aPriori

The Anatomy of Product Cost

Using Digital Manufacturing Simulation to Understand True Economic Cost

WHITE PAPER

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This paper outlines how cost estimation is full of challenging uncertainty. Digital manufacturing simulation helps cut through the variance and focus on a product's true economic cost.

INTRODUCTION

In this paper, we examine what makes up a product's true economic cost. Focusing on this concrete foundation of cost structure is the best way to avoid the variance associated with historical cost estimates and similar methodologies.

Drilling down to the true economic costs of a product requires the ability to analyze the production resources required by a design and its manufacturing process. In turn, fully accounting for this cost structure requires the capability to generate a true manufacturing cost model. With digital manufacturing simulation, designers and engineers can quickly generate holistic cost models that will help them understand how design choices iimpact a product's true economic cost.

Factors that determine the true economic cost of a product include: design cost drivers, manufacturing cost drivers, market cost drivers, and supply chain / purchasing cost drivers.

TRUE ECONOMIC COST

Manufacturing a component requires a complex combination of production resources. These include materials, labor, manufacturingcosts, tool depreciation, factoriy overhead costs, shipping, warehousing costs, and more. True economic cost refers to the fair-market cost of these resources in a truly efficient market with zero mark-up at any point in the supply chain. Some of the factors that determine the true economic cost include:

- **Design Cost Drivers:** a product's design greatly affects how much it will cost to produce. The geometry of the part, material selections, tolerances, surface finishes, and a number of other attributes determine what processes will be used in manufacturing.
- **Manufacturing Cost Drivers**: the capabilities of a given factory, including available machinery, process routings, and overhead costs affect a product's true economic cost.
- **Market Cost Drivers:** annual production volume of a product and the lifespan of the product line can have a powerful effect on the manufacturing processes used, suppliers selected, and whether to use capital investment to reduce the variable costs of production.
- **Supply Chain / Purchasing Cost Drivers:** the supply chain structure established by the purchasing group, including interplant logistics, directly affects product costs.

The cost drivers described thus far describe the combination of resources required to make a product. These production resources are established prior to any "accounting" or "costing". Accounting is a business practice that attempts to translate these engineering realities into a common financial language (dollars). Accounting allocates costs to these resources, but they are difficult to disaggregate from large expense "pools" and assign to an individual component.

True economic cost is represented as the first bar in Figure 1.

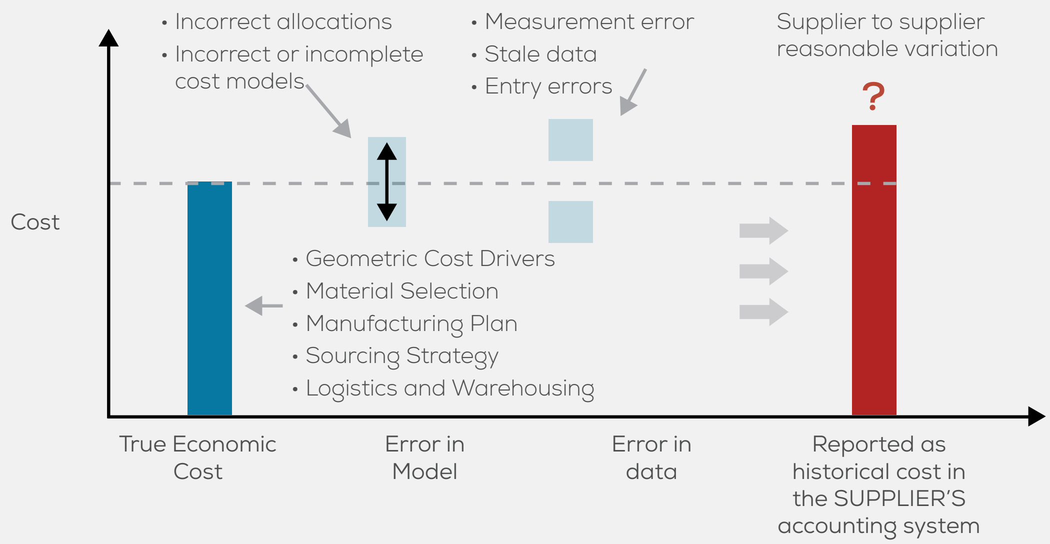

Figure 1. Getting from True Economic Cost to the Factory Door

Cost estimates are often calculated using out-of-date information and therefore do not reflect true economic cost.

SOURCES OF UNCERTAINTY IN TRADITIONAL COST ESTIMATION

In the real world, precise measurements for production resources and their costs are difficult to obtain. As a result, companies develop a variety of models that attempt to estimate the amount of resources consumed for a given part or product based on the total amount of resources used within a given time frame. But these models are imperfect, and they result in a band of uncertainty around the true economic cost. Most cost experts believe this uncertainty ranges from plus or minus 5-15 percent of the true economic cost.

However, if an organization could get precise measurements of resources consumed and compare them with the results of their expert estimates, they would find that the variance would be even more significant – somewhere between plus or minus 20-30 percent.

In addition to the foundational modeling of costs and resources, there are also allocations for indirect overhead costs. Overhead costs are perfectly allocated in true economic cost but are not very certain in the real world. The main goal of the popular accounting method "Activity Based Costing" is to allocate indirect overhead more accurately. This approach is represented by the second bar in Figure 1.

Cost models require a certain level of basic data to operate, further confounding the generation of a precise estimate. This data comes in a variety of forms including material rates, labor rates, overhead rates, and more.

While the quality of this data is usually more certain than the models and estimates that use them, the data can become stale fairly quickly. As a result, cost estimates are calculated using out-of-date information that does not reflect true economic cost. This degree of uncertainty is displayed in the third column of Figure 1. In aPriori's experience, 5% to 10% of data exhibits significant staleness problems or calculation errors. Modern ERP systems help with this problem but cannot completely avoid stale data. ERP software can help prevent stale data by providing a 'single source of truth'. However, if input data to ERP is stale, any system will calculate incorrectly.

The cost at the factory dock (in an internal factory without complex transfer pricing) is presumed to be within this combined uncertainty range. For the sake of argument, the fourth bar with the question mark above it represents the cost carried in the factory's accounting system or the supplier's system.

SUPPLY CHAINS & COST

Buying components from suppliers adds another level of complexity to the cost of a product. It is reasonable to expect that a supplier will want a profit on the manufacture of a component. Assuming an economically efficient market with many supplier alternatives, one would expect a competitive mark-up clustered around a specific average.

This mark-up is represented in the second bar of Figure 2.

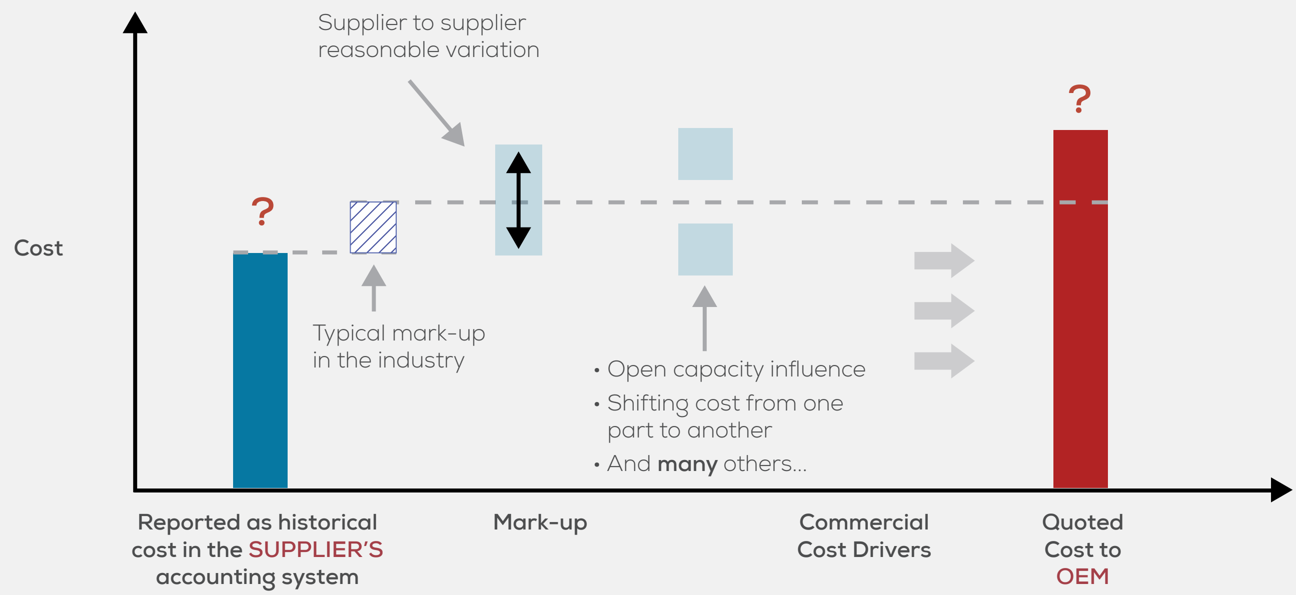

Figure 2. How Cost or Price Changes from Supplier to Customer

> No cost model or accounting system can predict or account for the random effects of commercial cost drivers on estimates.

In the real world, however, suppliers have different business models that result in some reasonable supplier to supplier variation in the mark-up. Beyond this reasonable variation, there are also "commercial" cost drivers to consider. These cost drivers stem from specific operational contexts that can be almost impossible to predict. Some examples include:

- **Excess Capacity:** the supplier has idle assets and needs to fill the factory with work to cover fixed costs. As a result, they lower their price.
- **Insufficient Capacity:** the supplier has too much work and charges a large penalty for interrupting their schedule.
- **Loss Leaders:** the supplier is trying to "buy" new business, so they play a shell game where they shift part of the true economic cost and efficient market mark-up from one part to another. This practice makes a key part look cheaper in order to win business.
- **Relationship Effect:** the supplier quotes or the customer accepts a price outside of the range of a rational buyer, based on a personal or corporate relationship.

The effects of commercial cost drivers are significant, typically much bigger than any reasonable variation in mark-up and many times greater in variation than the magnitude of the efficient market mark-up itself. No cost model or accounting system can predict or account for these commercial cost drivers. They are effectively random in nature.

Adding the efficient market mark-up, reasonable market variation, and the variance from commercial cost drivers to the cost the supplier carries in their accounting system, we arrive at the right-most bar in Figure 2 as seen above.

As the cost variance stacks up, companies move further away from true economic cost.

COST VARIANCE STACK-UP

Figure 3 combines the cost variances from internal and supplier sources (Figures 1 and 2). Note that the stable and invariant parts of the cost are the true economic cost and the efficient market mark-up. All the other variances add or subtract from the sum of these invariant components. Furthermore, each variance type is additive to the others, starting with the left-most bar and resulting into the right-most bar in Figure 3.

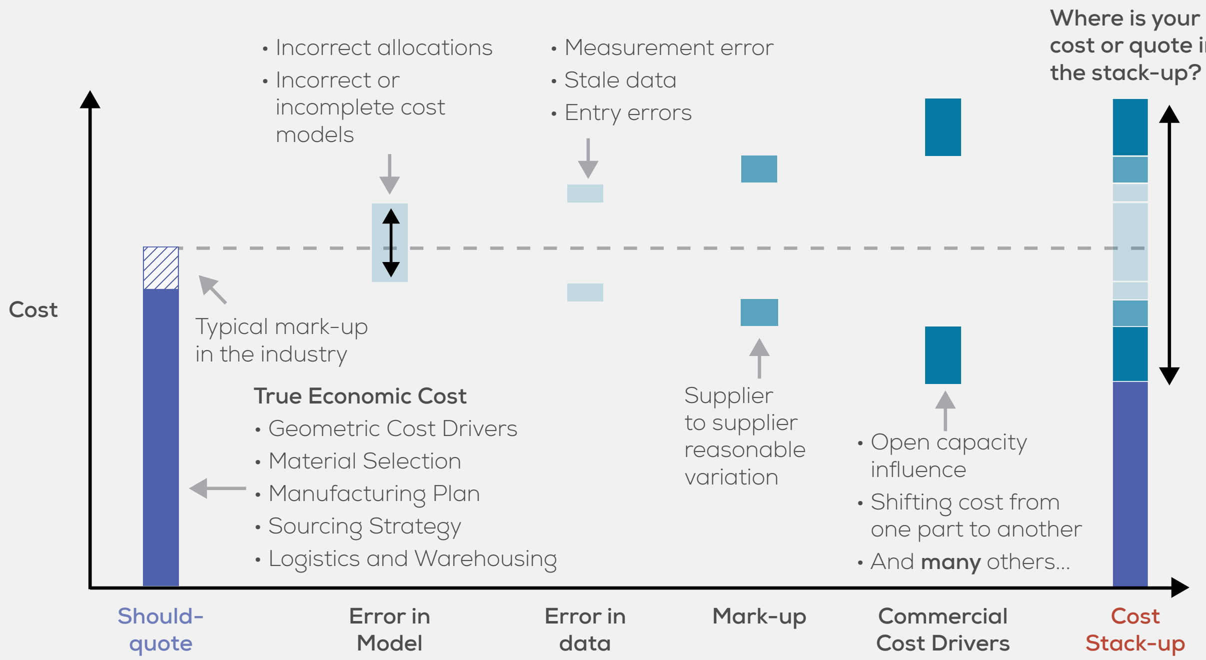

Figure 3. Cost Variance Stack-up

The true economic cost is shown by the first bar in Figure 3, but the price carried in the ERP system at the supplier's customer can be anywhere within the large band shown in the last bar in Figure 3. Note that the range of this variance is significant and can almost outweigh the effect of the true economic cost. One can actually measure how much of this cost confusion occurs by applying the electrical engineering concept of signal to noise ratio.

The real-world example discussed thus far only demonstrates the cost uncertainty present in a supply chain to the level of a single supplier layer. Adding layers to a supply chain further increases the cost variance, with each added supplier in the chain adding to the aggregate uncertainty.

A REAL-LIFE CASE STUDY IN QUOTE VARIATION

TTo further illustrate the costing challenge, consider the following real-world case. Using a popular online manufacturing work bid web site, a product company requested a quote for a very simple turned part. Within a week, the buyer received 18 quotes for the part. The part and the bidding results are displayed in Figure 4.

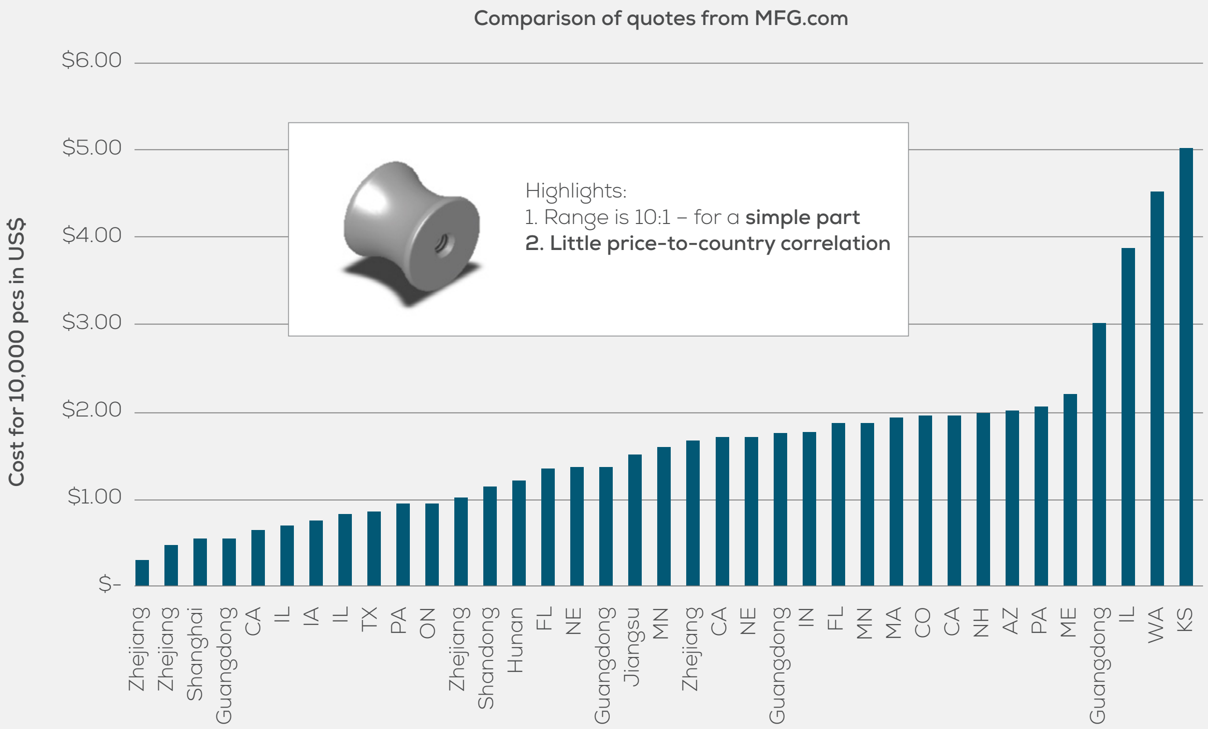

Figure 4. Quotes on a Simple Turned Part

Notice that the range of bids from highest to lowest is 10x. Notably, geography had little effect on the size of the quote; a number of US suppliers quoted significantly less than some suppliers in China. Why did this happen? A portion of this cost differential could be from added shipping cost, but it is most likely rooted in the massive impact of commercial cost drivers.

Based on discussions with suppliers, the buyer also noted that the price would decrease based on the number of times he spoke to the supplier. These discussions were not formal negotiations, just a series of questions around how the part would be made and the suppliers' capabilities. Clearly, the relationship effect was active here.

The 10x range could also be a result of the low volume run on the part. However, similar cases with higher volumes of production typically result in quotes with ranges of two to three times. Figure 5 outlines two additional examples from real product companies. The first part received five quotes and the second part received four. The variable costs, the upfront capital tooling, and the fully amortized costs of the part are shown. Note the tremendous level of variability in the quotes according to several different metrics.

Cost Metric	Quote 1	Quote 2	Quote 4	Median	Standard Devition	Max/Min Range	(Max Quote) / (Min)	Range As % Of Median Quote	(Std. Dev) / (Median), i.e. Noise Signal
COMPLEX DIE CASTING WITH MACHINE 1									
Variable Cost	$6.90	$18.10	$22.40	$18.10	$8.41	$23.20	4.4	128%	36%
Captital Investment	$131,300	$77,610	$101,000	$101,000	$27,105	$70,665	1.9	70%	40%
Full burdended Cost	$9.47	$19.60	$24.30	$21.00	$8.16	$22.53	3.4	107%	36%
COMPLEX DIE CASTING WITH MACHINE 2									
Variable Cost	$17.30	$37.30	$8.00	$16.05	$12.60	$29.30	4.7	183%	43%
Captital Investment	$103,800	$72,000	-	$87,000	$48,543	$103,800	1.4	119%	47%
Full burdended Cost	$18.10	$37.90	$8.00	$16.85	$12.75	$29.90	4.7	177%	43%

Levels of varation in the quote are huge compared to the magnitude of the quote itself

Figure 5. Quote Data for Two Machine Die Castings

Digital manufacturing simulation allows for a more precise understanding of the required production resources that form a stable cost foundation amidst all this variance.

SHIFT IN FOCUS: FROM “NUMBER IN THE BOX” TO TRUE ECONOMIC COST

The cost variation discussed so far leads to some important subsequent questions. Why do organizations focus on absolute cost numbers in early cost assessments when this historical cost or price is so variable? Furthermore, what good is it to reduce cost when the cost signal to noise ratio may be low? How does a company know if it is reducing cost when the noise could overshadow the gains?

The answer is that cost reduction is about relative changes in cost, not absolute changes. This means that manufacturers need a high-fidelity method for calculating true economic cost. Understanding required production resources is the key: there will always be noise and there will always be commercial cost drivers. A robust analysis of the underlying true economic cost is essential for filtering out this inevitable variance.

Embrace the fact that you probably are not paying what you should and engage the supplier or your own plant to explain *how* they arrived at their numbers. Doing so will help improve your manufacturing cost models.

CONCLUSION: TIPS FOR MORE PRECISE COST MODELING

- **Stop Focusing on the Noise (Historical Cost):** manufacturers should avoid trying to model random noise, like historical supplier prices and factory costs, in their cost modeling efforts.
- **Start Focusing on the Signal (True Economic Cost):** first, start by measuring the direct cost impact of specific design choices. For example, a large part of the Six Sigma methodology focuses on just being able to measure what is occurring. The same is true with managing product costs. If you can provide actual, certified measurements of time, mass, labor, etc., this capability is far more useful than historical cost estimates. Unlike the random nature of commercial cost drivers, true digital manufacturing simulation provides a repeatable, consistent, and logical understanding of the interaction of design, manufacturing, purchasing, and market cost drivers.
- **Compare Trends and Orders of Magnitude, Not Absolute Costs:** historical cost estimates are useful for verifying that modeled costs show the same *trend* as the historical numbers. There is simply too much noise in historical numbers, however, for them to be used to confidently certify that your cost estimates are absolutely correct. If a company asks for quotes on ten designs and none of the quotes matches the company cost model's results, that is not particularly concerning. If the ratio of the costs for each of the ten parts from the model is not like the supplier quotes, however, there may be cause for concern.
- **Realize That What You Do Pay is Not What You Should Pay:** a natural corollary to the points above is that you should not be terribly disturbed if your digital manufacturing simulation demonstrates cost estimates that do not match the quote you see or the price you currently pay. Embrace the fact that you probably are not paying what you should and engage the supplier or your own plant to get an explanation of *how* they arrived at their numbers. Doing so will help improve your manufacturing cost models. If the historical numbers were correct, this exercise will be a learning experience to help improve your manufacturing cost models If not, you have an opportunity to save money and increase profit. It is important to realize that your supplier may be just as unaware of quoting noise as you are.

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aPriori is the leading provider of digital manufacturing simulation software that brings product design and sourcing teams closer to production. By leveraging the digital twin within our digital factories, we automatically generate design for manufacturability (DFM) and design for cost (DTC) insights, helping manufacturers collaborate across the product development process to make better design, sourcing and manufacturing decisions that yield higher value products in less time. aPriori solutions are now available either in the cloud or on-premise.