Cost Estimating

What is it?

How do you do it?

What can it do for you?

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Abstract

Cost estimating is the approximation of probable cost of a program, project, or product computed on the basis of available information. This paper will explore cost estimation as well as various product cost reduction methodologies used in product cost reduction. Example applications of cost estimating will be discussed.

This paper is dedicated to the Memory of Francis "Jim" McWilliams May 20, 1952 – March 22,2012

Jim was good friend and colleague. He had a kind heart, was brilliant and had an encyclopedic mind. Throughout his career, DEC, Compaq, HP, Sun and Oracle Jim was the best electrical cost estimating engineer of all time. He will be missed by all who knew him

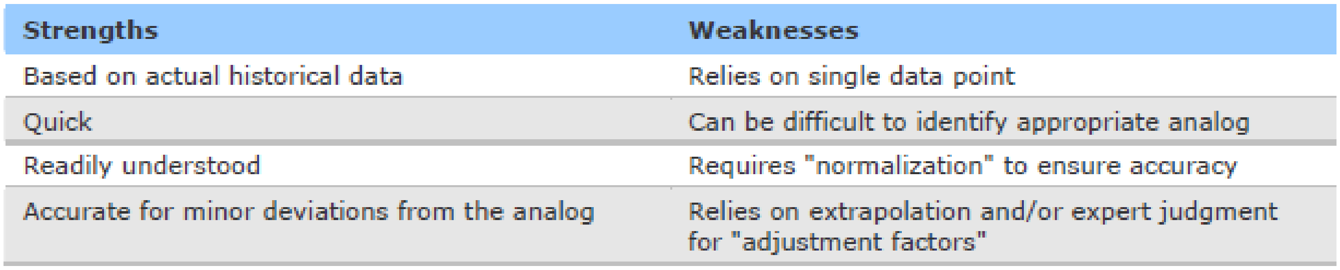
What is it?

Cost estimating is the approximation of the probable cost of a program, project, or product computed on the basis of available information. Three basic methodologies for building cost estimating models exist:

1. Analogy
2. Parametric
3. Engineering

Analogy

Analogy estimates are typically performed early in the project life when there is very little definition or data. Analogous data is usually pulled from past similar programs to create estimates. Cost data is adjusted up or down depending on how closely the new part or project matches the old one. Naturally as the product design begins to deviate from the past program these subjective deviations have a much wider margin for error. The validity of these estimates is questionable. The analogy methodology places heavy emphasis on the opinion of experts' modification of old data. The validity of the modification depends both on the expert and on additional considerations like complexity, technology, inflation and volumes changes. The model's strengths and weaknesses are listed below.



Strengths	Weaknesses
Based on actual historical data	Relies on single data point
Quick	Can be difficult to identify appropriate analog
Readily understood	Requires "normalization" to ensure accuracy
Accurate for minor deviations from the analog	Relies on extrapolation and/or expert judgment for "adjustment factors"

[1]

Parametric

Parametric estimates relate cost as a dependent variable to an independent cost driving variable using historical data. Linear regression can provide a simple equation to relate the two variables. In some cases a nonlinear regression provides a better fit. [2]

This method requires the estimator to create Cost Estimating Relationship (CER'S) by looking at attributes of the part / project being estimated. The first step is usually to plot the data to visually inspect for a relationship. Using Excel or a statistical package a regression analysis is then performed. This analysis is not used to confirm causality but rather to estimate and test the strength of the mathematical relationship between the variables. Analysis on the residuals should also be performed in order to identify whether the mathematical fit is appropriate. Any systematic pattern indicates the need for a better fitting model.

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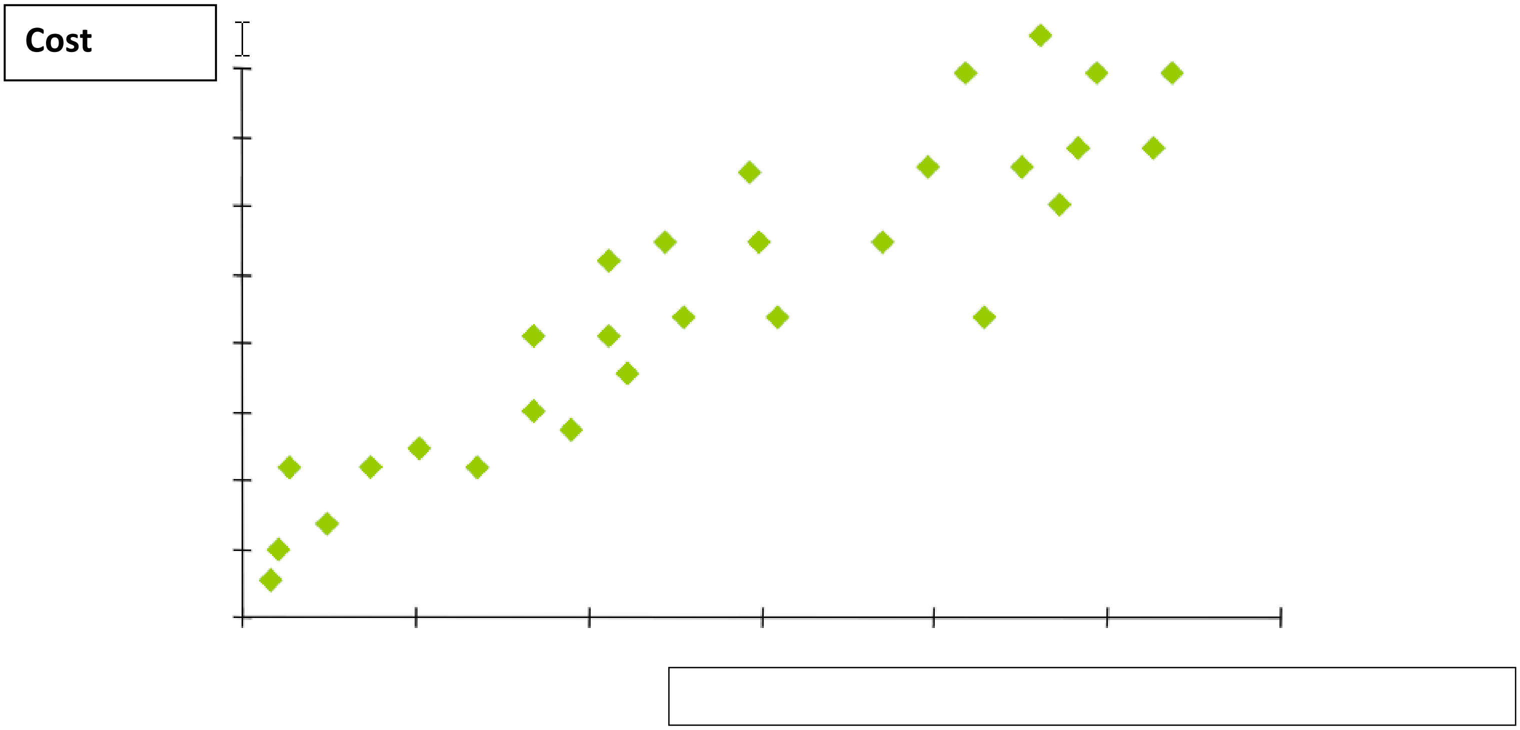
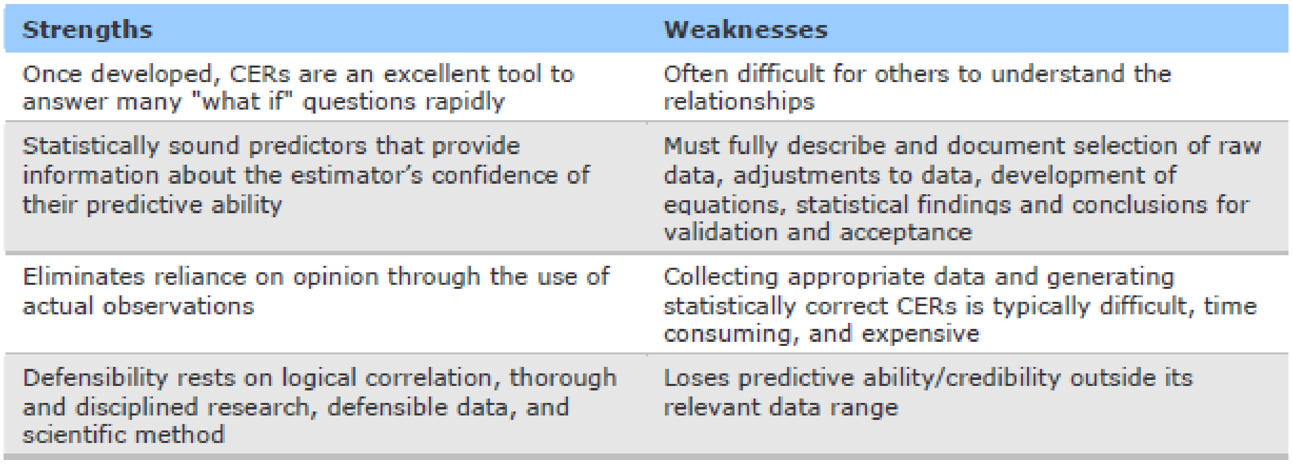
[1] 2008 NASA Cost Estimating Handbook, http://www.ceh.nasa.gov, Volume 1, page 1-31

[2] Special thanks to Dr. Luanne Isherwood for her helpful suggestions and comments.



The models robustness depends on how through you have been in data collection, analysis, and testing.



Strengths	Weaknesses
Once developed, CERs are an excellent tool to answer many "what if" questions rapidly	Often difficult for others to understand the relationships
Statistically sound predictors that provide information about the estimator's confidence of their predictive ability	Must fully describe and document selection of raw data, adjustments to data, development of equations, statistical findings and conclusions for validation and acceptance
Eliminates reliance on opinion through the use of actual observations	Collecting appropriate data and generating statistically correct CERs is typically difficult, time consuming, and expensive
Defensibility rests on logical correlation, thorough and disciplined research, defensible data, and scientific method	Loses predictive ability/credibility outside its relevant data range

[3]

Engineering

Engineering estimates, sometimes called "bottoms up," involve creating a complex set of models to accurately predict for the price of a particular commodity and the cost of the process associated with making a part. Understanding everything from start to finish that goes into creating a part from a specific material and process is necessary. For example, this includes the cost of making the part, machine rates, processing

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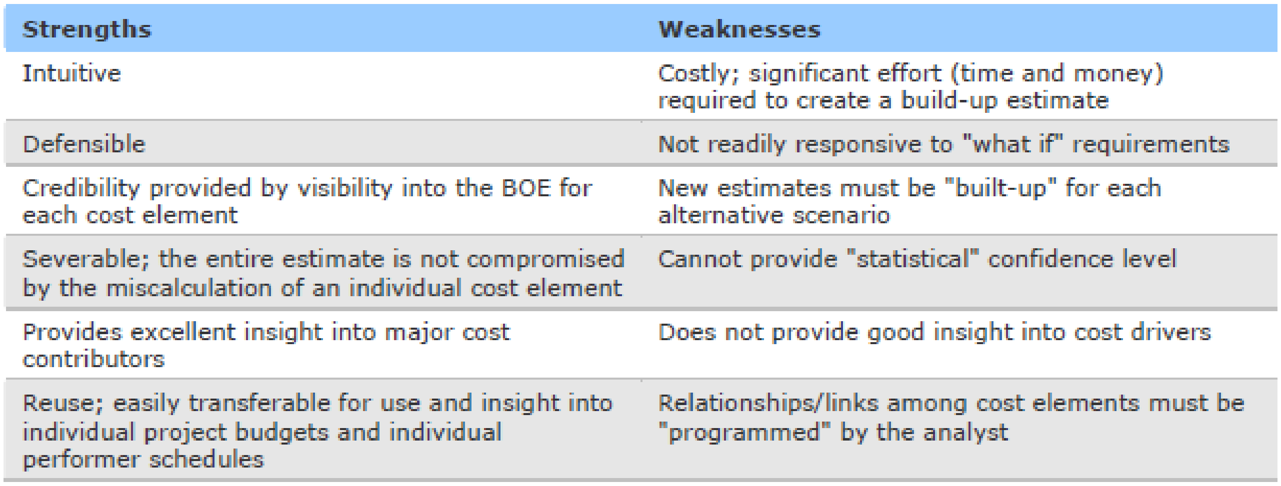
[3] 2008 NASA Cost Estimating Handbook, http://www.ceh.nasa.gov, Volume 1, page 1-30

parameters, material cost, scrap rates of material, quality levels, and labor rates of various persons needed to make the parts, and secondary operations and all their associated costs. Such models tend to be complex and require a lot of data, and typically, they are built by teams of knowledgeable individuals who understand the physics of the manufacturing process around temperature, cooling, flow rates, design for manufacturing rules, and material properties.



Strengths	Weaknesses
Intuitive	Costly; significant effort (time and money) required to create a build-up estimate
Defensible	Not readily responsive to "what if" requirements
Credibility provided by visibility into the BOE for each cost element	New estimates must be "built-up" for each alternative scenario
Severable; the entire estimate is not compromised by the miscalculation of an individual cost element	Cannot provide "statistical" confidence level
Provides excellent insight into major cost contributors	Does not provide good insight into cost drivers
Reuse; easily transferable for use and insight into individual project budgets and individual performer schedules	Relationships/links among cost elements must be "programmed" by the analyst

[4]

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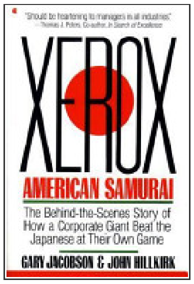
[4] 2008 NASA Cost Estimating Handbook, http://www.ceh.nasa.gov, Volume 1, page 1-31

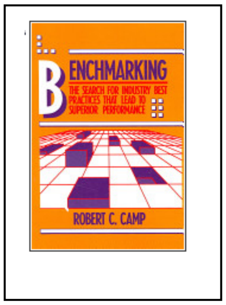
Product Cost Reduction Methodologies

Cost reduction methodologies also provide an estimate of product cost. These include: Benchmarking, Design for manufacturing and Assembly (DFMA), Design to Cost (DTC), Cost as an Independent Variable (CAIV), Value Engineering/Value Analysis (VE/VA, and Should Cost. Each method was created to address different circumstances, and each uses different methodologies to achieve overall cost reduction.

BENCHMARKING (XEROX)

In the 1980's Xerox saw it dominance in a market that they had invented rapidly slipping away. Benchmarking, the continuous process of measuring products and services and practices against the toughest competitors, originated from the realization that the first Japanese copiers to enter the market were being sold at prices that were below Xerox's manufacturing cost. Xerox set out to understand how this was possible. This journey and its learning are chronicled in the book *Xerox American Samurai*[5]. Robert Camp of Xerox solidified benchmarking into a 10 step process to achieve peak performance, by analyzing the gap and using the delta to set new goals. [6]





DESIGN FOR MANUFACTURING and ASSEMBLY (DFMA)

DFMA has its origins in the 1970's NSF funding for research into parts handling and orientation for the pending robotic revolution, although never materialized to the extent predicted. Boothroyd and Dewhurst realized the concept of handling and orientation could be applied to products. In 1983 the first revision of DFMA software was released. At its core, DFMA analyzes a product structure simplifying its design by eliminating parts and optimizing the manufacture of parts and assemblies.

DESIGN TO COST (DTC)

Created in 1988, Mil-STD-337 Design to cost was an attempt to eliminate waste in the defense spending on items like $100 dollar hammers and $3000 coffee machines. DTC focuses on projected average unit procurement costs. Projected operations and support (O&S) cost objectives receive only secondary attention. Officially, DTC was supposed to identify drivers of downstream costs for specific weapons systems, especially early in the life of that acquisition program, and to consider ways to keep those costs under control. In practice, DTC focuses on controlling near-term costs. Incentives to reduce production and O&S costs are few. Because of these flaws, the military abandoned DTC in favor of CAIV.

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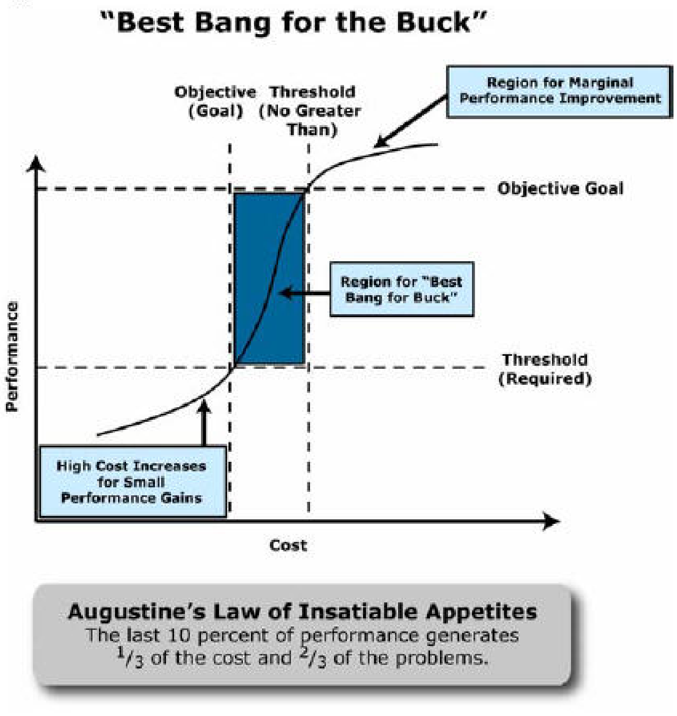
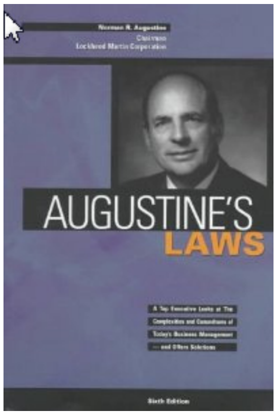
[5] G. Jacobson, J. Hilkirk, Xerox American Samurai Collier Books 1987, ISBN 0020338309

[6] Robert C. Camp, Benchmarking : The Search for the industries Best Practices that Lead to Superior Preformance productivity Press Inc. 2006. ISBN 1563273527

COST AS AN INDEPENDENT VARIBLE (CAIV)

CAIV was proposed in 1995 and implemented in March 1996 as a part of the new 5000 Series regulations on defense systems acquisition (DoD5000.2R, 1996). Traditionally, the success of acquisition programs was judged by their accomplishments with respect to three parameters: cost, schedule and performance. Of these, performance usually received the most emphasis, and therefore was treated as a "fixed" or "independent" variable. Schedule and cost were allowed to vary to achieve some desired level of performance. In an era of shrinking defense budgets, DoD adopted the CAIV philosophy of treating cost as the independent variable of the three, allowing performance and schedule to vary somewhat in an attempt to keep weapon systems affordable. Figure 1 shows graph of this trade off space that were tradeoffs can be made in attempt to hit cost targets.





[7]

Figure 1 Trade-off space

VALUE ENGINEEING / VALUE ANALYSIS (VE / VA)

The concept of value engineering evolved from the work of Lawrence Miles who, in the 1940's, was a purchase engineer with the General Electric Company. Shortages of materials including steel, copper, bronze, nickel, bearings, and electrical resistors during WWII were ubiquitous. In this environment, GE wished to expand its production of turbo supercharger for B24 bombers from 50 to 1000 per week. Miles he could not obtain the specific material or component specified by the designer, so he reasoned, "if I cannot obtain the product, I must obtain an alternative which performs the same function". Miles observed that many of the substitutes provided equal or better performance at a lower cost.

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[7] Norman R. Augustine, Augustine's Laws Viking Press 1986 ISBN 1-56347-240-6

SHOULD COST

Should cost is a term that thanks to management consulting companies has become over used and poorly understood.

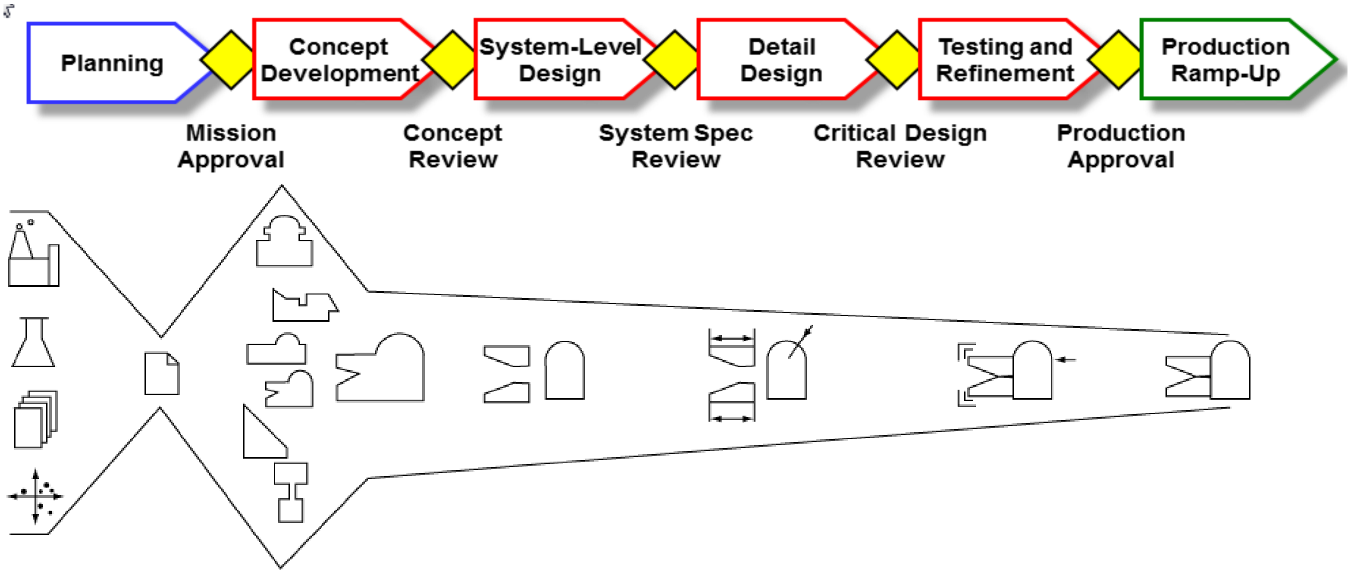
Code of Federal regulations 48 15.407-4 creates administrative law for the government to conduct should-cost reviews, which is a specialized form of cost analysis:

(a) General. (1) Should-cost reviews are a specialized form of cost analysis. Should-cost reviews differ from traditional evaluation methods because they do not assume that a contractor's historical costs reflect efficient and economical operation. Instead, these reviews evaluate the economy and efficiency of the contractor's existing work force, methods, materials, equipment, real property, operating systems, and management. These reviews are accomplished by a multi-functional team of Government contracting, contract administration, pricing, audit, and engineering representatives. The objective of should-cost reviews is to promote both short and long-range improvements in the contractor's economy and efficiency in order to reduce the cost of performance of Government contracts. In addition, by providing rationale for any recommendations and quantifying their impact on cost, the Government will be better able to develop realistic objectives for negotiation. [8]

A should-cost review has historically taken on the connotation that a contractor costs are out of line with what efficient design and manufacturing practices would dictate as fair and reasonable.

Selecting Cost Estimating Methodology

Selecting an appropriate methodology for cost estimation depends on both the phase of the project and the data available. The following graphic provides a quick way to select an appropriate methodology.



From *Product Design and Development* by Karl Ulrich and Steven Eppinger (McGraw-Hill/Irwin)

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[8] http://www.law.cornell.edu/cfr/text/48/15.407-4

Parametric	●	●	◑	◑	○
Analogy	●	◑	◑	◑	○
Engineering Build Up	◑	◑	●	●	●

Legend: ● Primary ◑ Applicable ○ Not Applicable [9]

How do you do it?

Depending where in the product development process you are and which model type you selected they all require the same thing to get started. **DATA**

This is probably the most important phase since the cost estimator needs as much accurate information as possible to build the most accurate model possible. Important information to gather includes, but is not limited to, cost data, technical operational data, project data, and economic data (constant dollars, inflation, etc.).

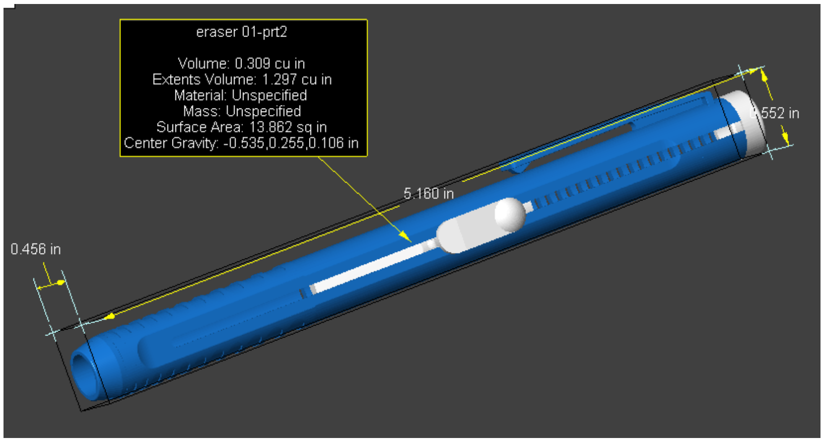
Analogy

The analogy model relies on an expert in this case it is you the reader. Below is a retractable eraser.

Please write down what you think it costs to make ______________________________________

And write down what you think it retail price is. ____

I will give you a few more additional facts now. It weighs 0.6 ounces. It is made in Germany. The eraser is Phthalate and latex free. How does this additional data affect your initial cost estimates?



eraser 01-prt2

Volume: 0.309 cu in
Extents Volume: 1.297 cu in
Material: Unspecified
Mass: Unspecified
Surface Area: 13.862 sq in
Center Gravity: -0.535,0.255,0.106 in

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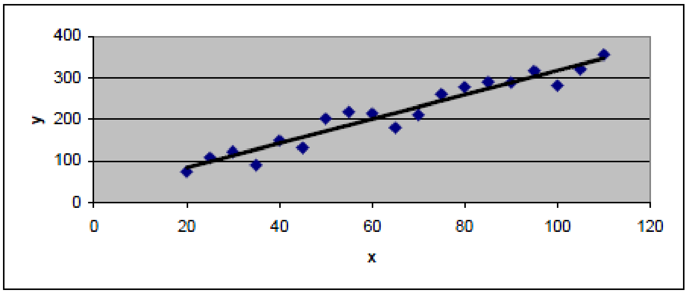
[9] 2008 NASA Cost Estimating Handbook, http://www.ceh.nasa.gov, Volume 1, page 1-31

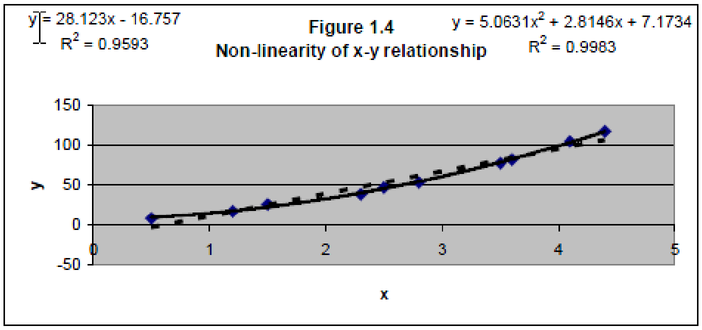
Parametric

Parametric modeling requires a lot of data, both cost and attribute data about the part in question. Attributes like weight, volume, total linear feet, or color may be a major cost driver.

These attributes are plotted in a scatter plot data in order to see a trend or grouping. Not every part can be modeled parametrically. Also not every plot is a linear relationship; non -linear parametric relationships are possible. It is about what mathematical expression best fits the data.



Example Linear Regression



[10]

Example of Non-Linear Regression

Engineering

It would be difficult in the context of this paper to derive complete bottoms up analysis for a process commodity and the part that it makes. So as an excellent example, I will point you to Chapter 8 of *Design for Injection Molding*, the classic text for Product Design for Manufacture and Assembly, by G. Boothroyd, P. Dewhurst, and W. Knight. Here the authors take you systematically through the creation of an engineering model by looking at each of the elements of the material, process and tools. Each section in the chapter lays out the individual elements that when combined create an engineering estimate for injection molding.

Chapter 8. Design for Injection Molding [11]

8.1 Introduction
8.2 Injection Molding Materials
8.3 The molding cycle
8.4 Injection Molding Systems
8.5 Injection Molds
8.6 Molding Machine Sizes

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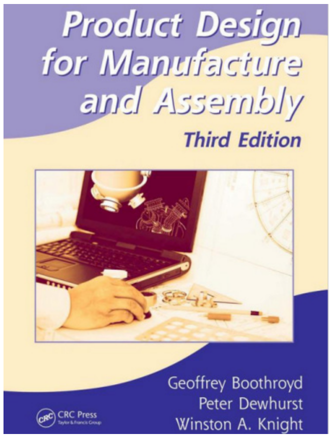
[10] Parametric Estimating Handbook, International Society of Parametric Analysts. Fourth edition April 2008, www.ispa-cost.org. ISBN 0-9720204-7-0

[11] G. Boothroyd, P.Dewhurst, W. Knight, Product Design for Manufacturing & Assembly , Marcel Decker 2002 ISBN 0-8247-0584-x

8.7 Molding Cycle Time
8.8 Mold Cost Estimation
8.9 Mold Cost Point System
8.10 Estimation of Optimum Number of Cavities
8.11 Design Example
And so on ………………………..

You will note when reading this chapter that some of the engineering model sub pieces are built using the techniques of both Analogy and Parametric methods.



What can it do for you?

Throughout the product development cycle there are unlimited opportunities to apply the discussed modeling techniques.

Before beginning a new project, the first step is to use your modeling tools to analyze similar products as benchmarks. The beauty of this is that you will be able to compare these competitive products with your new design “apples to apples” as it were. Below is an example of competitive coin handlers that were analyzed using B&D DFMA software. [12]

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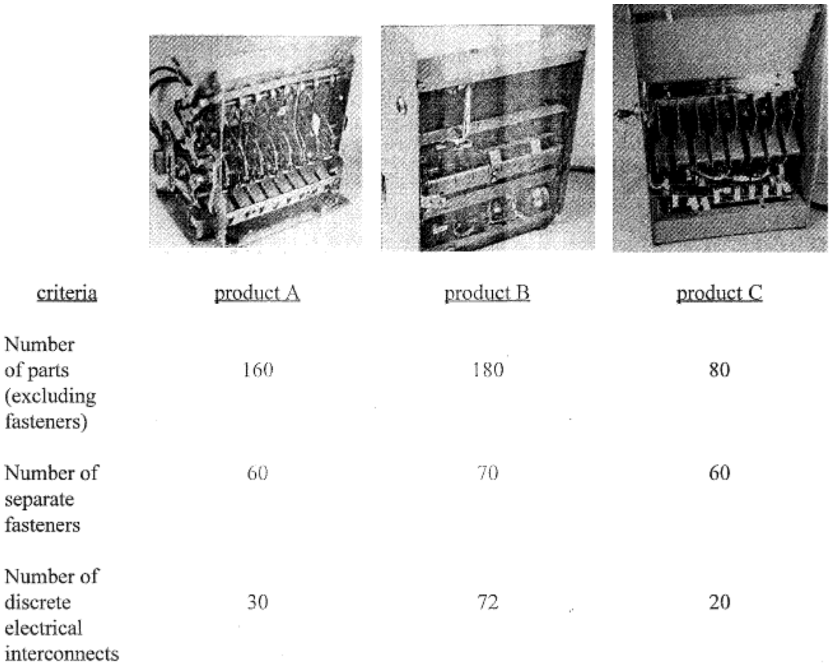
[12] DFMA and itsRole in the Integration of Product Development Process, David Meeker, Art Rousmaniere. DFMA conference June 1996



criteria	product A	product B	product C
Number of parts (excluding fasteners)	160	180	80
Number of separate fasteners	60	70	60
Number of discrete electrical interconnects	30	72	20

Parts count comparison of competitive coin handlers

After you have done benchmarking it is time to start working your next design – for this next discussion we will use laptop as a vehicle to talk about modeling. At the beginning of a project the next generation laptop you should have a matrix for the various sub-assemblies / functions and rules of thumb from the last project.

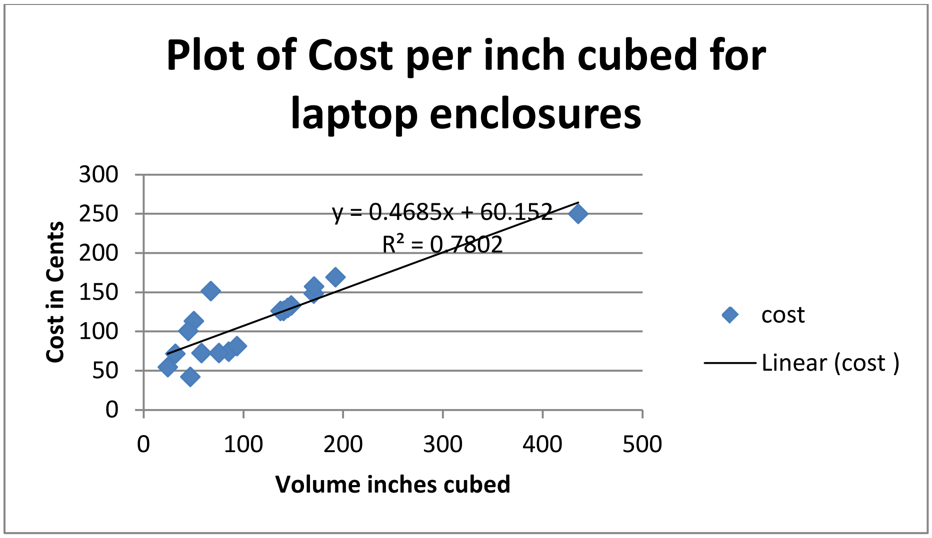
Enclosure	$0.10 cents per cubic inch
PCB Raw	$0.09 cents per square inch per layer
CPU Board	$13.57 per inch squared
Power supply	$0.235 per watt

And so on…

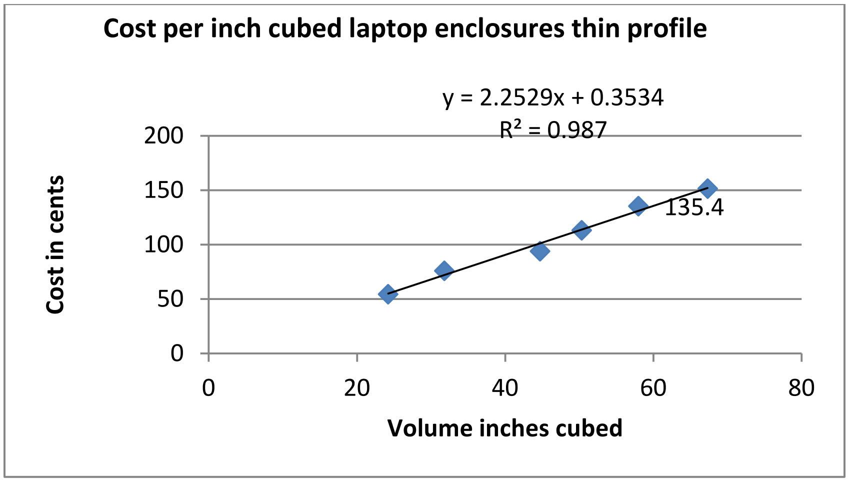
Given the performance specs you can get a quick estimate of what the new machine will cost. What needs to happen is the old machine metrics need to have adjustments made up or down depending on what the system expert feels is appropriate.

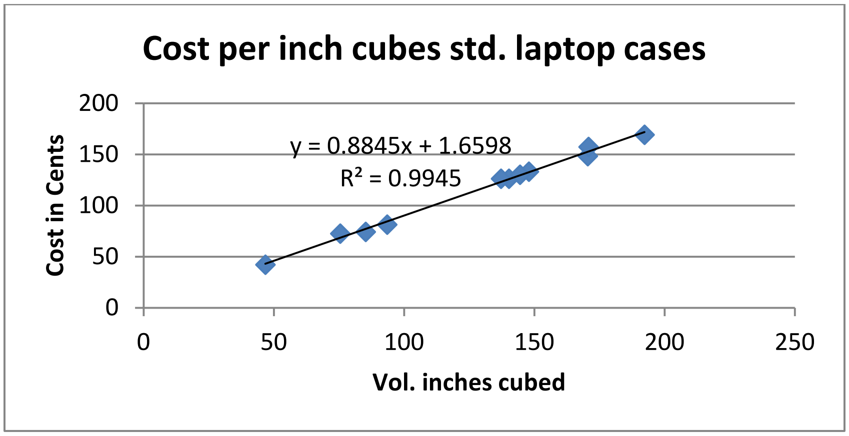
This also works in reverse when marketing say they want a product that has LCD Display, Large Battery, Radio, flashlight and the Kitchen sink, and cost $49.87 to make your adjust rules of thumb can tell marketing whether it is remotely feasible or not and give them a rough estimate of each features cost.

As the program develops more definition you will want to transition from analogy to parametric models. In this case the enclosure cost can be more accurately modeled off data collected on cost per cubic inch of historic cases as well as initial estimates of the new design.



As you look at the data there appear to be two different trends and one outlier. The line fit is not particular good with R Squared = 0.7802. The outlier represents a high end custom painted gaming case and as such is not relevant for the analysis. Examining these remaining points shows two distinct clusters. Further examination shows that these points represent two different types of case, thin profile 0.34 inches thick and standard thicknesses 0.98 – 1.3 inches.



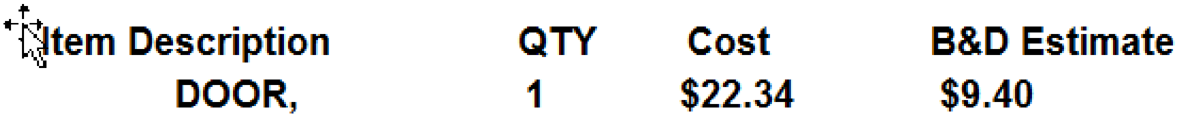


For thin profile enclosures the equation is y= 2.2529X + 0.3534. for standard enclosures the equation is y=0.8845X + 1.6598 Both of these equations can be used separately or entered into B&D software as a quick and dirty calculation early on in in product development.

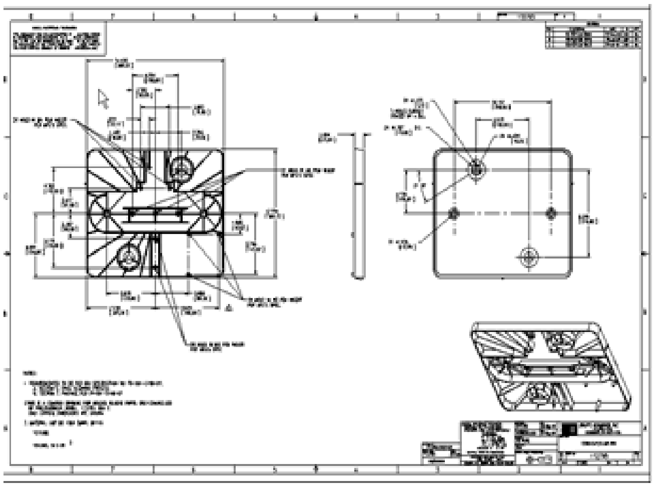
Next step in modeling enclosure would be to start using and engineering model such as the one mentioned above in this case Boothroyd and Dewhurst injection molding DFM software.

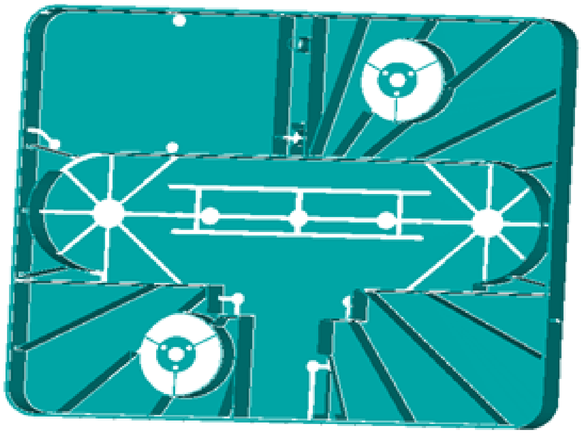
At the same time you are using B&D software to create a more detailed estimate, you should send the part drawing and CAD file out for quote to an number of your preferred injection molding vendors. With a cost model of the part you sent out, you now have a way to compare and evaluate the returning quotes.

If the quote is too high, you may have missed a cost or underestimated a critical step. If it is too low the vendor either missed a critical step or is just trying the business. Whether the quote is too high or too low, you need to understand the WHYS. Below is an example of a part that was estimated and them sent out for quote.

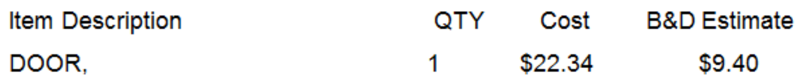


Item Description	QTY	Cost	B&D Estimate
DOOR,	1	$22.34	$9.40





Clearly further investigation is needed.



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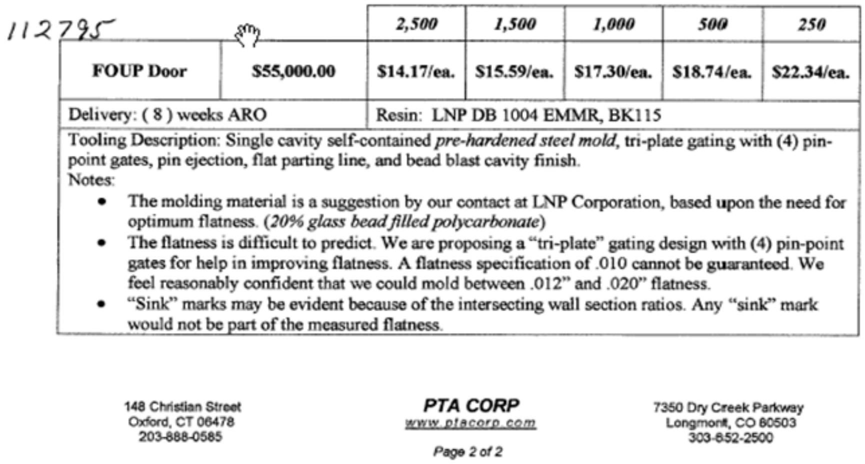

112795

		2,500	1,500	1,000	500	250
FOUP Door	**$55,000.00**	**$14.17/ea.**	**$15.59/ea.**	**$17.30/ea.**	**$18.74/ea.**	**$22.34/ea.**

Delivery: (8) weeks ARO

Resin: LNP DB 1004 EMMR, BK115

Tooling Description: Single cavity self-contained *pre-hardened steel mold*, tri-plate gating with (4) pin-point gates, pin ejection, flat parting line, and bead blast cavity finish.

Notes:

- The molding material is a suggestion by our contact at LNP Corporation, based upon the need for optimum flatness. (*20% glass bead filled polycarbonate*)
- The flatness is difficult to predict. We are proposing a "tri-plate" gating design with (4) pin-point gates for help in improving flatness. A flatness specification of .010 cannot be guaranteed. We feel reasonably confident that we could mold between .012" and .020" flatness.
- "Sink" marks may be evident because of the intersecting wall section ratios. Any "sink" mark would not be part of the measured flatness.

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Page 2 of 2

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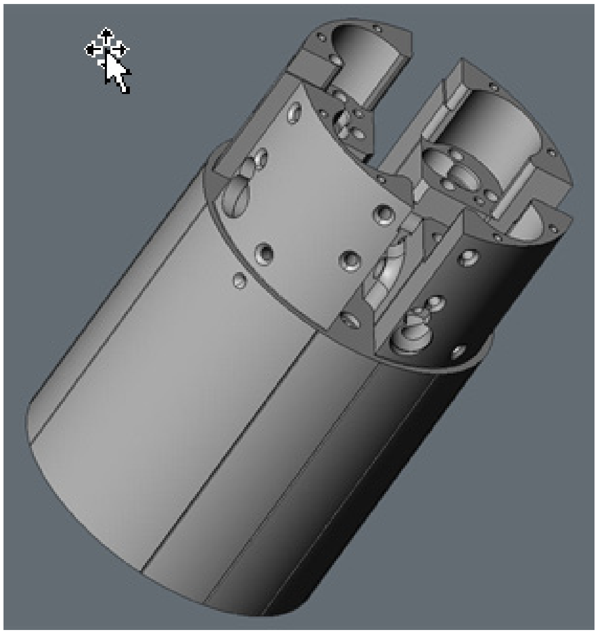
303-652-2500

Clearly such a large delta indicates that the model missed something, in this case, resin cost. The model used generic polycarbonate; this material was 20% glass bead filled. GE at the time was asking $7.62/lb. PTA was charging us $7.35/lb so it was clear PTA was passing some or all of their material cost savings along. A new plastic Material database was created in DFM software with this information. The cost estimate was rerun and the revised B&D estimate was $23.30 much nearer to the vendor quote of $22.34. Even this difference should be followed up on but at this point this is enough to understand the difference and improve the model at this initial juncture. [13]

B&D tool can also be used to compare different design implementation methods and different processes without a large investment in materials and tooling just by running models of different embodiments. Below is an example that Gordon Lewis created showing the power of this type of trade off study.



DaTuM 3D

The part as originally designed as a machined part which was difficult to manufacture. The part had,

- Non Standard holes
- Hole depths that were very deep
- Undercut chamfers
- Deep counter bores
- Double undercuts
- Side operations

The current part design - time to manufacture between 12-15 hours at a cost of $780 -$975 each. There were 16 specific recommendations made following good DFM guidelines and machining practices. Re-designed DFM part - time to manufacture 7 – 10 hours at a cost of $450 -$650 each.

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[13] David Meeker, DFMA a Multi-Functional Analysis Tool DFMA Conference 2007

Alternative Methods of Investment Casting and Metal Injection Molding were also explored using the software. Both of these methods required re-design, and after the initial parts were made, some secondary machining but nothing as elaborate as the original design. Investment casting B&D DFM estimate was appropriately $135 dollars and the Metal Injection molded estimate was $160 dollars.

This analysis required no steel to be cut; only a CAD model and the use of Engineering model in this case Boothroyd and Dewhurst DFM Concurrent Costing software was required.

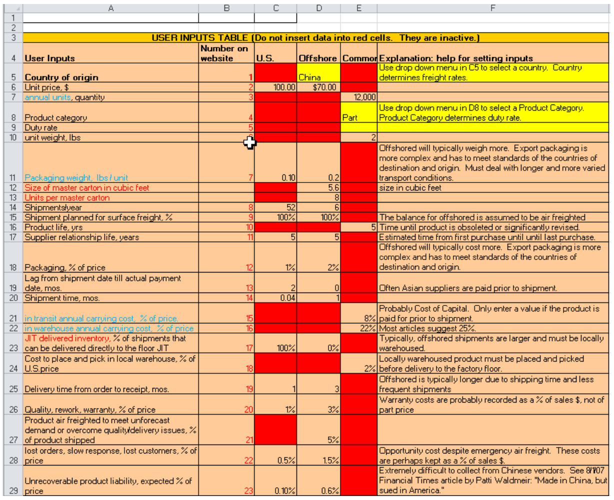
Total Cost of Ownership

Final Cost estimate model discussion is still being debated in the press, with outsourcing, offshoring, on shoring, reshoring, and any other the terms having entered the debate.[14] Before you can make an intelligent decision about which of these to do you need a model that looks at the Total Cost of Ownership.

Reshorenow.org http://www.reshorenow.org has a TCO calculator that is very complete and will let you run scenario after scenario to understand the Total Cost of outsourcing. Harry Moser founded the Reshoring Initiative to bring manufacturing jobs back to America by helping original equipment manufacturers (OEMs) better understand the full cost of offshoring and the benefits of reshoring.

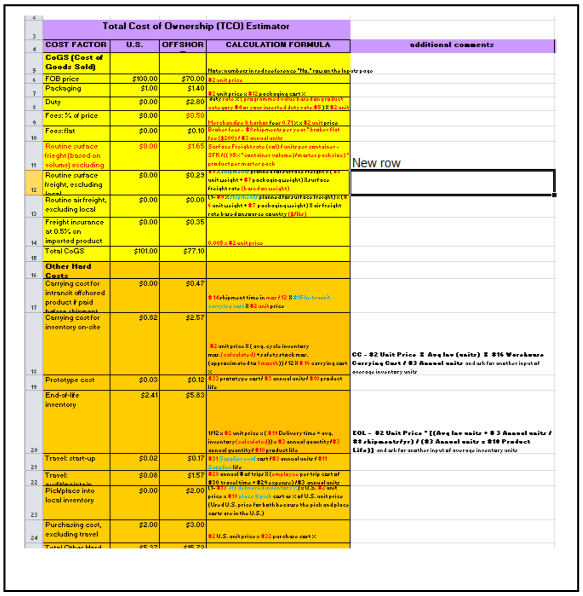
The TCO model allows a more accurately assess their total cost of offshoring, and shift collective thinking from offshoring is cheaper to local reduces the total cost of ownership. The TCO is quite large so I am just showing partial snapshots of various pieces.

User input screen



	A	B	C	D	E	F
1						
2						
3	USER INPUTS TABLE (Do not insert data into red cells. They are inactive.)					
4	**User Inputs**	**Number on website**	**U.S.**	**Offshore**	**Commor**	**Explanation: help for setting inputs**
5	**Country of origin**	1		China		Use drop down menu in C5 to select a country. Country determines freight rates.
6	Unit price, $	2	100.00	$70.00		
7	annual units, quantity	3			12,000	
8	Product category	4			Part	Use drop down menu in D8 to select a Product Category. Product Category determines duty rate.
9	Duty rate	5				
10	unit weight, lbs	6			2	
11	Packaging weight, lbs / unit	7	0.10	0.2		Offshored will typically weigh more. Export packaging is more complex and has to meet standards of the countries of destination and origin. Must deal with longer and more varied transport conditions.
12	Size of master carton in cubic feet			5.6		size in cubic feet
13	Units per master carton			8		
14	Shipments/year	8	52	6		
15	Shipment planned for surface freight, %	9	100%	100%		The balance for offshored is assumed to be air freighted
16	Product life, yrs	10			5	Time until product is obsoleted or significantly revised.
17	Supplier relationship life, years	11	5	5		Estimated time from first purchase until until last purchase.
18	Packaging, % of price	12	1%	2%		Offshored will typically cost more. Export packaging is more complex and has to meet standards of the countries of destination and origin.
19	Lag from shipment date till actual payment date, mos.	13	2	0		Often Asian suppliers are paid prior to shipment.
20	Shipment time, mos.	14	0.04	1		
21	in transit annual carrying cost, % of price.	15			8%	Probably Cost of Capital. Only enter a value if the product is paid for prior to shipment.
22	in warehouse annual carrying cost, % of price	16			22%	Most articles suggest 25%.
23	JIT delivered inventory, % of shipments that can be delivered directly to the floor JIT	17	100%	0%		Typically, offshored shipments are larger and must be locally warehoused.
24	Cost to place and pick in local warehouse, % of U.S.price	18			2%	Locally warehoused product must be placed and picked before delivery to the factory floor.
25	Delivery time from order to receipt, mos.	19	1	3		Offshored is typically longer due to shipping time and less frequent shipments
26	Quality, rework, warranty, % of price	20	1%	3%		Warranty costs are probably recorded as a % of sales $, not of part price
27	Product air freighted to meet unforecast demand or overcome quality/delivery issues, % of product shipped	21		5%		
28	lost orders, slow response, lost customers, % of price	22	0.5%	1.5%		Opportunity cost despite emergency air freight. These costs are perhaps kept as a % of sales $.
29	Unrecoverable product liability, expected % of price	23	0.10%	0.6%		Extremely difficult to collect from Chinese vendors. See 8/1/07 Financial Times article by Patti Waldmeir: "Made in China, but sued in America."

Output screen



	Total Cost of Ownership (TCO) Estimator				
4	**COST FACTOR**	**U.S.**	**OFFSHOR**	**CALCULATION FORMULA**	**additional comments**
5	**CoGS (Cost of Goods Sold)**			Note: numbers in red reference "No." row on the Inputs page	
6	FOB price	$100.00	$70.00	#2 unit price	
7	Packaging	$1.00	$1.40	#2 unit price x #12 packaging cost %	
8	Duty	$0.00	$2.80	duty rate % (programmed value based on product category #4 or your inserted duty rate #5) X #2 unit	
9	Fees: % of price	$0.00	$0.50	Merchandise & harbor fees 0.71% x #2 unit price	
10	Fees: flat	$0.00	$0.10	Broker fees - #8 shipments per year * broker flat fee ($200) / #3 annual units	
11	Routine surface frieght (based on volume) excluding	$0.00	$1.65	Surface Freight rate (vol) / units per container - SFR / ((85% *container volume)/master pack size) * product per master pack	New row
12	Routine surface freight, excluding local	$0.00	$0.29	#9 % shipments planned for surface freight x (#6 unit weight + #7 packaging weight) X surface freight rate (based on weight)	
13	Routine air freight, excluding local	$0.00	$0.00	(1- #9 % shipments planned for surface freight) x (#6 unit weight + #7 packaging weight) X air freight rate based on source country ($/lbs)	
14	Freight insurance at 0.5% on imported product	$0.00	$0.35	0.005 x #2 unit price	
15	Total CoGS	$101.00	$77.10		
16	**Other Hard Costs**				
17	Carrying cost for intransit offshored product if paid before shipment	$0.00	$0.47	# 14 shipment time in mos / 12 X #15 In-transit carrying cost X #2 unit price	
18	Carrying cost for inventory on-site	$0.82	$2.57	#2 unit price X (avg. cycle inventory mos. (calculated) + safety stock mos. (approximated to 1 month)) / 12 X # 16 carrying cost %	**CC - #2 Unit Price X Avg Inv (units) X #16 Warehouse Carrying Cost / #3 Annual units** and ask for another input of average inventory units
19	Prototype cost	$0.03	$0.12	#33 prototype cost / #3 annual units / #10 product life	
20	End-of-life inventory	$2.41	$5.83	1/12 x #2 unit price x (#19 Delivery time + avg. inventory (calculated)) x #3 annual quantity / #3 annual quantity / #10 product life	**EOL - #2 Unit Price * [(Avg Inv units + # 3 Annual units / #8 shipments/yr) / (#3 Annual units x #10 Product Life)]** and ask for another input of average inventory units
21	Travel: start-up	$0.02	$0.17	#31 Supplier eval cost / #3 annual units / #11 Supplier life	
22	Travel: audit/maintain	$0.08	$1.57	#28 annual # of trips X (employee per trip cost of #30 travel time + #29 expense) / #3 annual units	
23	Pick/place into local inventory	$0.00	$2.00	(1- #17 JIT delivered inventory %) x U.S. #2 unit price x #18 place & pick cost as % of U.S. unit price (Used U.S. price for both because the pick and place costs are in the U.S.)	
24	Purchasing cost, excluding travel	$2.00	$3.00	#2 U.S. unit price x #32 purchase cost %	
25	Total Other Hard	$5.37	$15.73		

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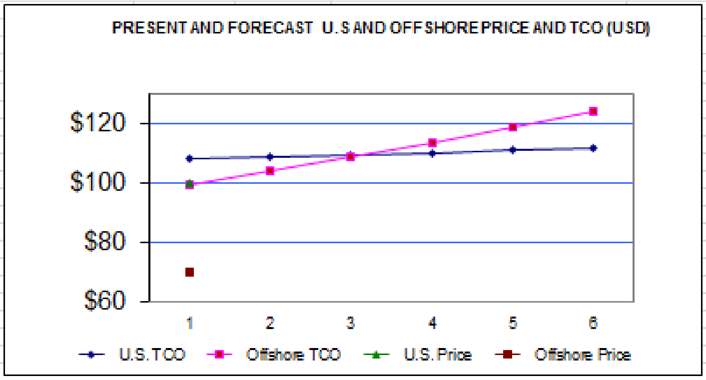
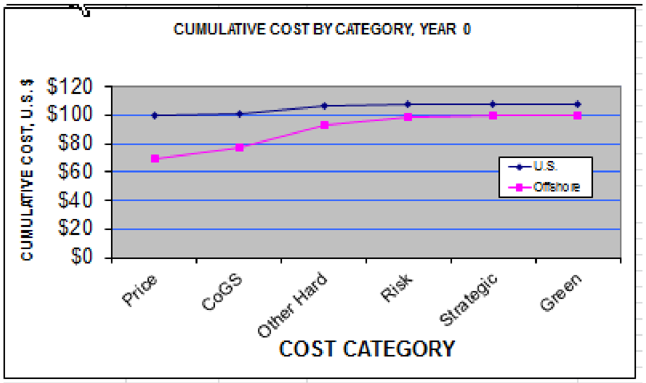
[14] http://www.economist.com/debate/debates/overview/245

Sample output graphs





Summary

Cost models are extremely useful tools in product development. They also require a lot of work to create, validation and keep updated. These costs / efforts are far out weighted by the benefits and savings that can be generated by their use.