Concurrent Engineering Frameworks

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Abstract

The environment surrounded by industries is represented by the 3Cs: Customers, Competition, and Changes. The 3Cs drive industries to pursue external business targets such as customer's needs and marketplaces with BPR (Business Process Reengineering). BPR addresses core business processes. One of these core business processes is product development. This product development process has been reengineered by the concept of CE (Concurrent Engineering).

The aim of the paper is to build frameworks of CE to clarify the CE concept. This paper begins with investigating the product development process from the perspectives of three drivers: cost, quality and speed. CE frameworks are then followed. The first framework is concerned with the CE definition and thus three keyphrases are extracted: from the outset, concurrent design and systematic approach. Concerned with the CE implementation, the second framework is composed of five components: generalist & specialist, cross-function team, enabling tools & techniques, success metrics, and total visibility.

This paper concludes that the CE practice is hard to achieve because of the 'don't-tell-them-early' attitude of upstream people, and the 'wait-and-see' attitude of downstream people. As resolution, a change management program is recommended that changes an employees mind-set. This paper also supposes computer systems which facilitate and keep automatic track of the CE process as engineered. Finally it gives a warning that computer systems alone do not guarantee success without being preceded by process re-engineering.

1. Introduction

Up to the seventies and early eighties, industries managed their businesses based upon functional structures. Stimulated by the encroachment into the marketplace of some Japanese companies, western industries began to make close assessments on the practices taken by these companies and found out about TQM (Total Quality Management) and JIT (Just-In-Time) practices. However, the implemented results are still unsatisfactory because of the 3Cs: Customers, Competition, and Changes (Hammer and Champy, 1993). The 3Cs drive industries to pursue external business targets such as customer's needs and marketplaces, and to accelerate the Business Process Reengineering (BPR) practice.

BPR is the means by which an organization can achieve radical change in performance as measured by cost, cycle time, service and quality, by the application of a variety of tools and techniques that focus on the business as a set of related customer-oriented core business processes rather than a set of organizational functions (Carr, *et al.*, 1992). The customer-oriented core business process is defined as a set of linked activities that crosses functional boundaries and, when carried out in concert, addresses the needs and expressions of the marketplace and drives the organization's capabilities. One of the core processes is a product development process.

This paper investigates the Concurrent Engineering (CE), which is regarded as BPR in the product development process. The aim of the paper is to build frameworks of CE. CE cannot be successful unless it is performed in the frame of BPR. At the same time, CE needs to be clearly differentiated from BPR because individual core processes are distinct.

2. Drivers in Product Development Process

The product development process is investigated from the perspectives of three drivers: cost, quality and speed. For the convenience of explanations, the development process is divided into 4 stages: concept, design, prototype and production stages.

First, the prototype and production stages usually require a lot of capital and tool investment, materials and human resources. The costs occurring at these stages occupy most of product cost. Preventive measures should be taken in the product development process, so as not to reinvest the most expensive portion of product cost.

Secondly, a classic quality metric is the number of engineering changes, which normally continues to increase at the prototype stage and again slightly after shipping. Early detection of quality problems would not only enable the planned schedule to be

met but reduce customer's complaints and eliminate wasteful cost resulting from reworks.

Regarding speed, there are two observations. The first one is that a shipping date should be timely met to achieve a planned profit. The development team may outsource its work load; and it may spend money on the air-borne delivery of materials. All of these attempts seem to be easy to execute, but in reality people lose the timing for the right decision, mainly because of the function-oriented bureaucratic management. The second observation is that since it is unreliable to anticipate the exact shipping timing, it is best to keep as short a development period as possible. The development with the shortest period cannot be attained simply by the overruns of material and development costs. This requires an overhaul of the development process.

3. CE Frameworks

3.1. CE Definition and Keyphrases

This paper has adopted the concise definition of CE made by USA's IDA report R-338, 1986: "a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from concept through disposal, including quality, cost, schedule, and user requirements."

There are three rationales for this adoption. The first one is that it explicitly mentions the issues of what and how: all life cycle elements and concurrently. The second one is that it explicitly directs us where to focus during the development process; that is, from the outset. The third rationale is that it guides us how to implement the process. It suggests us systematically to do an integrated and concurrent development. The three keyphrases, which are From the Outset, Concurrent Design and Systematic Approach in the definition sentence, compose the framework for the concept of CE.

From the Outset

This keyphrase has three attributes: front-loading, estimation and collaboration. CE requires all resources to be entered up front. Before starting, a cross function team is assembled. They prepare product specifications and proceed with their individual work assignments referring to the product specifications. Since nothing has been decided clearly at this early time, everyone must have the skill to estimate results by referring to the legacy data and experiences.

The great asset at this early stage would be lessons learned built by previous developers. As an enabler, QFD (Quality Function Deployment) will be extensively utilized. This will facilitate the team to reach an agreement on product and test specifications from the start and allow the team to maintain consistency of the specifications through development. These efforts reduce engineering changes at later stages.

Concurrent Design

This keyphrase has three attributes: concurrency, accessibility and synergism. Once a team is organized for a development project, each member performs his/her respective work concurrently. Since their work is not mutually exclusive but interrelated, they need to access each other's work frequently. The means of an access can range from face-to-face meetings to database inquiries. Accessibility eliminates unilateral design viewpoints and allows the team to take an effect of synergism on individual skills.

Each member performs pull operations in the sense that they expedite the upstream discipline's results. The results might be partial and incomplete, but the pull operations enable some conflicts to be resolved in advance. In this way, the concurrent design of a cross-functional team attempts to eliminate possible losses coming from functional barriers.

Systematic Approach

This keyphrase has three attributes: well-structured, consistency and flexibility. CE requires a well-structured development process. This attribute is particularly important due to the concurrent design. At the same time, CE requires consistency in data, information and procedures. Since the CE environment is apt to change, the development process should be flexible enough to adapt to a new environment.

Based upon a well-structured process, a generalist or a "guru" leads a host of specialists and pursues efficient ways to deal with a plethora of data and information. To enhance the effectiveness and efficiency of the development process, several tools and technologies can be selectively used. Well-proven tools and technologies aid in maintaining the consistency of the process and enabling generalists and specialists to perform continuous process improvement.

The CE concept has been examined and brought into a framework. The framework describes the state that a CE environment should reach. The next section will talk about what components should be included for that state. In other words, the

components describe transitional preparation activities.

3.2. CE Components

There are five components: generalist & specialist, cross-function team, enabling tools & techniques, success metrics, and total visibility. Carter (Carter, 1990) suggests 4 components of CE and NTIS (National Technical Information Service, USA) (Linton, *et al.*, 1991) presents 11 first principles of CE.

Generalist & Specialist

Generalists are those who understand the product development process. Although all of the developers do not have to be generalists, some of developers should consolidate several disciplines and one of them should become a "guru" who leads the rest of the developers. There may be many roles required of him/her pertaining to product development. One of the most important roles is interdiscipline trade-offs. The guru should possess collaboration skills to relate between specific disciplines and resolve conflicts. The best way for him to learn the skill is to utilize process mapping which not only shows current detailed work flows but also gives some opportunities to streamline them.

Specialists must be strategically cultivated; given greater exposure to new technologies, provided with a promotion ladder separate from generalists. Advanced products tend to be complex in the sense that several disciplines need to be integrated and collaborated. However, since each discipline uses its own jargon, it is difficult for specialists to achieve full collaboration. This is one of the reasons why a cross-function team is formed and a guru appears as a team leader.

Cross-Function Team

It is strongly recommended not to co-locate a cross-function team members, although some argue that they must be co-located. The major reason is that they should be able to keep up with recent technologies while they remain in their individual departments.

Since they are remotely located and working for cross-function team operations, they need some commitments from their functions' chiefs and from the top. With these commitments, they are more willing to communicate and make decisions on the spot. This is the key aspect of CE.

The team leader is given special attention. There are three kinds of supporters: product sponsor, gate keepers and technical experts. The product sponsor, usually at the top level, delegates his authority to the team leader. The gate keepers serve as staff to the leader, collecting and analyzing all the product development information including marketing news. The technical experts advise the leader and answer technical issues.

The team infrastructure's success really depends on to what degree team members can collaborate. A collaboration degree can be measured in three forms. The first one is unity of project purpose, the second one is integrated product perception and the third one is unified development reasoning. The collaboration degree could be enhanced much better and faster if some tools and techniques are used.

Enabling Tools and Techniques

Tools and techniques are useful for team collaboration in terms of a timeliness and accuracy. They can be grouped into four categories: CAX tools, DFX tools, PDM tools, and Techniques;

- CAX tools include CAD(design), CAE(engineering), CAM(manufacturing), CAT(testing) and rapid prototyping.
- DFX tools include DFM(manufacturing), DFA(assemblibility), DFR(repairability), and DFQ(quality).
- PDM tools include data management, configuration management with product structures, workflow management, and project management.
- Techniques range from benchmarking through process mapping to target costing, QFD, FMEA, and DOE.

Additional tools and techniques may also be beneficial.

This paper does not discuss each tool and technique. Rather, it gives two general guidelines. First, as enablers, tools and techniques should be discretely selected and phased in. Secondly, these tools and techniques should be applied during the process of the product development, not for the purpose of individual tools themselves. People tend to adopt and use some tools because competitors also do that. Only from the viewpoint of a development process peculiar to a specific company, the tools selected will produce the results expected.

Success Metrics

CE is concerned about cycle time together with cost, quality and service in the product development process. CE activities should be measured and rewarded from the viewpoint of team collaboration. The measurement is the vehicle by which functions can break their barriers in between and provides a basis for team rewards.

As the backbone of a company, middle management has a tendency to focus on short-term functional targets. This is really true since the company's organization has been function-oriented. As CE is about to be applied, middle management is no longer measured by individual functional targets, but from the process viewpoints such as cycle time, market share, number of changes and target cost.

Project management is a tool for this purpose. Using project management, team members are provided with project targets and are informed of the progress status immediately. The more CE environment is pursued, the more project management is required. The project management also enables the project leader to outperform his/her role.

Total Visibility

Total visibility is the capability for developers to share information regarding new product development. In the previous, three collaboration measurements are given: unity of purpose, integrated perception and unified reasoning. The capabilities to support these measurements are called design view and decision support.

Design view provides team members with project information of what should be done by whom, when, and where. By design view, project information should be transparent in a timely fashion. Workflow management in PDM (Product Data Management) systems is one of the emerging techniques to support design view. The other techniques may include next generation CAD systems which are capable of containing design rationale, and QFD systems which consist of customer requirements, product requirements, process requirements and quality requirements in a consistent way.

Decision support is the capability with which team members can make prompt, accurate decisions. They need previous experiences of others, which are contained in a lessons learned database. The lessons learned database can take shapes of data management in a PDM system and a knowledge database. Data management allows the access of legacy data such as CAD data and test results contained in a data vault. A knowledge database can include success and failure stories written by previous developers.

Design view and decision support capabilities enable a project team to share their understanding and knowledge. Using network infrastructure, a project team becomes a virtual project team and is able to make use of computer conferences. The network infrastructure is not limited to LAN (Local Area Network) and WAN (Wide Area Network). The more business is globalized, the more important satellite networks become .

4. Conclusion

The intention of this paper is to clarify the CE concept. People tend to embark on CE implementation without having full understanding of the CE concept. This causes CE practices to fail. Poor understanding may even cause a product development team to stray from the development process.

The CE practice, although it yields excellent benefits, is very hard to achieve because of front-loading and concurrency. Front-loading requires the pain and anxiety of the developers involved since they start with nothing but their technology skills. Concurrency is inherently risky unless there is good project management. Front-loading has been inhibited because of the 'don't-tell-them-early' attitude of upstream people, and concurrency is inhibited because of the 'wait-and-see' attitude of downstream people. Therefore, there should be a program that changes an employees mind-set and the best way is to drive them to go through process re-engineering.

The success of front-loading and concurrency cannot just depend on process re-engineering. It needs computer systems which facilitate and keep automatic track of the CE process as re-engineered. It may be the PDM system that provides the capability of securing the CE process. However, it must be remembered that the PDM system alone does not guarantee success without being preceded by process re-engineering.

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