How Cost Arises – How We Can Reduce Cost

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Abstract

This paper is based upon nine years of research for NASA on how cost arises and how we can reduce cost. A summary of this research was first published as the 500+ page NASA Design for Competitive Advantage web site (Dean, E. (1994-1998)).

This paper illustrates how cost arises, suggests various means of reducing cost, and provides resources for those who desire to further this research.

How Cost Arises

The typical accounting cost measures are labor and material. But material can be broken down at the next lower level to labor and material, and so on until we finally arrive at labor and land rights. Thus, cost is almost totally created by people doing something. Cost is a fundamental measure of the effort expended to do something. Cost is determined by the complexity of doing something including the way we do something and how many times we do something that way. Thus, to reduce the cost of something we must change the way we do something.

A bit of terminology is useful here. A work breakdown structure is a tree of items to be purchased. A function is what a system must do in the form [verb,noun]. A function is an abstract concept. An activity is the effort required for a system to do what it must do in the form (verbphrase, nounphrase). A process is a network of activities that does something (verbphrase, nounphrase). The architecture is what physically does what a system must do.

The author composed the word genopersistation from genesis and persist to describe the processes involved in bringing forth, operating, sustaining, and disposing of an entity or system. The desire is to envision cost as continuous flows without the artificial temporal distortions created by project reviews. Below, to the left, are the processes of genopersistation. Below, to the right, are the processes that determine how the system will be genopersisted. They are substantial cost drivers.

(genopersist, system)	(design, (genopersist, system))
(conceptualize, system)	(design, (conceptualize, system))
(evaluate, system)	(design, (evaluate, system))
(design, system)	(design, (design, system))
(prototype, system)	(design, (prototype, system))
(test, system)	(design, (test, system))
(produce, system)	(design, (produce, system))
(deploy, system)	(design, (deploy, system))
(operate, system)	(design, (operate, system))
(support, system)	(design, (support, system))
(evolve, system)	(design, (evolve, system))
(dispose, system)	(design, (dispose, system))
(manage, system)	(design, (manage, system))

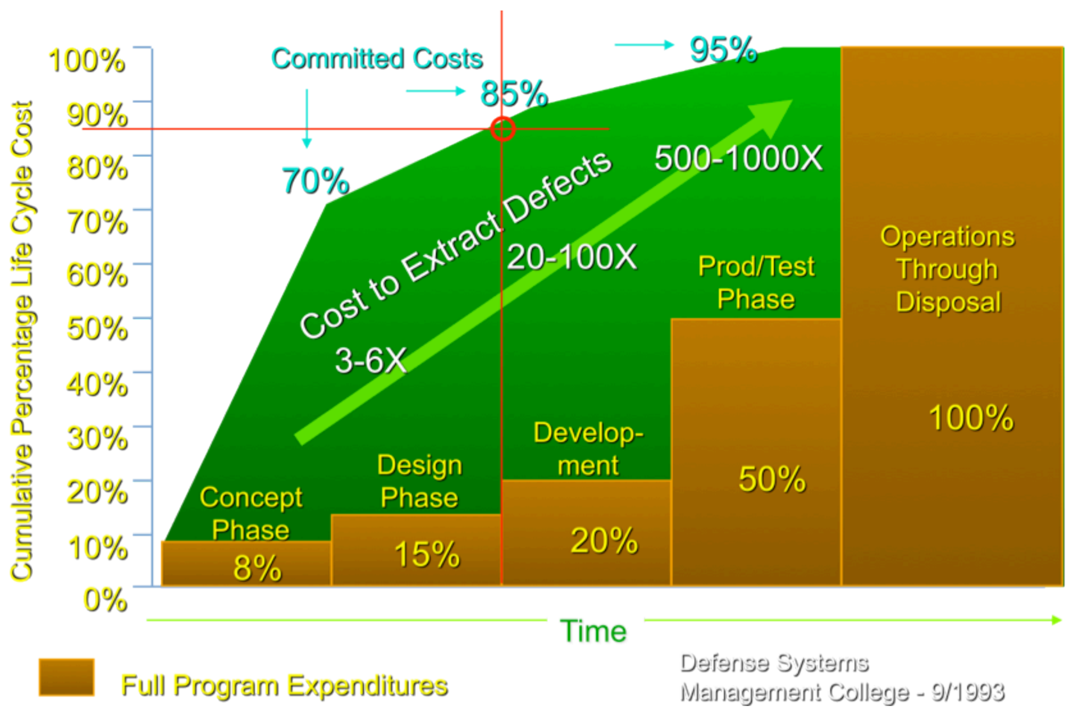
It is interesting that almost no effort is expended to design the genopersistation of the system – a major cost driver. The tendency is to genopersist each system the same as was done the previous time. When you do what you have always done you will get what you have always gotten, including cost results.

Note that a work breakdown structure is an after genopersistation accountants view with no insight into how the cost arose.

Dean, E. (1993a) provides further insights on genopersistation.

Another cost driver is rework. One definition of quality is that the entity does what it is supposed to do the first time and every time thereafter. If that is not the case, effort must be expended to approach quality as defined above. Failures during the genopersistation process create rework. The lowest cost case is when the genopersistation process is perfect, no rework is required, and cost is substantially reduced - but people are not perfect. In my 65 or so cost estimates for NASA, the system that was delivered was not the system I estimated – change is the norm and each change requires rework.

The Defense Systems Management College chart below illustrates very well the cost effect of rework.



Requirements change. System architecture often changes. New technology often has unintended consequences. Supply chains do not always work as expected. These are some of the many reasons that system related things create rework. However, many of the things that create rework come from the inadequate design of the genopersistation of the system. Perhaps a more reliable supply chain should have been chosen. Perhaps quality function deployment was not used to solidify the customer's needs. Perhaps value engineering was not applied to determine a better system architecture. Perhaps process quality was not addressed adequately. These, and many other things, can create rework because of inadequate design of the genopersistation process.

There are a number of systems involved with the system or entity. There is the system to bring forth, operate, sustain, and dispose of the entity. It includes the developing organization, the operations organization, the sustainment organization, and the disposal organization. The system to bring forth, operate, sustain, and dispose of the system to bring forth, sustain, and dispose of the entity includes the organizations that define how the system will be developed, operated, sustained, and disposed of.

From another perspective there is the system [the entity] where we account for the cost to purchase the entity and its subsystems in the form of the work breakdown structure. The system to bring forth, operate, sustain, and dispose of the entity is where cost arises from the activities to bring forth, operate, sustain, and dispose of the entity. It is here that activity based costing accounts the cost in the manner in which the cost arises. The system to bring forth, operate, sustain, and retire the system to bring forth, operate, sustain, and retire the entity is where the doing of the bringing forth, operating, sustaining, and disposing of the entity is defined. It is here that the level of the cost to bring forth, operate, sustain, and dispose of the entity is defined.

Complexity is a measure of how difficult it is to do something. The complexity depends on what the something must do, on how the something does what the something must do, on the architecture of the something, and on the technology of the something. The complexity of the system to develop, operate, sustain, and dispose of the entity drives cost as much or more than the complexity of the entity.

The way something is done applies to the system [the entity], the system to bring forth, deploy, operate, sustain, and dispose of the entity {the project}. The system to bring forth, deploy, operate, sustain, and dispose of the system to bring forth, deploy, operate, sustain, and dispose of the entity {the contractor}. The system to bring forth, deploy, operate, sustain, and dispose of the system to bring forth, deploy, operate, sustain, and dispose of the system to bring forth, deploy, operate, sustain, and dispose of the entity {the contractee}. There is a fractal like structure created by the levels of genopersistation.

To get a better feeling for genopersistation, let us examine the process (conceptualize,system). This process answers the following questions. Who are the customers? Who are the stakeholders? What do they desire? These desirements are quality characteristics that can be determined using quality function deployment (QFD}. What must the system do to fill the desires? These are the functions [verb,noun] determined by system engineering, value engineering, extended QFD. How will we know if the system fills the desires? Here we have requirements [verb,noun,measure] determined within systems engineering, value engineering, and extended QFD. How will we group the things the system will do? This is the functional architecture determined within systems engineering, value engineering, and extended QFD. What will the physical implementation be? This is the physical architecture determined within systems engineering, value engineering, and extended QFD.

Potential parameters for estimating cost(conceptualize, system) are the complexity measured by the number of customers, the number of stakeholders, the number of functions, and the number of requirements; the difficulty characterized by technology readiness level; and the physical size.

We can prepare for conceptualizing the system by no preparation or by doing the process

(Genopersist, (Conceptualize, System))
(Conceptualize, (Conceptualize, System))
(Evaluate, (Conceptualize, System))
(Market, (Conceptualize, System))
(Design, (Conceptualize, System))
(Prototype, (Conceptualize, System))
(Test, (Conceptualize, System))
(Produce, (Conceptualize, System))
(Deploy, (Conceptualize, System))
(Operate, (Conceptualize, System))
(Support, (Conceptualize, System))
(Evolve, (Conceptualize, System))
(Dispose, (Conceptualize, System))
(Manage, (Conceptualize, System)).

Which do you think would provide the better result?

Dean, E. (1992b) and Dean, E. (1993b) provide additional insights on how cost arises.

How We Can Reduce Cost

The cost estimating community uses the term Cost as An Independent Variable. But this is a vague mathematical perspective with no perception of how that can be done. The cost estimating community also uses the term Design to Cost. But it is a vague perspective that somehow the design process can be used to reduce cost. Design for Cost is a perspective that the author provided in various papers and on the NASA Design for Competitive Advantage web site (Dean, E. (1994-1998)). It provides methods of reducing cost. Dean, E. and R. Unal (1991) , Dean, E. and R. Unal (1992a), and Dean, E. (1993c) provide more on the design for cost concept.

In addition to applying the genopersistation recursion where each level consciously genopersists the level below it, design for cost has many tools. The most powerful of the tools are probably the following.

The Design for X Ilities:

Design for

(Conceptualize, System)	Conceptualizeability
(Evaluate, System)	Evaluability
(Market, System)	Marketability
(Design, System)	Designability
(Prototype, System)	Prototypeability
(Test, System)	Testability
(Produce, System)	Produceability, Manufacture
(Deploy, System)	Deployability
(Operate, System)	Operability
(Support, System)	Supportability
(Evolve, System)	Evolveability
(Retire, System)	Retireability
(Manage, System)	Manageability
System Cost	Affordability, Target Costing, Value Engineering
Initial Operating Capability	Scheduling
X	Xility

Bralla, J. (1996) provides an excellent introduction.

Value Engineering

The value engineering process includes: The gather information process answers the questions: Who is doing it? What could it do? What must it not do? The measure process answers the questions: What are the alternate ways of meeting requirements? What else can perform the desired function? The analyze process answers the questions: What must be done? What does it cost? The generate process answers the question: What else will do the job? The evaluate process answers the question: Which Ideas are the best? The develop and expand ideas process answers the questions: What are the impacts? What is the cost? What is the performance? The present ideas process sells alternatives.

Fowler, T. (1990) provides and excellent introduction to value engineering.

Quality Engineering

Again, something has good quality if it does what it is supposed to do the first time and every time thereafter. Quality engineering is the process of ensuring that an object has good quality. The cost of unquality arises because an object does not have good quality, often in the form of costly rework. An example of the cost of unquality is in Shuttle operations. The shuttle has a structural flaw that requires it to slow down during launch as it passes max G. This flaw is very sensitive to payload location within the bay. Each time a payload is changed for a flight, many reevaluations occur to ensure safety. Each payload change, thus, creates substantial additional operations cost through rework.

Juran, J. and A. Godfrey (1998) is a standard against which quality engineering books are evaluated.

Six Sigma

Six sigma is a business management strategy that seeks to improve the quality of process outputs by identifying and removing the causes of defects (errors) and minimizing variability in manufacturing and business processes. It is a subset of quality engineering that was heavily inspired by six preceding decades of quality improvement methodologies such as quality control, total quality management (TQM), and zero defects, based on the work of pioneers such as Shewhart, Deming, Juran, Ishikawa, Mijuno, Taguchi and others.

Jugulum, R. and P. Samuel (2008) provides insights into six sigma.

Lean

Lean is a production practice that considers the expenditure of resources for any goal other than the creation of value for the end customer to be wasteful, and thus a target for elimination. It was derived from the Toyota Production System and is centered on preserving value with less work. It advocates increasing efficiency, decreasing waste, using empirical methods to decide what matters, rather than uncritically accepting pre-existing ideas. It is now being extended to many forms of human endeavor.

Womack, J. and D. Jones (1996) provides the early perspective of lean.

Lean Six Sigma

Lean six sigma is the simultaneous use of lean and six sigma.

Yang, K. and B. El-Haik (2009) provides insights into both lean and lean six sigma.

Target Costing

Target costing is a business system used by firms. It is defined as a cost management tool for reducing the overall cost of a product over its entire life cycle with the help of production, engineering, research, and design. The target cost is the maximum amount of cost that can be incurred on a product and with it the firm can still earn the required profit margin from that product at a particular selling price. It involves setting a target cost by subtracting a desired profit margin from a competitive market price. It has four basic steps: define the product, set the price and cost targets, achieve the cost targets, and maintain competitive costs. The big differences are that the cost estimation tools can provide valid cost guidance and that tools such as value engineering, extended QFD, quality engineering, and lean methodologies are used to actually achieve cost targets.

Cooper, R. and R. Slagmulder (1997) provides and excellent introduction. Dean, E. (1996) provides the authors perspective.

Theory of Constraints

Goldratt, E. (1990) and a number of follow on books provide interesting insights into the engineering process.

Who Should Be Responsible For Cost?

My best shot at this question is as follows:

The accountant should establish and provide a parametric process based cost database. The engineer should design subsystems ***for*** cost. The project manager should manage cost. The systems engineer should design the system ***for*** cost and oversee and report cost. The parametric cost analyst should provide accurate cost guidance. The almost nonexistent project designer should design the genopersistation of the system ***for*** cost using design for X.

General Relevant Information

Emblemsvag, J. (2003) and Smart, C., et. al. (2007) provide insights on process based cost estimating. Mar, B. (1992) provides an excellent description of the systems engineering process.

Resources For Further Study

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