GENOPERSISTATING THE SYSTEM

Edwin B. Dean *
NASA Langley Research Center
Hampton VA

Abstract

There is great concern for the competitiveness of the aerospace industry today. This paper examines the concept of competitiveness, introduces the concept of the genopersistation recursion, and summarizes a number of concepts which, when applied, seem to drive a product toward greater competitiveness.

Introduction

There is great concern recently in the aerospace industry about remaining competitive in the rapidly evolving world marketplace. Dertouzous, Lester, and Solow[9] reported on the Massachusetts Institute of Technology Commission on Industrial Productivity analysis of our national productivity as have others. They, as have others, postulated causes as well as potential cures for our increasing national uncompetitiveness. But what does it mean from a practical viewpoint to be competitive and how does one go about becoming more competitive?

To be competitive, a product must provide sufficient value to justify the price. The value of the product is ultimately defined by the consumer. Price is determined by the typical value placed on the product by the consumer and by the cost of delivering the product to the consumer. The consumer often factors in the cost of purchase or the cost of ownership as determinants of value. Thus, quality (customer value) and cost drive the purchasing decision. Since companies do not stay in business if they consistently sell a product at a price below the cost of delivering the product to the customer, their survival depends on the ability to keep customer value far enough above cost to guarantee survival and, hopefully, a profit as well. The best situation is when the product has high quality and low cost.

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*Technical Resource Manager, Member AIAA

As purchasers, we pay for the work required to bring forth and market the product. This is the cost of acquisition. As owner of the product, we pay for the work required to deploy, operate, maintain, evolve, and dispose of the product. This is the cost of ownership. Both the cost of acquisition and the cost of ownership are value, and hence quality, drivers. As an example, when I buy a car I create a list of cars by make, model, and year, which are rated low in maintenance by the Consumer Reports 19XX Buying Guide Issue. I then purchase a second hand car from that list for which the acquisition cost is within my current budget. In that manner I attempt to insure the lowest life cycle cost (the sum of the costs of acquisition and ownership) for a car I feel has acceptable quality.

This brief argument indicates that competitiveness is a function of both quality and cost. The ideal situation is to be able to design a system with both high quality and low cost. This paper discusses techniques which drive design simultaneously in the directions of high quality and low cost.

In order to set the framework for examining these techniques, genopersistation, a word without history, is defined to mean the bringing forth, sustaining, and eventual annihilation of something. The word is derived from the root words "genesis" and "persistence". For a product, genopersistation is the conceptual design, design, development, test and evaluation, production, deployment, operation, support, evolution, and retirement of the product. The genopersistation process is the application of these life cycle functions to the product.

Dean and Unal[8] noted that each of these functions is applied to each of the life cycle phases. For example, we conceptually design the design phase by determining how we will conduct the design; we design the design phase by determining the specific tools to be used during design; we develop the design phase by assembling a prototype of the design phase; we test and evaluate the design phase by testing the design system prototype; we produce the design phase by fabricating and assembling the components to be used during the design phase; we deploy the design phase by putting the final design system into place where it will be used; we operate the design phase by designing the product; we support the design phase by ensuring that the design system and needed supplies are available; we evolve the design phase through continuous improvement within the design system; and we retire the design phase after all engineering changes are complete.

A little reflection indicates that, somehow, the genopersistation functions belong to a different level of system than the functions within the phases. This is represented by the genopersistation recursion as follows. At the lowest level of this recursion is the product. The next level up is the system to genopersistate the product. The functions, <verb,noun>, ConceptuallyDesignProduct ... Retire Product are functions of this level. The next level up is the system to genopersistate the system to genopersistate the product. It contains the functions ConceptuallyDesignConceptuallyDesignProduct ... RetireRetireProduct. It is the genopersistation of the product genopersistation and hence is a planning/preparatory function. It genopersistates the project to genopersistate the product. The next level up is the system to genopersistate the system to genopersistate the system to genopersistate the product. It is of particular interest to those interested in engineering management as a research topic. The functions of my own research which has generated this concept are those of EvolveConceptuallyDesign ConceptuallyDesignProduct ... EvolveRetireRetire Product, which are contained in this level. Although an infinite number of levels exist above this level, they are beyond the scope of this paper.

If a product is to have high quality and low cost it must be inherent within the product and its genopersistation. The acquisition cost of a product is generated by the functions ConceptuallyDesignProduct ... DeployProduct. The cost of ownership of a product is generated by the functions DeployProduct ... RetireProduct. Note that the cost of deployment may be split between acquisition cost and cost of ownership. The cost of those functions is determined by the functions ConceptuallyDesignConceptually DesignProduct ... RetireRetireProduct. It is those same functions which determine how quality will be designed into the product. As noted by Unal and Dean[29], cost and quality can and must be designed into the product together. Thus cost and quality are generated by the system to genopersistate the product (the project) but are determined by the system to genopersistate the system to genopersistate the product (the project genopersistators). It is interesting to note that although literature abounds on project management, very little exists on project genopersistation or project genopersistation management. A corollary is that little literature, and hence knowledge, exists on how to determine quality and cost. A further corollary is that we don't know much about how to be competitive.

The remainder of this paper summarizes techniques which can be used to simultaneously genopersistate both high quality and low cost into a product.

Taguchi Methods

Taguchi methods[27] were probably the first of the tools specifically designed to design for quality. In his monumental treatise Taguchi[28] linked quality and cost through the quality loss function and applied the design of experiments[23] to the experimental optimization of the product parameters to attain quality objectives. Optimizing for cost is as simple as choosing cost for the quality objective[29].

The quality loss function models the cost of ownership as a quadratic with the minimum at the quality target. This permits the quantification of the cost of ownership as a function of quality characteristic variation. High cost of ownership thus results from unquality or product variation from the target. The target quantifies customer expectation. Customer expectation can be defined by applying Quality Function Deployment (QFD). Taguchi's concept of designing for minimum product variation gave rise to the robust design approach[26].

By using orthogonal arrays, Taguchi was able to combine engineering intuition with fractional factorial experiments to attain large efficiencies in the number of experiments required to obtain a near optimum set of quality characteristics for a given quality objective. His technique assumes that the quality characteristics are uncorrelated or that all correlated pairs of quality characteristics are known. If the quality characteristics are uncorrelated then a linear model is sufficient. If correlated pairs of quality characteristics are known then columns are set aside which capture the interaction which results from the correlation. In both cases, far fewer experiments are required than would be required with a full factorial design. The result is an efficient optimization algorithm which can be implemented by empirical investigation when equations are not available.

Taguchi methods are associated with eighty percent of recent quality gains in Japan.

Although Taguchi methods have primarily been applied within the system to genopersistate the system, they appear to be applicable at higher levels of the genopersistation recursion.

Response Surface Methodology

Response surface methodology[23] is a competitor of Taguchi methods which uses the design of experiments and linear regression to approximate a multidimensional response surface with a quadratic form. Because a quadratic form is used, all interactions are automatically captured.

Canonical analysis permits estimation of the quality characteristics at stationary points which correspond to either a minimum, a maximum, or a saddle point of the approximated response surface. The value of the response surface can be estimated from the coefficients obtained by the regression, as well as the fact that the stationary point is a minimum, a maximum, or a saddle point.

In order to capture the full effects of response surface curvature, Taguchi methods require at least three levels for each quality characteristic. Specific experimental designs, such as central composite design, can capture the curvature with greater efficiency than the 3^k full factorial designs required by the Taguchi method.

Response surface methodology may also be used to capture multiple response surfaces which cross disciplines. Empirical data, simulations and known equations may be combined to generate these surfaces. The resulting equations may be used in a nonlinear optimizer to accomplish approximate multidisciplinary optimization.

Current applications of response surface methodology lie primarily within the system to genopersistate the system; however, they appear to be applicable at higher levels of the genopersistation recursion, particularly for generating equations to simulate the system to genopersistate the product.

Quality Function Deployment

Quality Function Deployment (QFD) is a tool developed by Akao[1] and others to help design quality into the product. It may be viewed from several perspectives.

It is a tool for defining. It helps answer the questions: Who wants it? What do they need? What is it going to do? How will they know if they have it? What must it do? What do you want it to do? What is going to do it? What genopersistates it? How can it fail? What are the possible concepts? What is the final concept? These questions are answered respectively by the QFD functions: DefineCustomers, DefineCustomerDesires, Define Functions, DefineQualityCharacteristics, Define Requirements, DefineGoals, DefineSubsystems, DefineTechnology, DefineFailureModes, Define AlternateConcepts, and DefineFinalConcept.

It uses affinity diagrams, tree diagrams, and matrix diagrams, three of the seven new tools of Mizuno[21], to generate cascading matrices which transfer customer value to functions, quality characteristics, requirements, goals, subsystems, technologies, failure modes, and alternate concepts.

It can be used as a design-to-cost tool by transferring customer value to functions or subsystems and then allocating target cost as a percentage determined by relative customer value to each of the functions or subsystems. It can be used as a design-for-cost tool by identifying functional measures which can be used as parameters with a system optimization process such as robust design[26] or response surface methodology[3].

It is a natural mechanism for maintaining cross traceable requirements within a powerful project structure which provides both planning and control mechanisms. In fact, it is an effective and efficient implementation of both a system engineering process and a project management process.

There are many forms of QFD. King[16] describes the Akao form. Hauser and Clausing[11] introduced the "House of Quality." Clausing and Pugh[5] provide an enhanced QFD. Dean[7] provides a QFD for use with large systems.

QFD should be perceived as a tool set which must be tailored to the situation in which it is to be applied.

QFD may be used at any level of the product genopersistation recursion.

Hoshin Kanare

Hoshin kanare is the means by which total quality management is deployed. It is an extension of the QFD toolset which has been developed by Akao[2] and others to deploy policy within an organization. It is also called hoshin planning[17] or policy deployment. It may be viewed as a tool for management by which they align an organization toward a single vision. It uses the seven new tools and QFD as well as several unique tools. Phase 1 focuses on process management; phase 2 focuses on self-diagnosis; phase 3 focuses on alignment within the organization; and phase 4 drives toward a single vision.

Hoshin kanare is primarily a tool for use in the system to genopersistate the system to genopersistate the product.

Activity Based Costing

Activity based costing[24] is a powerful tool for cost reduction as well as for capturing the cost of unquality. Instead of allocating overhead arbitrarily to direct labor or production line hours, care is taken to assign overhead costs to the activities they support. The total cost of the activity, the activity specific direct and indirect costs, is then allocated to products on the basis of the number of activities they consume. The result is a greatly enhanced accounting accuracy for the cost of a specific product. It is quite common for companies who switch to activity based costing to discover that they were making very bad decisions previously because they really did not understand the true cost of their products.

There is a close tie between QFD and activity based costing[7]. QFD includes a functional analysis and an allocation of functions to subsystems. Activities implement the functions within the system to genopersistate the product. Thus activity based costs are a natural consequence of allocating costs to the functions of the system to genopersistate the product, i.e., the project. These are in turn allocated to the subsystems of the product to obtain unit costs.

Activity based costing is primarily a tool for use within the system to genopersistate the product, but is equally applicable for measuring resource utilization at all levels of the product genopersistation recursion.

Concurrent Engineering

Winner, Pennell, Bertrand, and Slusarezuk[31] point the way to increased quality and reduced cost through the application of concurrent engineering. Two primary dimensions of concurrent engineering have emerged to date. The first is the management dimension which focuses on employee empowerment and getting the appropriate skill mix into interactive teams to address the genopersistation of the product. Progress is occurring under various labels which include total quality control[22], total quality management[6], continuous improvement[12], and sociotechnical systems[25]. Carter and Baker[4] focus on the second dimension which concerns electronic communications.

Although concurrent engineering is primarily a tool within the system to genopersistate the product, it appears to be applicable at any level of the product genopersistation recursion.

Multidisciplinary Optimization

Although there is an increasing effort now being placed into multidisciplinary optimization[18], very little includes cost or quality as variables. There are several excellent exceptions. Johnson[13,14,15] determines aircraft design parameters which correspond to minimum acquisition cost, minimum fuel cost, minimum operating cost, and minimum life cycle cost. Waller, Carlson, Dwyer, and Nicholas[30], as part of a small business innovative research task, demonstrate the nonlinear minimization of cost for a space based radar system.

The works of Lasdon[19] and Mesarovic´, Macko, and Takahara[20] offer great potential for the global coordination of hierarchical structures such as project organizations and hierarchical system decomposition. Evans[10] points the way to simultaneously optimizing for both quality and cost.

Although multidisciplinary optimization is primarily a tool within the system to genopersistate the product, it appears to be applicable at any level of the product genopersistation recursion.

Conclusions

There are a number of tools, which, when applied, seem to improve competitiveness. The tools that seem to work best have to do with the empowerment of the employee. Note that empowerment has two dimensions. The first dimension includes the necessities which have to do with permitting the employee to do the job as they do it best. The second dimension includes the sufficiencies which give the employee the knowledge and processes to do the job effectively and efficiently. It makes sense. After all, the human brain is a very high technology tool. Why shouldn't we set it free and then channel it to solve the problem.

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