A Concurrent Function Deployment Process for Product Life-cycle Management

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Abstract

In this paper, an alternate framework for deployment called Concurrent Function Deployment (CFD) for managing a product’s life-cycle process is described. The framework considers parallel deployment of several value characteristics as opposed to a single value such as Quality. The American Supplier Institute’s (ASI's) quality function deployment (QFD) concept [Sullivan, 1988] is a typical case of a conventional four-phased deployment process, where quality is the prime consideration for deploying life cycle functions. CFD is not based on using a single measurement, such as “Quality” as in ASI's QFD. Six concurrent values, namely Functionality (Quality), Performance (X-ability), Tools & Technology (innovation), Cost, Responsiveness, and Infrastructure (delivery) are considered simultaneously in CFD rather than serially in QFD. Three-dimensional Value Characteristics Matrices (VCM) are employed to ensure that both the company and the customers’ goals are optimally met. In the present setting, ASI’s deployment scenario emerges as a special case of Concurrent Function Deployment. CFD enables the planners and strategic decision-makers --early-on during a design process -- to deal with tradeoffs among the crucial factors of artifact values.
1. Introduction

3. Limitations in Deploying QFD in a Concurrent Design Process

Early on, when Japanese became successful in bringing cars to market in record time, many automotive world leaders mistakenly assumed that their success was solely because of technical tools. This explains the initial flurry of activities (with QFD, SPC, Taguchi, Pugh, Kaizon, etc.) that American industries went through during 1980s. As many American automotive industries failed on this front, manufacturers began to unearth the cause of their failures. It did not take very long to realize their apparent short-sightedness. They discovered that many of the barriers to global competitiveness were rooted in their assumptions. That is they were basing their product design, development and delivery (PĐ) decisions primary on “quality characteristics” while ignoring other design aspects such as costs, design for x-ability, tools and technology, infrastructure. These later set of "value characteristics" might have relevance to the overall design output and might required to be deployed with "quality characteristics" simultaneously.

A conventional implementation scenario of QFD does not specifically address the cost, tools & technology, responsiveness (time-to-market) and organizational aspects in the same vein as it does to the "quality" aspect (see Figure 1). While some consider the product design process as being independent from technology, design-for x-ability, cost and responsiveness, the reality is that they are tied together by a common set of product and process requirements. A conventional implementation of QFD towards a design process only provides a product design from the perspectives of a single performance (i.e., the quality). The product design performance requirements drive the product selection (including system, subsystems, components, parts and material selection) process and influence the selection of the fabrication (process and production) method. Others have argued that while performing "Quality FD", designers could choose to include requirements and constraints (RCs), which belong to considerations other than quality in the original customers’ list of HOQ [Dika and Begley, 1991; Carey, 1992; Kroll, 1992]. Accomplishing this through a conventional deployment process such as
QFD is not a simple task. Working on the multiple lists of requirements and constraints (RCs) as part of a single function deployment (say under a quality FD) is a much tougher problem.

⇒ **First**, it would be a complex undertaking in a conventional deployment process to consider just the size of the resulting relational matrices.

⇒ **Second**, deploying the value characteristics (VCs) serially would be a long drawn process.

⇒ **Third**, cascading the RCs all together as we did in the case of "Quality functions" in a conventional deployment, the resulting matrix would be very large. It would be difficult to handle the complexity of such deployment.

⇒ **Fourth**, there is no way of insuring that the design obtained by repeating this "Quality FD" process combinatorially for each VC one at a time for a PD$^3$ process would not result in a sub-optimized design. Meaning, a product may appear to be optimized for a set of characteristics related to quality but actually may not be optimal with respect to all possible value considerations.

What is required in optimizing an artifact is designing with respect to all important functions that characterize a “world-class product” today. Normally in actual practice, information for these measurements is independently obtained and design in a product design, development and delivery (PD$^3$) process often proceed in parallel. Paralleling allows the combinatorial problems to be addressed in sizable chunks, which in turn can be handled by a number of specialized work-groups comfortably. Parallel deployment of values would allow concurrent teams to work independently, thus reducing the PD$^3$ cycle-time.

Conventional deployment cannot account for the increasing complexities of our product and the conflicting requirements (RCs) that need to be addressed. As a consequence, the best efforts of the concurrent team in the phased deployment (similar to conventional deployment forms) simply do not result in products that optimally meet customer requirements. It is not because the teams are not able to work closely, but the deployment vehicle for a PD$^3$ process was not robust enough to accommodate multiple functions deployment simultaneously. Conventional deployment (such as with the use of QFD) for a "team-based design process" lacks the vigor to
implement simultaneously a number of conflicting value characteristics (VCs) such as cost, responsiveness, quality, etc. In the absence of any better deployment vehicle, the team often repeats the conventional deployment process for each value one at a time. This elongates the PD³ cycle-time into a multi-year ordeal.

QFD was designed originally to take the Voice of the Customer (called customer objectives) and translate them into a set of design parameters (called "quality characteristics"). These VOCs can be deployed vertically top-down through a serial four-phase process [Sullivan, 1988]. The four phases, known as ASI’s four-phase process, are: Product Planning, Parts Deployment, Process Planning and Production Planning. The overall objective of QFD -- when introduced in 1967 -- was primarily a “Quality” deployment technique, today in traditional deployment forms, is still the product’s quality. Focus on "quality characteristics" as pertinent columns of the relational matrix for deploying customer requirements was also the reason why QFD was named Quality Function Deployment by the Japanese [Crosby, 1979; Taguchi and Clausing, 1990]. Recently Don Clausing and others have introduced some structural changes in the way the QFD template or a set of matrices is arranged. The new arrangement is commonly called the extended House of Quality [Hales, Lyman and Norman, 1990; Taguchi and Clausing, 1990], however, its original focus on "quality characteristics" and its traditional orientation for a phased deployment has not changed at all.

This extended House of Quality (HOQ) consists of eight fundamental areas, all of which are not essential (see Figure 1). In the following section, we examine its limitation in deploying to a product life-cycle management process.
3. Concurrent Product Development

The first step in creating a great product is an understanding of what exactly makes a product great. Kim Clark defines a great product as one that meets all pertinent characteristics that are required to ensure product integrity. As discussed further in Prasad [1997], development of a new artifact does include considerations for several life cycle values that are pertinent to meeting the customers' requirements. Many of these values are independently specified, i.e., there is very little or no interaction between them. The author has done a series of studies at General Motors and EDS with QFDs, deploying one value at a time (in a serial mode) and deploying all values together simultaneously. The author has also studied deploying them concurrently so that the "value characteristics" do overlap. Through a series of these implementations and studies, the author has found that the deployment of many artifact functions (called here values) can proceed in parallel with what we know today as "quality FD." Examples are: X-ability (performance), tools and technology, cost, responsiveness and infra-
structure. Generally, these functions or values are independently specified and estimated. The results of experience can be used to specify the requirements and expectation for each of the values in parallel without having to wait until a deployment of a “value function” is complete.

5. Mechanics of Concurrent Function Deployment

In Reference [Prasad, 1997], Prasad expanded the original definition of conventional deployment as to include parallel deployments for a PD³ process. This provides a method to consider the deployment of competing values simultaneously for a team-based product engineering and design. We have called this approach Concurrent Function Deployment (CFD). The intent of CFD is to incorporate “Voice of the Customers” into all nine phases of the product development cycle. That is, the intent is to integrate VOC through Mission definition, Concept Definition, Engineering and Analysis, Product Design, Prototyping, Production Engineering and Planning, Production Operations and Control, Manufacturing and finally into Continuous Improvement -- Support and Delivery -- tracks (see Figure 4.2 of Volume I [Prasad, 1996]). In other words, CFD is customer driven PD³ methodology.

CFD is a Concurrent Engineering methodology that enforces the notion of concurrency and deploys simultaneously a number of competing artifact values. It is not based on deploying quality alone as done in a conventional deployment. The artifact value deployment in CFD is through all its life-cycle phases. If a specification chart is being developed for the product, the taxonomy for requirements and constraints (RCs) must reflect all value considerations that a product may encounter during its life-cycle. RCs thus include customer requirements (CRs) , VOCs and all types of WHATs that one may encounter. There are many value characteristics (VCs) for artifact, such as quality, X-ability, tools and technology, costs, responsiveness, infrastructure, etc. Such taxonomy will ensure that all important aspects for product and process design have been identified and included. The focus of CFD, first, is on systematically capturing product information, such as, market competitive analysis and customer satisfaction rating. Second is on analyzing these ratings to improve product functionality (say an X-ability aspect) and the third is on adding an array of values that are important to
the customers and to the company. CFD, thus, ensures concurrent product development. CFD breaks the multi-year deployment ordeal by allowing work-groups to work concurrently on a number of conflicting values and compare their notes at common check points. CFD is a simple and powerful tool that leads to long range thinking and better communication across several value functions.

The paper presents a methodology for concurrently deploying a line of value objectives for successive product refinements leading to a “world-class” category. Also, since each life-cycle value of total value management (TVM) of a product meets only a partial set of its specifications, the characteristics of the chosen TVM values will dictate the entire life-cycle needs to manufacture or fabricate that product [Prasad, 1997].

6. CFD Methodology

Concurrent Function Deployment (CFD) is a methodology that allows designers and manufacturing engineers to communicate early and work in parallel during various stages of a PD³ process. One critical new tool to facilitate this early communication is “house of values,” which is a concept similar to the “house of quality” that was introduced in Akao's QFD. However, the term “values” is not used here to mean just “quality.” It ranges from quality characteristics as it was in conventional deployment to other value characteristics imposed by attributes, such as X-ability, tools and technology, cost, responsiveness, Infrastructure and other similar type of functions. The concept gives rise to a line of concurrent houses; namely House of Quality, House of X-ability, House of Tools and Technology, House of Cost, etc. House of Quality, thus, becomes a degenerate or a special case of this series --“House of Values”-- template.

6.1 Three-dimensional House of Values (HOV)

The basic tool of CFD is the “relational matrix” concept. Matrices are schemata to generically define and directionally relate multiple lists of identifiers, often referred as line-vectors or list-vectors. The basic matrix of CFD is the “house of values,” so named to keep resemblance with “house of quality” that forms one of the many objectives of CFD [Prasad, 1997].
The relational matrix in CFD translates the corresponding requirements and constrains (RCs) into a set of value characteristics (VCs). Figure 2 is a schematic view of a “House of Values (HOV)” template. This template (HOV) has 8 rooms. Four of the rooms form the basic perimeters of the house. These are two row-rooms: WHATs and HOW-MUCHes, and two column-rooms: HOWs and WHYs. Concurrent HOV also encompasses relationships among these four list-vectors resulting into four “relational matrices.” These are:

⇒ HOWs versus HOWs
The relationships between CFD components are shown in Figure 3. The three-dimensional matrix takes the form of three roofs and three relational matrices as shown in Figure 3. It has three list-vectors: artifact values (AVs), value characteristics (VCs), and requirements and constraints (RCs) list. Eight elements of AVs, nine elements of VCs and three major elements of RCs vectors are shown for example purposes. These lists may contain any number of values as necessary. Figure 4 shows a three-dimensional deployment scheme for CFD. The line-vectors are:

- RCs is deployed along the Z-axis (vertical dimension).
- AVs are deployed along the X-axis (horizontal dimension).
- VCs are deployed along the Y-axis (axial dimension).

The three relational matrices are:

- RCs versus VCs
- RCs versus AVs
- AVs versus VCs

These relational matrices are also shown in Figure 3. This completes the concurrent deployment of values along the three independent axes.

Figure 3: Relationship between CFD components

Figure 4: Concurrent Function Deployment -- Three Dimensional Deployment Schema

6.2 Life-cycle Deployment
The next section illustrates a degenerate case of CFD, that is of deploying a quality FD through a CFD trio process. This concept is virtually equivalent to a conventional deployment (similar to QFD for instance) when the "quality" is the primary "value function" for deployment.

6.3 Quality FD

Products are often divided into logical hierarchical blocks depending upon their complexity levels. Different parallel teams can work in these different hierarchical groups. Work-groups at each level can work concurrently. Some dependencies can exist between the levels. Establishing common quality standards for communications and definitions of VCs can allow parallel work-groups to work concurrently. The most commonly employed quality characteristics, $Y_{ij}$, are [Prasad, 1993]:

Where $Y_{ij}$ for $i=1$ (Quality FD) and $j=1, 5$ are:

1.1 Assembly
1.2 Sub-assemblies
1.3 Components
1.4 Parts
1.5 Materials, etc.

Figure 4 also shows the above set of “quality characteristics” spanned along the axial (Y-axis) dimension for a CFD setting. In Figure 5, the “quality” value for CFD tier 1 is further spanned axially (along Y-axis) into its characteristic (VCs). This axial expansion corresponds to the five VCs for quality that were listed in Figure 4. The axial expansion of the Product Planning tier ($Y_{ij}, j=1, 5$; levels I.1 through level I.5) uses the PtCs defined in tier 1 to evaluate alternatives and filter a design that meets most of the customers’ demands. At the end of Tier 1 (level I.5), a set of Product PtCs is identified that represents best of the class (see Figure 5). Process planning (tier 2) deals with selection of process concept and identification of critical operation parameters, here called as Key Process Characteristics (PsCs), which can cause the product PtCs identified in tier 1 to be satisfied.
Production Planning (tier 3) identifies Production PnCs (control requirements, maintenance requirements, mistake proofing, education and training issues, etc.) in line with the process (PsCs) identified in tier 2.

**Figure 5: Linked CFD House of Values for Quality: Axial Deployment (Y-axis)**

Figure 6 illustrates the CFD concept of deploying quality RCs vertically (along the z-axis) often embedded in the *Voice of the Customer*. The three-tier deployment structure is shown in Figure 6 for quality FD. Tier 1 is for a Product Planning path, Tier 2 is for Process Planning path, and Tier 3 is for Production Planning path. The same three-dimensional trio process is repeated for each tier. For example, during product planning, customer requirements (CRs) or *WHATs* are related to key quality characteristics, for which a list of *WHYs* and a list of *HOW-MUCHes* are then identified. *HOWs* define the desired key product characteristics (PtCs) of a product to counter the *WHATs*. *WHYs* are the overall evaluation criteria used within the organization to define acceptability of the product. Targets for the PtCs (*HOW-MUCHes*) are established based upon competitive benchmarks and the customer’s competitive assessment. Such deployment methodology is followed for tier 2 and the tier 3 trio sequences.

**Figure 6: Linked CFD House of Values for Quality -- Vertical Deployment (Z-axis)**

### 7. Merits of Concurrent Function Deployment

Figure 7 compares a conventional deployment technique (such as ASI's QFD approach) and CFD approaches in great depth. ASI's QFD is actually a subset of CFD template.

In traditional deployment processes (true with QFD also), quality is generally associated with manufacturing and for which several quality measurement tools -- such as SPC, QPC, Coordinates measuring machines (CMM), etc. -- are typically employed. For instance, activities such as performance measurements, dimensional control, and others, are often used to check "quality characteristics" compliance during manufacturing. In reality, such efforts need not be limited to only manufacturing. Quality is not just a manufacturing problem alone. It is a cumulative outcome of decisions that are made during an entire product life-cycle. It is, therefore, important to
affect all such decisions. What would be a more appropriate place to affect these decisions than during the individual processes where these decisions are made?

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*Figure 7: Comparison of CFD with a Conventional deployment*

In a concurrent deployment process (as in CFD methodology), quality begins with the quality of the introduced requirements and constraints (RCs). RCs, in this context, are not only those requirements which are
specified by the customers, but also includes those that are introduced directly by the cooperating CE teams [Prasad, Morenc and Rangan, 1993]. The burden of poor outcome of a design in a conventional deployment process has been shifted from the work-groups expertise in product manufacturing to the teams’ choice (or selection) of RCs at each CFD transformation step. If appropriate methods can be employed in systematically classifying, deploying, and solving the transformed problems, the assurance of VCs’ considerations during CFD becomes merely a scheduling and distribution job. Quality considerations are ensured by the proper selection of RCs and methods for solving the constrained problems. Satisfaction of RCs and VCs at each transformation state is what constitute a product’s “values deployment.” By following this methodology, it is expected that the taxonomy of transformation [Prasad, 1996] would lead to a “world-class” product, whose "value characteristics (VCs)" are appropriately distributed across various levels of transformation. At each loop level, differences between proposed RCs and the computed outputs provide a measure of the differences that exist among alternate trial designs. Dealing with "value characteristics" at loop level is straightforward, since problem definitions (number of RCs, inputs, VCs, and the transformation matrix) are small and are manageable at that scale. Satisfaction of RCs during these early loop levels (say a feasibility or a product synthesis loop) is easier when problem definition is more explicit in forms than when the product is somewhat mature, say, after the product has crossed several decision boundaries.

8. Concluding Remarks

In the example described herein only a three-tier trio (horizontal-axial-vertical) structure for CFD is shown. This is the most common [Prasad, 1997]. However, such a CFD structure can have as many tiers as needed. In the proposed development, the filtering process is shown through a solid pipeline connecting the “characteristics” (HOWs) room to the WHATs room (see Figure 5). It ensures that VCs (namely PtCs, PsCs and PnCs) that are critical to meeting the product, process, and production objectives are given proper and early attentions (during Y-axis deployment). It also ensures that HOWs are further deployed into their root or key characteristic factors during the subsequent vertical tiers (z-axis deployment). In order to make this practical however, some computer
tools and aids need to be developed to capture this methodology. The manuscript -- due to the limitations in releasing proprietary information -- could not include results of some benchmarking studies. Adequate technical benchmarking, implementation examples, case studies or mathematical development of CFD methodology are future topics of research that yet to be pursued. In summary, more research works need to be done, but not necessarily by this author alone.

9. References


2. ASQC (American Society for Quality Control), Automotive Division, American Supplier Institute (ASI), GOAL/QPC, Transactions from the fourth symposium on Quality Function Deployment (QFD), June 15-16, 1992, Novi, Michigan.


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