Optimizing Product Cost with Supply Chain Cost Modeling

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Abstract

Demands on the electronics industry for smaller, better, and cheaper packages have made the supply chain more complex. Outsourcing, new technologies, and increasing performance requirements make designing and building the right product for the right price more difficult than ever. We will present a framework for understanding and managing the supply chain through cost modeling. Cost models that accurately reflect the cost impact from technology and design decisions enable a more precise understanding of supply chain behavior. Cost models can show the extra cost of adding a layer, the expected savings from relaxing design rules, or the cost of package on package assembly compared to 3D packaging with through silicon vias (TSVs).

The models also provide context to understanding the "should cost" of a product and the path to achieving it. Since the guidance from cost models is based on the actual supplier cost drivers and pricing behavior, designer cost reduction efforts will result in higher savings compared to not using the cost models. Without cost models, designers risk missing their suppliers' real cost drivers and, therefore, the opportunity to decrease cost. This cost modeling framework allows the designers to realize the lowest cost product by matching the right design with the right supplier. It is a method for understanding a design decision's cost impact: a design change, a supplier change, or even the impact of new technology.

Key words: supply chain, cost model, should cost

Introduction

Finding the right design for a product early in the design cycle saves money. Redesigns are both expensive and time consuming and may delay the ultimate product release. To avoid these problems, designers have tools to validate the design, electrical performance, thermal performance, etc. In the same way, supply chain cost modeling helps designers evaluate the cost effectiveness of design decisions and find the right design as early as possible.

Supply Chain Cost Modeling Definition

Supply chain cost modeling uses cost models to quantify the relative cost impact of design trade-offs and ultimately helps designers make better technology trade-off decisions. These models help the designer understand how much more or less it costs to add a substrate layer, or to change the pitch or design rules. The framework has three parts: the cost models, model usage, and feedback. Before exploring the cost models, it is important to understand how the supplier request for quote (RFQ) process usually works.

Price vs. Cost

One company's price is another company's cost. This fact makes it confusing to talk about "cost models" because it is not always clear whether the supplier or the OEM costs are under discussion.

Figure 1. Components of Total Cost

Figure 1 shows all the different "costs" that are considered to generate a price. Most suppliers calculate their direct costs, distribute overhead and indirect costs, add profit, and sometimes add a risk factor to set a price.

The cost models are designed to quantify the suppliers' underlying cost drivers – not the actual costs – for design decisions. One of the primary benefits of this approach is to focus designers on the one area of the many pricing factors that they can control: the design. It's unusual that the OEM will have any control on how a supplier calculates and distributes overhead, their desired profit margins, or their risk factors. But if the design is optimized for a supplier's capabilities, everyone benefits because cost is removed from the product instead of reducing a supplier's profit through pricing negotiations.

Cost Models

In order for a designer to be able to use cost models for design decisions and technology tradeoffs, the cost models require two key features: relative cost accuracy and real supplier cost drivers.

Relative cost accuracy means the models correctly capture the differences between design decisions. The models should answer the question "How much more or less expensive is it if my design is X instead of Y?" The model is *not* a replacement for the normal quoting and negotiating process because it does not produce either actual supplier costs or formal quotes. The designer uses the cost models to find the technology choices which generate the optimal cost for their design without needing to know supplier confidential details.

The real supplier cost drivers refer to accurately capturing the way a supplier calculates their costs and how those costs are passed on in the pricing. Of all the factors in Figure 1, most of the cost of the design is captured in either direct or indirect/overhead costs. There is no industry standard for determining which costs are direct and which are indirect. This makes it important to understand which design configurations will actually reduce the "cost" for each supplier.

This framework only works if these models incorporate both of these features. A designer can generally determine whether a specific design decision causes the cost to go up or down. However, it becomes rapidly more difficult when a scenario involves multiple variables, such as shrinking the board, but including more difficult design rules. Is this more or less expensive? That's why it is so important to have a model that can identify the real cost drivers and *quantify* the difference. The designer now has a tool that can help identify the real expected value of their design decisions.

Using the Models

Once the models have been developed, they serve as a source of feedback from the supplier to the designer. It is important to understand what the models are and what they are not in order to receive benefit from them.

For the OEM, the model is a consistent way to evaluate the cost impact of design decisions. The model provides consistency in evaluating a design's cost effectiveness throughout the entire design cycle. It also allows a better design through rapid feedback very early in the design cycle before a majority of the cost has been committed in a specific configuration. Without the model, each designer would make different decisions based on a different perceived value which can lead to surprises later on.

What the model does not do, is commit the supplier to any particular pricing or reveal any confidential information about the supplier's costs or margins. The models produce accurate relative costs, but this allows all confidential and sensitive data to remain that way while still providing crucial feedback on how design decisions affect cost. The models are also not designed to be used as negotiation tool to get a better price. The model is fundamentally cooperative and is a vehicle for sharing the best design practices between OEM and supplier.

For the suppliers, the model's benefit is primarily in guiding designers to make better design decisions. If the model is being used as a source of evaluating which design choices are most cost effective, then it also becomes a way for suppliers to provide guidance on which design decisions are best suited for their manufacturing process and capabilities.

Feedback

Once the models are in use, they require periodic updates. This is especially important with any major technology changes being adopted by either side. By providing the input to create the model, there is an agreement that pricing on different design decisions will be accurate. If subsequent quotes do not seem to follow the relative cost differences originally built, it's reasonable to setup a discussion to find out why and update the models if necessary.

Implementation

Setting up this system can be a challenge. The models are fundamentally a cooperative approach to supply chain management and while they don't require a cooperative relationship between OEM and supplier, it is often helpful.

Considering all the natural concerns with confidential and proprietary data, gathering the data is the most challenging part of the process. To a supplier, the initial project can often sound like "Give us your cost data." which will almost always create problems. The question actually being asked is "How much more or less will I pay for this design decision?" This is a reasonable question that can benefit everyone involved. In fact, some of this data is often available somewhere in technology roadmaps, Kaizen events, and even sometimes as part of the normal quoting process. Often times, a third party can help by working directly with the supplier to sanitize any data before passing it on to the OEM so there is no chance of any confidential data being sent to a customer.

Implementation of the models can be approached using commercial modeling software, custom software, in-house tools, or some form of Excel. Regardless of the platform used, an activity-based approach works best because the models have to consider the effects of many different design parameters which can be difficult to capture in other approaches.

Activity Based Cost Modeling

Activity based cost modeling and parametric cost modeling are the two dominant cost modeling methods. Parametric cost modeling is done by statistically analyzing a large number of actual results and creating a model to match those results as closely as possible. This backward looking "black box" approach is appropriate for modeling processes that change slowly over time or cannot be decomposed into individual activities.

On the other hand, activity based cost modeling is the most accurate cost modeling method for forward looking technology tradeoffs because individual activities are characterized and analyzed. This is especially true for new technology where there is no history of pricing from which to derive a parametric model.

In activity based modeling, the total cost of any manufacturing process is calculated by dividing the manufacturing process into a series of activities and totaling the cost of each activity. The cost of each activity is determined by analyzing the following attributes:

- The time required to complete the activity
- The amount of labor dedicated to the activity
- The cost of material required to perform that activity – both consumable and permanent material
- Any tooling cost
- The depreciation cost of the equipment required to perform the activity
- The yield loss associated with the activity

Regardless of the implementation method selected for the model, an activity-based approach generally produces the best results. Because of confidential data concerns between the OEM and supplier, it's almost always impossible to actually construct a complete detailed activity based model this way. However, the approach is fundamentally working from the cost drivers forward, instead of working from past behavior and trying to infer the cost drivers. Just the process of having these discussions is often beneficial.

Design Trade-Off Example [1,2]

As an example of a design trade-off, let's start with a 29x29 mm 3-2-3 flip chip package. The trade-off the designer is considering is increasing the substrate layer count but shrinking the package size. A new 4-2-4 package will have a more expensive substrate panel, but depending on how many additional packages fit on the panel, the trade-off may or may not reduce total cost. We constructed this scenario using generic fabrication activity based models and generated the results in Table 1.

	Original Design	Alternate Design
Structure	3 - 2 - 3	4 - 2 - 4
Package Size	31 x 31 mm	29 x 29 mm
Yield	86.60%	86.29%
Packages per Panel	204	234
Panel Cost	$676.46	$906.98
Package Cost	$3.32	$3.88

Table 1. Trade-Off Results

The results show the increased packages per panel does not fully offset the increased cost of the panel and produces a net loss of about 56 cents. This table also explains why it is so important to have a cost model that can quantify all these up and down changes: What happens if the yield is even less? Or the package can be shrunk to 27 x 27 mm? Any of these conditions may change this trade-off.

This example is based on a generic fabrication process. Consider now adding the different characteristics or pricing behavior for different suppliers on just this one trade-off. What if a supplier may achieve a higher yield but has a higher labor rate? What if a supplier has tooling to support a non-standard package size? What if there is only 1 qualified designer with the capability to do this?

With the models as discussed, a designer can quickly generate Table 2. This shows how different designs, including assembly and fabrication decisions, behave across all the company's suppliers. This enables the designer to make much more informed decisions about the value of all the possible design decisions.

	Original Design	Alternate Design @ Supplier A	Alternate Design @ Supplier B	Alternate Design @ Supplier C
Structure	3 - 2 - 3	4 - 2 - 4	4 - 2 - 4	4 - 2 - 4
Package Size	31 x 31 mm	29 x 29 mm	29 x 29 mm	29 x 29 mm
Yield	86.60%	86.29%	93.20%	78.00%
Package Cost	**Baseline**	**17%**	**-2%**	**26%**

Table 2. Results from a Suite of Suppliers

Technology Trade-Off Example [3-10]

The previous example shows a detailed design tradeoff. Supply chain cost models are also an effective tool for making fundamental technology trade-offs. For example, a 3D implementation can be done by either stacking two die and then packaging, or packaging each die and then stacking. The key technology required to stack die is through silicon vias (TSVs), and the key technology required to stack packages is package-on-package (PoP).

TSV Cost - 14x14 mm Package	Yield Loss	Cost
Bottom Package (including wafer bumping)		$1.40
TSV Creation		$0.33
Top Die Micro Bump and Place		$0.60
Bottom die - Yield Loss after packaging	1.50%	
Top die - Yield loss after packaging	1.50%	
Yield Loss at Debond step	5.00%	
Yield Loss of 1 TSV (200 in package)	0.04%	
Cumulative Yield Loss	14.92%	$0.41
TSV OPTION TOTAL		**$2.73**

Table 3. 3D Results Using TSVs

PoP Cost - 14x14 mm Packages	Yield Loss	Cost
Bottom Package (including wafer bumping)		$1.54
Top Package		$1.00
Assembly		$0.07
Bottom die - Yield Loss after packaging	1.50%	$0.02
Top die - Yield loss after packaging	1.50%	$0.02
PoP OPTION TOTAL		**$2.65**

Table 4. 3D Results Using PoP

Tables 3 and 4 show the results of TSV compared to PoP to implementation for a 14x14 mm package. For the PoP case, the bottom package is more expensive because it includes through mold vias (TMVs) and is assembled using flip chip technology.

The substrate for the bottom package also has an extra surface finish. The top package is a 14x14 mm wire bond package using gold wire. Assembly of the two packages is done during SMT pick and place using a solder paste dip process which is automated in most new SMT assembly equipment. There is not an extra reflow step because the top package and the bottom package can be reflowed at the same time. The die yield loss after packaging for each package does not compound since the packages are fully tested before they are stacked. Therefore yield loss on the top package only cause the top package to be scrapped and yield loss on the bottom package only causes the bottom package to be scrapped.

Unlike the PoP case, the die yield losses after packaging and the yield losses of the TSV manufacturing process compound. The only test and scrap opportunity other than wafer probe is at the end of the process and everything must be scrapped if the test fails. In addition to the TSV manufacturing yield loss, another source of defects results from thin wafer handling problems. This thin wafer handling yield loss is typically introduced during the wafer debond step.

As shown in table 3 and table 4, the process cost for the TSV solution is less than the PoP solution. If zero yield loss is assumed for all steps, the process cost for PoP would be $2.610 and the process cost for the TSV solution would be $2.326. The extra cost of the PoP process is primarily due to the fact that there are two packages instead of one. However, if realistic yield loss is factored in to the comparison, the cost of a PoP solution is lower - $2.648 for PoP and $2.734 for TSV. The use of models shows that the total cost of the TSV case is higher even though the direct manufacturing costs are lower.

Should Cost

A natural extension of the models is to help identify a "should cost" or target cost. The concept of "should cost" is usually not well-defined and therefore can cause a lot of confusion. When talking about "should cost", we recommend discussing ranges, not values, and including conditions. So the question becomes "What is the "should cost" given all possible PCB suppliers?" or "What is the "should cost" compared to my competitors?"

Given an identical design, yield, supplier capability, and profit margins, if asked to share what the cost of the design is, two suppliers will always produce different costs. Variations in which activities are charged directly and accounting practices in applying overhead, mean there is no "should cost" for a design. Instead, it's valuable to find a "should cost" range that can include the normal amount of expected variation that results from normal demand issues, risk assessment, material price fluctuations, and all the other things that influence pricing.

To determine "should cost", there needs to be a scope that includes the range of possible suppliers and time frame. The question of how much should a product cost today is very different from how much a product should cost in two years considering possible technology changes.

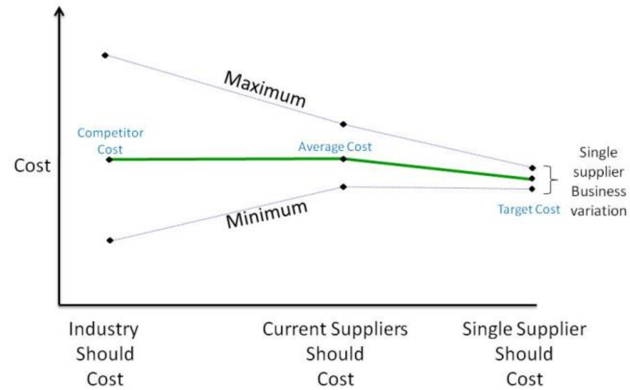

Figure 2. Levels of Should Cost

Figure 2 shows three levels of "should cost". First is the "should cost" range for all possible industry suppliers. This range is very wide because it includes a huge variety of suppliers that compute costs in many different ways. In addition, it includes costs for designs that may not be similar to the types of designs or volumes in an OEM's normal business. Next, the "should cost" scope is narrowed to only include suppliers that are in some way similar to a supplier's current business – perhaps all currently approved suppliers. Finally, you can identify a "should cost" based on a single supplier.

The models are an ideal foundation for this type of exercise. Instead of basing the actual model values on a specific supplier feedback, results from a benchmark, industry best practices, or just estimates from industry experts can be used. The real benefit in approaching "should cost" this way is that discussion around the targets or paths to achieving them can center on the state of specific activities or the cost of specific design features. The discussion is naturally moved into specifics rather than a discussion of whether the overall target number is right.

Conclusion

Supply chain cost modeling enables designers to realize the lowest cost product by matching the right design with the right supplier and making the right technology decisions. The two major requirements for any technology driven cost reduction project to be successful are -

- Technology decision makers understand the total cost impact of their trade-off decisions.
- The supply chain provides consistent and predictable pricing based on their customer's technology choices.

Cost models are the most effective way to accomplish both requirements.

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