy, since they will enable the actions that are specifically involved in improvement to be defined.

Table 1. Key Factors

Human Resources	**Processes**	**Technology**	**Integration**
Team Formation Empowerment Incentives System	Client Requirements Product Development Planing Design Methodologies Engineering Knowledge Standards Validation Design Documentation	Communications Product Development Tools Workflow Management Product Data Information Sharing Feedback Optimization Virtual/Rapid Prototyping	Team Integration Supplier Point of View

Maturity Levels. In order to elaborate the As-Is Questionnaire and the To-Be Matrix we established a series of Maturity Levels for each Key Factor. They do not only reflect the level of effort made by the team to communicate but also consider the level of collaboration performed in order to improve and innovate during product development. We understand that, following the NGM guidelines, there could be five levels of communication effort.

Project. This corresponds to a minimum communication effort: people do not need to exchange the information dynamically and only basic communication takes place.

Program. This involves a communication effort among different engineering disciplines to exchange information and negotiate the IPPD in an interdisciplinary way.

Concurrent. This level corresponds to a multidisciplinary work effort with communication that flows among the different disciplines involved in the process which, besides sharing information, are concerned about innovating and improving the product.

Enterprise. The Product Development Process is so complex that it requires many multidisciplinary teams and the communication environment must be spread throughout the whole company. A process vision is formally adopted and teams constantly seek the innovation and improvement of the product.

Collaborative. This level is attained when the process includes not only many multidisciplinary teams but also suppliers and other companies from the supply chain who are involved in an active way. This development process allows the exchange of information among different companies in order to generate better products, more quickly and in the shortest possible time.

For each Key Factor we have tailored five questions according to each maturity level scenario. During the assessment process, once the questionnaires and the matrix have been completed a qualitative analysis enables us to draw the results in the Change Diagram (Fig 3). Obviously the interview method supposes that lower levels must be satisfied before rising to a higher level.

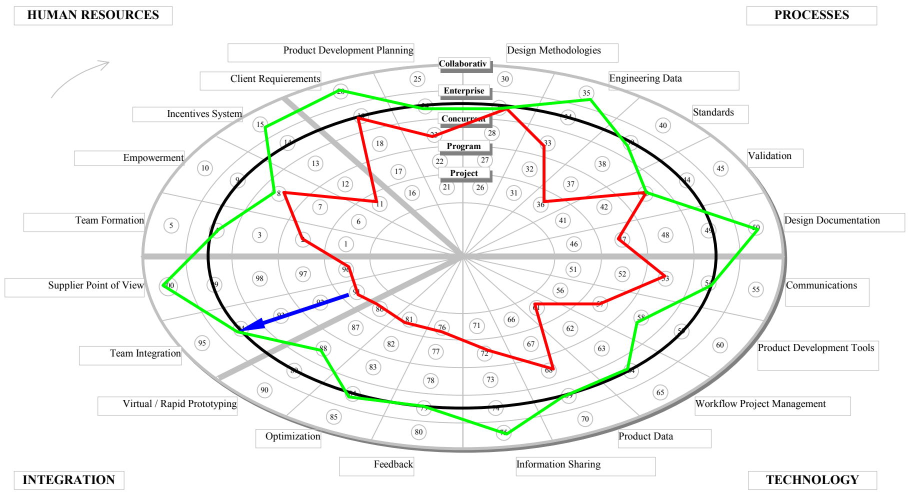

Fig. 2. Change Diagram.

The results will allow us to determine the degree of change for each key factor and for the whole process, at the same time seeking a balanced environment that should include most of the desired states and that should be acquired by progressively prioritizing the most important actions.

Conclusions

The main contribution of this research work lies in the definition of a reengineering process that considers the most important actions involved in the implementation of collaborative engineering. We believe that this assessment solves and updates some aspects of previous ones which did not consider certain aspects of concurrent engineering from the excellent manufacturing enterprise framework and the opportunity of using collaborative engineering as an approach. The process includes descriptive models following a top-down approach and which are guided by the NGM framework that must be demanded for the implementation of PLMs with the aim of favoring the management of the collaboration process.

The development of an assessment model for collaboration is important to researchers because, on the one hand, the literature on this subject is scarce and, on the other, it provides us with a deeper understanding of the activities associated to product development by defining the collaboration processes that take place, above all, when the organization is undergoing a process of delocalization and distribution of production. Thus, our model seeks to be more complete by adapting NGM and filling some gaps left by the previous system. In addition, the factors are guided toward analyzing the different mainstays of Collaborative Engineering.

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