

Investigation of Competitiveness Differences from Unequal Quality Offerings and  
Symbiotic Supply Chain Partner Design Strategies

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# Table of Contents

<b>Acknowledgments</b>	<b>ii</b>
<b>Executive Summary</b>	<b>iii</b>
<b>Introduction</b>	<b>1</b>
<b>Review of Literature</b>	
<i>Supplier Collaboration</i>	<b>2</b>
<i>Over-engineering and Waste</i>	<b>4</b>
<i>DFMA</i>	<b>5</b>
<b>Methods</b>	<b>6</b>
<b>The Case Study Company</b>	
<i>Design Authority, New Product Introduction, and DFMA</i>	<b>8</b>
<i>Suppliers and Supplier Selection, Communication, and Collaboration</i>	<b>8</b>
<i>Functional Integration</i>	<b>9</b>
<b>Cross-Tabulated Survey Results</b>	
<i>Key Questions by Organizational Role</i>	<b>10</b>
<i>Comparison to Expected Results</i>	<b>11</b>
<b>Conclusions</b>	<b>13</b>
<b>Recommendations</b>	<b>14</b>
<b>Works Consulted</b>	<b>14</b>
<b>Appendix</b>	

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## Executive Summary

While manufacturing suppliers may occasionally believe that they are constrained by their quality system and their competitiveness seems in question, the quality system is not the root problem.

1. While obvious on its face, manufacturing buyers want to save money on their custom machined parts without compromising delivery or quality. However, by buying only on the basis of price, they may rule out the types of suppliers they value. ISO9001 and AS9100 suppliers cannot deliver non-conforming parts without violating their quality management systems.
2. Most suppliers are experts in their given fields. For example, machine shops know how to make parts easier to machine. Most manufacturing buyers already recognize this and acknowledge that a great deal of waste and cost reduction comes from their suppliers.
3. Despite procurement realizing the savings, engineering and upper management are not always aware of the benefits of working with suppliers for design optimization. Manufacturing organizations are only somewhat effective at integrating suppliers, collaborating internally on supply chain initiatives, and reducing design waste.
4. It is recommended that a pilot implementation between a manufacturing buyer organization and a capable supplier be put together to develop best practices and procedures for widespread collaboration, integration, and waste reduction.

## Introduction

In my job position as sales manager for a small contract manufacturer, I have encountered many situations where my pricing is higher than the competition's. Sometimes the difference is substantial enough to cause me to take notice. In a few cases, I was bidding against a company that was already making the parts. Knowing that they could not be that much more efficient than my organization, I perceived that there must be a significant gap between their process and my planned process. Similarly, we have been awarded work that ended up being extremely difficult, and in some cases impossible, to manufacture per the customer's requirements. Upon receipt of a sample part, it was clear that the part was not being made "to print" but that it was "good enough" for the customer. The quality we were going to provide was excessive to the customer's real need. Marshall Goldsmith, coming from a behavioral perspective, would refer to this as "adding too much value." Industry wide, manufacturers struggle with the diminishing marginal benefit provided with the marginal cost of quality. That is to say, each additional dollar spent to manufacture a part will result in an incrementally smaller increase in the quality provided. A further complication is that quality is two-fold; both the objective and the subjective need to be satisfied.

Unfortunately, having an ISO9001/AS9100 quality system means delivering exactly what the customer asks for but not necessarily what is needed. There are ways of handling this, but they are often time-consuming. The two general approaches are to either request a design/drawing modification, or to request an advance deviation waiver. The problem with either approach is that there can be a significant time investment in reviewing and re-approving documentation; deliveries are often delayed. In many cases, there are regulatory issues that prevent design changes such as structural aircraft parts that have been tested to gain FAA approval, or implantable medical devices that have already passed rigorous testing.

All manufacturing organizations see the value of reducing manufacturing costs. However, many organizations make few products internally and rely on their supply chain to either provide parts, subassemblies, or entire assemblies. There is no reason to believe that this will change in the future. Engineers are not always conscious of the cost of manufacturing a particular design, and are often primarily evaluated on their ability to quickly get a product to market. These pressures usually come from upper management as representatives of shareholders or marketing on behalf of customers. It is hard to imagine a group of stakeholders more important than

shareholders and customers. Unfortunately, once a design is set, it is difficult and expensive to change.

Because procurement normally does not have the design knowledge that engineering has, and engineering often does not correspond with suppliers, opportunities for reducing the cost of manufacturing by collaborating with suppliers are foregone. Engineering will, either from a rush to produce part drawings or from poor process understanding, design parts and assemblies that have waste built into them. When procurement buys the parts or assemblies, the suppliers perpetuate the waste built into the design. Alternately, a company with relaxed quality standards may deliver parts that do not conform. Because parts after the first parts produced are often not scrutinized, parts that do not conform but meet the requirements of fit, form, and functions are delivered and accepted. A competitive advantage now lies with the company that does not do what it says it does, which for an ISO9001 or AS9100 company means never delivering non-conforming parts or assemblies. This would be a major failing of the supplier's quality management system, let alone any ethical considerations. With these realizations and a desire to survive in the marketplace, I decided to refer to what work may have been done in this area already, and what knowledge gaps may need to be filled.

## **Review of Literature**

Because of the lack of specific literature available for the subject of study, what follows represents three discrete areas of literature. These include supplier collaboration, over-engineering and waste, and DFMA (Design for Manufacturability and Assembly).

### **Supplier Collaboration**

Because supply chain partners are so connected, and suppliers add value to their customer's products, I felt it prudent to look at what literature was available in the area of collaboration between buying organizations and supply organizations. After all, that is a market in its simplest fundamental form: buyers and sellers.

In van Echtelt, Wynstra, van Weele, and Duysters, the authors take on supplier involvement in new product development. They examined eight case studies of a commercial equipment manufacturer to develop a cross-section of supplier involvement. What they found was that "timely consideration of alternative solutions and an integrated evaluation of product design, involving the relevant representatives early on in the project, were important in all of the case studies" (194). One requirement for success was collaborating with a supplier in an area of a product's design that was a core competency for the supplier, such as a power supply

manufacturer that had much experience in a specific area. Success also required that the parts and assemblies be relatively complex to get value from collaboration with suppliers. The simpler components did not get much benefit from collaboration. There are also two key areas of management processes that must be considered: the “strategic-management arena” and the “operational project management arena” (196). To get the most benefit from collaboration, companies must “build long-term relationships with key suppliers, where it builds learning routines and ensures that the capability sets of both parties are still aligned and are still useful for new joint projects” (197).

Leavy points out that there are two approaches to buyer and seller relationships. The “traditional approach” is one in which the market manages the relationships and ultimately the “buyer and seller see themselves as essentially competing with each other for margin” (326). On the other hand, the “partnership approach” is based on cooperation, and the “buyer and supplier are essentially partners-in-profit” (327). By working together in a carefully managed (i.e. appropriately transparent yet cautious) relationship, such a supply chain partnership “clearly offers many strategic advantages...” (331) by encouraging “very significant economies of cooperation...” (327).

Although Fawcett recognizes that “supply chain management is one of the most talked about competitive strategies of the 1990s,” he concedes that there is a “relatively meager understanding of how entire supply chains... should be structured and managed” (340). To integrate the supply chain, a company must address process change, information capability, performance measurement, and alliance management. Each one of those areas is touched upon all-too-lightly. One key suggestion is that “better communications play an important role in developing innovative products and services, and reduce concept-to-market leadtimes” (339).

One of the key points of Newman, Hanna, Gattiker, and Huang’s “Charting Supply Chain Management Integration and Initiatives: A Framework to Guide Implementation,” is that companies must be aligned internally before integrating their suppliers; they call this the “cross-functional” domain. They came to their conclusions based on case studies of four large manufacturers. Interestingly, they put DFMA within the cross-functional domain and not the “supplier/customer” domain (24). As a suggestion for future research, the authors recommended the following questions be answered: “What are the competitive objectives of our supply-chain improvement efforts and to what extent are they aligned? What degree of SCM (Supply Chain Management) integration have we achieved? Are there blind spots, or missed opportunities, in

our current trajectory of SCM improvement resulting from overlooked objectives or insufficient integration? And, what should be the highest priority in our SCM improvement efforts?" (29).

### **Over-engineering and Waste**

Before proceeding to look into ways to reduce waste, I wanted to make sure that waste in this area exists. In other words, there is no reason to seek a solution for a problem that does not exist.

An introduction to lean manufacturing practices and waste is made by Chris Ortiz. Two of these wastes are "over-processing" ("the act of redundant effort and extra unnecessary steps") and "defects/rejects" ("rework, mistakes, quality errors") (10). While Chris provided an opportunity for me to cite his succinct wording, these two wastes are part of the globally-accepted Toyota Production System.

G. J. McManus, in a relatively dated article, found that over-engineering was present throughout the supply chain. The big risk lies where engineers and suppliers stack up safety factors, introduce redundant refinements, and provide for too much capacity. In cases where there is a feature that the supplier believes is unnecessary, the supplier can "price the questionable feature separately" (54). This relates more to relationships where the supplier is involved in a traditional relationship as McManus states that "the supplier must ultimately defer to the customer, who, after all, is the expert on the objectives and requirements of the job." Suppliers should still, at the very least, remind their engineers of the "social effects" of their design (54).

Paul Rako, in a brief article titled "Overengineering: How Much Is Too Much?" hit upon exactly what design is. The anecdote that Rako provides involves comparing World War II German and American radio technology. The German equipment was much better, elegant even, but only assuming conditions that were not always present during wartime. The American equipment was easier to repair in the field and contributed to battle-winning communication during the war. "Good design is about making compromises on a continuum of choices" (10).

Cooke, McMahon and North recognized that many areas of industry, particularly manufacturing, have increasingly been evaluated with metrics. While it is relatively easy to come up with effective measurements for both manufacturing productivity and product quality, it is not as simple to develop metrics for design and engineering. They decided to code design changes as either preventable or non-preventable, and then broke the categorization down further. Design changes could be caused a "failure to meet specification", "manufacturing easement", "assembly easement", "design data errors" or "design improvement" (525).

## **DFMA**

DFMA, as previously mentioned, is an acronym for Design for Manufacturability and Assembly. It is the most widely used process for optimizing part and assembly design to reduce manufacturing costs. In the case of DFM (Design for Manufacturability), this is done by removing or modifying features that are cost drivers, changing material type or shape, or drastically redefining the part to match a process. For example, a part with a feature that requires contour machining to create a rounded edge may be simplified by removing the feature. DFA (Design for Assembly), on the other hand, focuses on reducing the cost of the entire assembly. Often, DFA can increase the complexity of individual parts by incorporating features of other parts so that the part count can be reduced. An example would be adding a small tab or flange to a part so a 90-degree bracket can be removed. In the context of this project, I am considering DFA and DFM together with the end goal of removing as much cost as possible from the entire assembly.

Steven Ashley cites a survey of DFMA adherents that found “typical results are a 51 percent reduction in parts count, a 37 percent decrease in parts cost, 50 percent faster time-to-market, a 68 percent improvement in quality and reliability, a 62 percent drop in assembly time, and a 57 percent reduction in manufacturing cycle time” (75). While that is a compelling case for DFMA, Ashley refers his readers to expensive consultants and software. Despite the winning arguments in favor, DFMA “remains a woefully underused tool” and that “by the time the design is in manufacturing, about 80 percent of the cost is locked in....” He further found that upper management is often skeptical of the benefits of DFMA.

Paul Teague spoke at the 2008 International Forum on Design For Manufacturability and Assembly. He says that audience members were “eager to share ideas and learn from each other how they could design products more cost effectively by reducing part count, using alternative materials and components and simplifying manufacture and assembly.” He puts the responsibility of implementing DFMA on engineers and buyers. There are no suggestions provided on how to do this. He states that “purchasing as a profession has been knocking on the door of engineering for a long time”, but that buyers have “an attitude that purchasing’s only jobs are to beat up suppliers for lower costs and write purchase orders.”

In an unpublished work by Dewhurst and Meeker, the case for DFMA is made clear. In two case studies, significant savings were enjoyed by both Milwaukee Electric Tool and a consumer manufacturer by using DFMA practices. Besides a shallow understanding of the true costs of

offshoring, manufacturers become “myopic in the design process when they look only to outsourcing for cost reduction” (3). To effectively evaluate offshoring, manufacturers must both realize that it is possible to reduce part count and simplify designs to reduce cost and apply the true costs of offshoring to their Cost of Goods Sold. The Milwaukee Electric Tool case study showed that DFMA processes could bring products previously made in China back onshore and reduce cost by eliminating parts while strategically increasing component complexity (15-17). A second study found that for a child’s toy, the cost of manufacture for a product that had not been optimized in the U.S. was \$53.28 and in China \$43.91 (includes a 24% adder to reflect hidden costs of doing business in China). At first glance, it makes sense to make this product in China. However, after DFMA was applied, the redesigned product could be made in the U.S. for \$38.89. The assembly and component parts were now too complicated to make in China, but due to the savings from DFMA, could now be made cost-effectively in the U.S. (18-19).

Mike Shipulski, in an article titled “Resurrecting Manufacturing,” presents a case for preserving manufacturing in the United States by using DFMA practices. His audiences are design engineers that he accuses of having become complacent from being “protected” from globalization. While DFMA is “straightforward work” it is “hard work” that requires that a “forcing function must come from company leadership” (28). DFMA can, in Shipulski’s opinion, amplify lean manufacturing methods and remove non-value added activity from not just the value stream but from the entire supply chain. Studies have shown “radical savings from DFMA work, and material and labor reductions of 20 percent to 50 percent are commonplace” (25).

In “DFMA to RP, ASAP”, Jack Raplee provides some history of DFMA. He breaks DFMA into four distinct approaches. “Design for assembly lowers the complexity of products through part reduction... design for manufacture... allows users to make tradeoff decisions between process and assembly cost and optimized part designs... design for service supplies a method of designing products for efficient maintenance and repair... design for environment helps to quantify design in terms of cost and environmental impact...” (73). Raplee believes that DFMA “brings the entire design team to the table” and that it is critical in its use as “a communication tool” (74).

## Methods

Based on the literature, I found that suppliers and customers can and should work together, that design waste and over-engineering exists, and that there is a prospective solution in the form of DFMA. I wanted to take a wider view of DFMA, how it is applied, when manufacturing buyers

collaborate with their suppliers, and how well the manufacturing buyer organization collaborates internally (a requirement for integrating suppliers based on literature reviewed). I decided to design a survey to be administered to engineers, buyers, managers, and other manufacturing personnel. More than 100 solicitations were sent out to current customers and contacts of the author. Although it was expected that as few as twenty-five percent of those solicited would complete the survey, forty-one surveys were submitted. The survey was designed and administered electronically through software-as-service survey provider SurveyMonkey.com. The results of the survey have been collected, tabulated, and analyzed by the author. A case study company produced from the cross-section of data follows. I have also included some cross-tabulated and filtered facts of specific interest to this project obtained through SurveyMonkey.com's cross-tabulate and filter tools.

Please note that the results of this survey may or may not be generalizable beyond the scope of the survey sample. To be clear, the sample group is not random nor does it represent a distinct population except customers and contacts of the author. Further, some of the comments left by respondents expressed concern about their ability to make general statements about their organization. Specifically, engineers that are not engineering managers were concerned that their personal knowledge did not extend deeply enough into procurement to answer some questions with confidence particularly in the area of supply chain initiatives. However, for the scope of this project the author believes it is reasonable to make decisive conclusions from the data despite the lack of tests of statistical significance. The value of the recommendations made at the end of this report are not diminished by a reliance on anecdotal evidence.

## **The Case Study Company**

Using statistical analysis of the survey data, I have illustrated a case study company. This case study company manufactures assemblies primarily for the aerospace market, but has some medical and consumer products as well. They have between 101 and 500 employees and their annual revenue for the fiscal year ending in 2009 is somewhere between six and fifty million dollars. This company has registered ISO9001 and AS9100 quality systems, and has implemented Lean/Kaizen, Six Sigma, and TQM, but not fully. They use machined parts in their business, and the machined parts constitute anywhere from fifty-one and seventy-five percent of the value of their finished product; there is between eleven and twenty percent of design waste in their machined parts. Almost all design and engineering is performed internally, but only about half the prototypes are manufactured internally; almost all production parts are manufactured

externally while subassemblies are mostly manufactured internally. Final production assemblies are manufactured almost all internally.

### **Design Authority, New Product Introduction, and DFMA**

Procurement and suppliers are involved in the new product introduction process after the design is relatively frozen and prototypes are needed. Customers of this company delegate design authority and MRB (Material Review Board) only some of the time; of the products manufactured by this company, almost all are designed by the company and not its customers.

Dock-to-stock has not been implemented; all purchased parts and subassemblies have to go through receiving inspection. However, since this company has design authority and customer-delegated MRB at least some of the time, quality requirements passed down to suppliers are relaxed accordingly. Generally this means the organization will judge quality based more on fit, form, and function rather than on strict conformance to the drawing. Further, having design authority increases the likelihood that this company will have customer-delegated MRB authority.

Our case study company uses DFMA processes internally, and has saved money in the past through DFMA. These savings have come primarily from the internal engineering department, and from suppliers and the internal manufacturing department to a lesser degree. They have not paid for DFMA services from a consultant, and members of the organization have not participated in DFMA workshops or training. The company is only somewhat effective at using DFMA as a tool to reduce costs, but not because they believe that DFMA cannot reduce part and assembly costs.

### **Suppliers and Supplier Selection, Communication, and Collaboration**

The case study company has an approved supplier list, but has not recently reduced its supplier base. The supplier characteristics that are critical are that suppliers should at a minimum be approved as a supplier, have a quality management system, understand engineering requirements, never knowingly deliver non-conforming product without an advance waiver, and always meet delivery commitments. Further, it is very important, but not imperative, that suppliers have a registered quality management system, are willing to participate in supply chain initiatives, and can be trusted with limited design authority. It is considerably less important that suppliers provide design assistance or practice “c = 0” Zero Acceptance Number Sampling Plans; “c = 0” is where a predetermined number of parts are inspected and must be found completely conforming during manufacturing. Concerning competitive advantage, quality

is the number one advantage offered by suppliers, followed by price and delivery; specialized knowledge is much less important.

When it comes to the company's comfort level, the amount they are willing to share with suppliers depends much more on the supplier than on the item of confidence. They will freely share subassembly and assembly drawings that are related to the parts that the supplier is making. However, they will only rarely share their customer's drawings and specifications. They think very hard about disclosing their customer's name, and are extremely unlikely to involve their suppliers in conversations with their customer. There are elements of their business that are proprietary and trust is hard-earned by suppliers. The company is not satisfied with the degree of integration of suppliers within its organization, and most often only communicates with suppliers about day-to-day topics such as requesting quotes, placing orders, and inquiring about order status. Strategic communication with suppliers is infrequent.

### **Functional Integration**

When it comes to strategic supply initiatives collaboration, accounting and finance perform a good deal of the research and data collection. Engineering and design, manufacturing and manufacturing planning, and operations all influence the initiatives. However, the decisions are made by procurement, quality, and upper management with implementation left to procurement. Sales is not usually involved at all.

Besides the qualitative aspects noted above, we know that in regards to supply chain initiatives, procurement and engineering collaborate relatively often. Procurement and manufacturing and procurement and quality collaborate to a slighter degree. Not surprisingly, procurement and sales collaborate rarely. The company is not satisfied with the degree of collaboration regarding supply chain initiatives within its organization.

In regards to NPI (New Product Introduction) collaboration, procurement and engineering again collaborate together most frequently, followed closely this time by procurement and manufacturing; procurement and quality collaboration happens nearly as often. Procurement and sales collaborate rarely, but more frequently than they collaborate on strategic supply initiatives. The case study company is much more satisfied with NPI collaboration than with collaboration on supply chain initiatives. This company feels that it is only somewhat effective in the areas of internal collaboration, supply chain integration, and NPI collaboration, with the strongest feeling of dissatisfaction about effectiveness in the area of supply chain integration.

## Cross-Tabulated Survey Results

### Key Questions by Organizational Role

Because the conclusions of this research project hinge in part on the responses of survey takers, it is important to understand how their roles affect the collective summary of the results of the survey. I filtered the survey responses by the roles that respondents reported filling within their organizations. As was established with the case study company in the area of functional integration, different functional areas play different roles in supply chain initiatives. If suppliers are going to be relied upon for their DFMA assistance, what are the current views about DFMA held by those that will research, influence, make decisions, and implement supply chain initiatives? Of the researchers, accounting/finance is alleged to be the most involved, followed by sales and manufacturing/manufacturing planning. The primary influencers are engineering and design and quality; to a lesser degree manufacturing/manufacturing planning influences the decision as well. Later, procurement, quality, and upper management actually make the supply initiative decisions. Finally, it is up to procurement to implement the initiative with support from operations and manufacturing/manufacturing planning.

Only one respondent reported filling the role of accounting/finance and I would be remiss in representing any level of confidence from a single data point. However, the other functions are well-represented. Before I begin relaying data, I need to point out that each respondent could report filling multiple roles. For example, a respondent could report that they are in sales, quality, and upper management.

Only 50% of quality representatives reported their organizations used DFMA internally, followed by manufacturing/manufacturing planning at 57.1%, 66.7% in procurement, 68.4% in engineering, 75% in operations, and 80% in both upper management and sales. Of the seven groups, upper management, procurement, manufacturing/manufacturing planning, and sales reported that they felt their organization used DFMA somewhat effectively, while engineering and operations said the use was ineffective. There were four respondents from quality, and each one chose a different level of effectiveness leaving their collective response perfectly inconclusive.

The average rating for the amount of design waste in machined parts and assemblies varied significantly; in order of percentage, quality reported 13.5%, manufacturing/manufacturing planning 14.63%, sales 15.25%, upper management 16.89%, procurement 18.15%, and engineering 22.17%. Over 90% of each group reported having saved money with DFMA except

procurement, where only 80% of respondents reported having saved money. Finally, and for me most interestingly, a breakdown of the percentage of cost savings that can be attributed to suppliers follows. The greatest percentage of savings by suppliers was reported by procurement (65%), followed by 50% for manufacturing/manufacturing planning, operations, and quality. Importantly, upper management (and sales) only attributed 40% of DFMA cost savings to suppliers and engineering only 29.4%.

In summary, to differing degrees all groups see the ongoing value of DFMA from collaborating with suppliers and believe their organizations can do a better job based on their reports of effectiveness. However, engineering and upper management need to be better convinced that suppliers can help. Procurement has clearly been convinced. All of these data fit when the poor ratings of collaboration with suppliers and functional integration are considered.

### **Comparison to Expected Results**

As part of my research proposal, I came up with a list of six expected results. I would like to compare them with what I discovered.

I had expected to find that buyers had recently reduced their supplier base. Only 41.5% of respondents reported having reduced their supplier bases recently. I decided not to ask as part of the survey if respondents would like to spend less on their parts if it meant there would be no compromises to quality or delivery; this seemed obvious on its face. Manufacturing buyers rely on their suppliers, first and foremost, for quality, followed by price, delivery, and lastly specialized knowledge.

The second premise I developed was that when buying companies have design authority, fit, form and function are much more important than conformance to part documentation. This was validated by the survey instrument; 63.4% of respondents reported this to be the case. Further, a full 80% reported that having design authority affected the quality requirements passed down to suppliers. Only a small margin, 52.6%, reported that having design authority increased the likelihood that they have customer-delegated MRB (Material Review Board) authority.

I felt sure I would find that companies that have design authority are going to be more likely to have integrated their supply chain. Indeed, respondents that had design authority “all of the time” rated their supply chain integration effectiveness as slightly higher than those that reported having design authority “some of the time”. There was one respondent that reported having design authority “never” said their supply chain integration was “very effective”. I cannot say the

connection is conclusive between integration and design authority but there is at least a weak correlation.

Do companies believe that their suppliers can provide information and design assistance, such as DFMA, that will save them money? In hindsight, I did not ask questions that were direct enough. Despite that, we know that respondents strongly believe that DFMA can reduce their part and assembly costs (97.4% of respondents). Half the respondents attributed their organization's savings from DFMA to suppliers. Further, 11.8% of respondents rely on suppliers completely due to their specialized knowledge, and 41.2% heavily rely on their supplier. Only 23.5% of respondents barely rely or do not rely at all on their suppliers for "specialized knowledge". Unfortunately, this is not conclusive as the "specialized knowledge" may or may not be DFMA support. But the implication is strong that companies believe that suppliers know how to help reduce costs.

In terms of functional integration, I believed that I would find that procurement and engineering, quality and procurement, and engineering and quality already work together some of the time. When I designed the survey, I narrowed the focus to procurement's functional integration with the other functions, leaving the question about engineering and quality's integration unasked. However, concerning procurement and engineering, 89.7% of respondents reported that they collaborate at least some of the time on NPI (New Product Introduction) and 81.6% of respondents reported that they collaborate at least some of the time on strategic supplier initiatives. Procurement and quality had similar levels of collaboration, with 92.1% of respondents reporting collaboration at least some of the time on NPI and 91.8% reporting collaboration at least some of the time on strategic supplier initiatives. There is no doubt about the functional integration between engineering and procurement and quality and procurement, at least in the areas of NPI and strategic supplier initiatives.

Finally but most importantly, I thought I would find that suppliers are not as integrated with buying organizations as buying organizations feel they should be (i.e. suppliers are underutilized). Only 12.5% of respondents reported that their supply chain integration is "very effective", 65.0% "somewhat effective", and 22.5% "somewhat ineffective". As far as the degree of integration of suppliers into their organization's operations, only 47.4% were satisfied. From the survey data, there is room for improvement in supplier integration.

## Conclusions

There are two clear losers here: the company with poor design will be inextricably connected to a low-value shop and the well-meaning, fully conforming contract manufacturer that will not be awarded projects with poor design. The only winner is the relatively cheap, low-overhead manufacturer that has no regulatory, quality-standard driven, or ethical obligation to manufacture what the customer has asked for and not simply what they need.

Organizations without design authority cannot make decisions about fit, form, and function, and are at a competitive disadvantage when it comes to quality. Either companies with solid quality systems will not be able to compete, or they will have to find some other way to add value for their customers. For manufacturing buyers, resorting to a less-expensive, lower-quality supplier to accommodate for poor design is rarely a good option; it is just a work around.

In terms of the savings to be had, a majority of respondents have annual revenue that ranges from six to fifty million dollars per year. Meanwhile, most respondents estimated that custom machined parts accounted for somewhere between fifty-one and seventy-five percent of their finished product's value. The rating average for the amount of waste the respondents believed is in the design of machined parts as a percentage of total cost is about nineteen percent. Using only conservative numbers, I calculate the total savings for the forty-one survey takers to be twenty-three million dollars per year. When the savings are applied to the 14,000 U.S. manufacturers, the annual potential savings from design waste is in excess of seven billion dollars. The real significance of this work is that products can be brought back onshore while costs are cut. While the "world is flat" and globalization is the norm, ingenuity and cooperation can overcome offshoring. The amount of savings from DFMA eclipses the savings from offshoring. This is a "win-win-win" for American manufacturers, contract manufacturers, and consumers.

Upper management needs to be further convinced of the importance of DFMA. Engineers that are protective of their territory may have simultaneously understated how much improvement is possible and overstated how much of it they do to representatives of upper management. On the other hand, buyers realize the value that suppliers bring to reducing design waste. Whether it is ego, as suggested by one survey respondent, or a lack of time to do things right, the waste must be reduced. Buyers and self-confident engineers need to heed the battle call and change their organizations. As Albert Einstein once said, "in the middle of difficulty lies opportunity."

## Recommendations

The work I have done is relatively conclusive within a narrow scope but has identified a need for further exploration. The data from this survey, along with anecdotes of successes, needs to be shared with engineers and representatives of upper management. The best way to do this would be through a white paper made available to the public immediately. Further, a sample implementation of some of the systems and processes described here, where a supplier or many suppliers help a manufacturing buyer with DFMA, should be used as an implementation case study. With the data collected, a step-by-step collection of processes and best practices could be turned into a deeper work in the form of a book.

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# Appendix

## Glossary

AS9100 – a quality management system standard issued by the Society of Automotive Engineers and the European Association of Aerospace Industries that provides guidance specifically to organizations that are involved with parts and assemblies that eventually are incorporated into aerospace vehicle systems, including aircraft and technologies related to defense; this standard expands on the ISO9000 standards

Concurrent engineering – the integration of several product development tasks that can be performed in parallel to reduce the time to take a product to the market

Configuration management – the configuration of parts and assemblies are the set of characteristics required by the designer (and therefore buyer); manufacturers must manage the configuration of parts and assemblies to ensure that the parts and assemblies delivered to the customer meet the contract requirements

Delivery – the combined physical and legal act of moving something of value from seller to buyer, collectively described by a location, time, and method

Design authority – the ability of a particular member of the supply chain to determine part and assembly characteristics to meet design specifications and fit, form, and function requirements

DFMA – Design for Manufacturability and Assembly, the practice of refining parts and assemblies to make them less expensive to manufacture with as few tradeoffs as possible

Fit, form, and function – the general ability of a particular part or assembly to meet the requirements of the end user for as long as expected; phrased as questions, Does it *fit* with mating parts acceptably? Does it roughly meet the expectations for *form* (shape and size)? Does it *function*, that is to say, does it do what is expected mechanically or electrically (for example, does the knob turn and release the latch so the door can be opened)?

ISO9001 – a body of standards from the International Organization for Standardization that provides minimum quality management system requirements

Lean – a system of analysis and processes that seeks to eliminate wastes

Quality – both the objective and subjective values that contribute to customer satisfaction; “the summation of the [positive and negative emotional responses] by each [internal or external] customer of each [entity of interest] that creates customer satisfaction” (Wicks & Roethlein, 92), where customer satisfaction is successfully meeting the customer's demands (84)

SCM (Supply Chain Management) – loosely defined as applying the principles of lean to the external relationships of an organization, supply chain management is a way of integrating the business processes of one organization with either a customer's or supplier's with the end goal of making the entire supply chain more efficient

Six Sigma – process improvement system that comprises a closed-loop feedback system that monitors predetermined statistics with the goal of reducing the defect rate to no more than 3.4 defects per million opportunities

Supply chain – the interconnectedness of organizations that form from buyer and seller relationships

Value-added – anything that increases the value of a service or product; for example, the time spent to cut a rough gemstone into a shape adds to the value of the gemstone, often in much greater proportion than the value of the time spent

Waste – anything that adds no value to the customer; one of seven general categories of operations, including overprocessing, overproduction, transportation, motion, waiting, inventory, and defects/rejects

## Statistical Data

This data is from a survey titled “Symbiotic Supply Chain Partner Machined Part and Assembly Design Strategies” designed and administered by the author.

### Section: You and Your Organization

<b>Please select one or more of the following to describe your role within your organization:</b>		
<b>Answer Options</b>	<b>Response Percent</b>	<b>Response Count</b>
accounting/finance	2.4%	1
engineering/design	46.3%	19
manufacturing/manufacturing planning	19.5%	8
operations	9.8%	4
procurement	53.7%	22
sales	12.2%	5
quality	9.8%	4
upper management	24.4%	10
	<b>answered question</b>	<b>41</b>
	<b>skipped question</b>	<b>0</b>

**Please indicate the percentage of business your organization does in each of the following markets, where applicable, so that the total is about 100%:**

Answer Options	< 5%	5 - 25%	26 - 50%	51 - 75%	76 - 90%	> 90%	Rating Average	Response Count
% aerospace	5	0	2	5	1	13	66.31	26
% commercial/ consumer	3	6	3	4	0	2	36.39	18
% defense	2	9	3	3	3	1	37.52	21
% industrial/ machinery	5	4	1	0	1	3	34.36	14
% medical	4	1	3	4	1	1	40.79	14
<b>answered question</b>								<b>41</b>
<b>skipped question</b>								<b>0</b>

**Approximately what was your organization's annual revenue for its fiscal year ending in 2009: (if your organization is a division of a larger organization, please consider only your division)**

Answer Options	Response Percent	Response Count
< \$1 million	15.8%	6
\$1-5 million	10.5%	4
\$6-50 million	36.8%	14
\$51-100 million	18.4%	7
\$101-1,000 million	15.8%	6
> \$1,000 million	2.6%	1
<b>answered question</b>		<b>38</b>
<b>skipped question</b>		<b>3</b>

**Approximately how many people are employed by your organization: (if your organization is a division of a larger organization, please consider only your division)**

Answer Options	Response Percent	Response Count
< 25	24.4%	10
26 - 100	24.4%	10
101 - 500	31.7%	13
501 - 1,000	12.2%	5
1,001 - 5,000	7.3%	3
> 5,000	0.0%	0
<b>answered question</b>		<b>41</b>
<b>skipped question</b>		<b>0</b>

**Does your organization use machined parts in its product line or as part of its business?**

Answer Options	Response Percent	Response Count
Yes	100.0%	41
No	0.0%	0
<b>answered question</b>		<b>41</b>
<b>skipped question</b>		<b>0</b>

**Does your organization perform the following functions internally or does it outsource them:**

Answer Options	Almost all internally	Mostly internally	About half internally and half outsourced	Mostly outsourced	Almost all outsourced	Rating Average	Response Count
designing and engineering	27	10	3	1	0	1.46	41
manufacturing prototypes	8	8	13	8	4	2.80	41
manufacturing production parts	6	5	9	9	12	3.39	41
manufacturing production subassemblies	10	13	10	5	3	2.46	41
manufacturing production assemblies	21	11	3	3	2	1.85	40
<b>answered question</b>							<b>41</b>
<b>skipped question</b>							<b>0</b>

**Of your organization's finished product value, please estimate how much as percentage are custom machined parts. (for example, an organization with a great deal of sheetmetal parts and a few custom machined components might be 20%)**

Answer Options	< 5%	6 - 10%	11 - 20%	21 - 30%	31 - 40%	41 - 50%	51 - 75%	> 75%	Rating Average	Response Count
% of custom machined parts	2	8	4	3	2	3	11	8	41.73	41
<b>answered question</b>										<b>41</b>
<b>skipped question</b>										<b>0</b>

**Approximately how much waste do you believe there may be in the design of your organization's machined parts, as a percentage of total cost? (a perfectly optimized part would be 0%, an extremely poorly optimized part would be 80%)**

Answer Options	< 5%	6 - 10%	11 - 20%	21 - 30%	31 - 40%	41 - 50%	51 - 75%	> 75%	Rating Average	Response Count
% of design waste	2	11	12	7	3	3	1	0	19.28	39
<b>answered question</b>										<b>39</b>
<b>skipped question</b>										<b>2</b>

**To the best of your ability, please select which quality management systems and business processes your organization currently has in place:**

Answer Options	Certified, Registered, or Fully Implemented	Comply With or Somewhat Implemented	N/A	Response Count
ISO9001	26	4	6	36
AS9100	17	2	14	33
ISO13485	2	1	20	23
TS16949	1	2	19	22
Lean/Kaizen	10	15	8	33
Six Sigma	2	12	11	25
TQM	6	10	10	26
<b>answered question</b>				<b>40</b>
<b>skipped question</b>				<b>1</b>

### Section: New Product Introduction and Design Authority

**When is procurement involved in the new product introduction process?**

Answer Options	Response Percent	Response Count
immediately after concept formation	22.0%	9
after 3D models have been created	12.2%	5
after preliminary sketches have been made	12.2%	5
after design is relatively frozen and prototypes are needed	36.6%	15
after design is completely frozen and prototypes are needed	2.4%	1
once production parts are needed	12.2%	5
N/A	2.4%	1
<b>answered question</b>		<b>41</b>
<b>skipped question</b>		<b>0</b>

**When are suppliers involved in the new product introduction process?**

Answer Options	Response Percent	Response Count
immediately after concept formation	12.2%	5
after 3D models have been created	26.8%	11
after preliminary sketches have been made	14.6%	6
after design is relatively frozen and prototypes are needed	31.7%	13
after design is completely frozen and prototypes are needed	2.4%	1
once production parts are needed	9.8%	4
N/A	2.4%	1
<b>answered question</b>		<b>41</b>
<b>skipped question</b>		<b>0</b>

**Please provide an estimate of the percentage of time your organization has:**

Answer Options	All of the time	Some of the time	Rarely	Never	Rating Average	Response Count
design authority	17	20	1	1	2.36	39
customer-delegated MRB (Material Review Board) authority	8	17	8	4	1.78	37
<b>answered question</b>						<b>40</b>
<b>skipped question</b>						<b>1</b>

**Of the products your organization manufactures, what proportion of them are designed by your customer versus designed by your organization?**

Answer Options	Almost all designed by customer	Mostly all designed by customer	About half designed by customer and half designed by organization	Mostly all designed by your organization	Almost all designed by your organization	Rating Average	Response Count
Design authority	1	2	8	13	16	4.03	40
<b>answered question</b>							<b>40</b>
<b>skipped question</b>							<b>1</b>

**Does your organization have a "dock-to-stock" program, where incoming shipments of machined parts bypass standard incoming receiving procedures?**

Answer Options	Response Percent	Response Count
Yes	45.0%	18
No	55.0%	22
<b>answered question</b>		<b>40</b>
<b>skipped question</b>		<b>1</b>

**In your opinion, when your organization does have design authority for a customer's project, does it affect the quality requirements passed down to suppliers?**

Answer Options	Response Percent	Response Count
Yes	80.0%	32
No	20.0%	8
<b>answered question</b>		<b>40</b>
<b>skipped question</b>		<b>1</b>

**Does having design authority increase the likelihood your organization will have customer-delegated MRB (Material Review Board) authority?**

Answer Options	Response Percent	Response Count
Yes	52.6%	20
No	47.4%	18
<b>answered question</b>		<b>38</b>
<b>skipped question</b>		<b>3</b>

**Does having design authority increase the likelihood that your organization will judge quality based on fit, form, and function in lieu of strict conformance to drawings?**

Answer Options	Response Percent	Response Count
Yes	63.4%	26
No	36.6%	15
<b>answered question</b>		<b>41</b>
<b>skipped question</b>		<b>0</b>

**Section: DFMA (Design for Manufacturability and Assembly)**

<b>Does your organization use DFMA or similar design review processes internally?</b>		
<b>Answer Options</b>	<b>Response Percent</b>	<b>Response Count</b>
Yes	70.0%	28
No	30.0%	12
<b>answered question</b>		<b>40</b>
<b>skipped question</b>		<b>1</b>

<b>Has your organization saved money through DFMA or other design optimization processes?</b>		
<b>Answer Options</b>	<b>Response Percent</b>	<b>Response Count</b>
Yes	82.1%	32
No	17.9%	7
<b>answered question</b>		<b>39</b>
<b>skipped question</b>		<b>2</b>

<b>Which of the following were responsible for the DFMA or similar design process that resulted in the savings? (select at least one)</b>		
<b>Answer Options</b>	<b>Response Percent</b>	<b>Response Count</b>
internal engineering department	81.6%	31
internal procurement department	44.7%	17
internal manufacturing department	47.4%	18
supplier	52.6%	20
customer	10.5%	4
outside consultant	10.5%	4
other	5.3%	2
<b>answered question</b>		<b>38</b>
<b>skipped question</b>		<b>3</b>

<b>Has your organization paid for DFMA services from a consultant?</b>		
<b>Answer Options</b>	<b>Response Percent</b>	<b>Response Count</b>
Yes	8.3%	3
No	91.7%	33
<b>answered question</b>		<b>36</b>
<b>skipped question</b>		<b>5</b>

<b>Is it your opinion that design modifications, such as those associated with DFMA, can or cannot reduce part and assembly costs?</b>		
<b>Answer Options</b>	<b>Response Percent</b>	<b>Response Count</b>
Can reduce	97.4%	38
Cannot reduce	2.6%	1
<b>answered question</b>		<b>39</b>
<b>skipped question</b>		<b>2</b>

<b>Have members of your organization participated in DFMA workshops or training (formal or otherwise)?</b>		
<b>Answer Options</b>	<b>Response Percent</b>	<b>Response Count</b>
Yes	43.2%	16
No	56.8%	21
<b>answered question</b>		<b>37</b>
<b>skipped question</b>		<b>4</b>

<b>How effective do you feel your organization is as a whole at reducing costs through design modifications such as DFMA?</b>						
<b>Answer Options</b>	<b>Very effective</b>	<b>Somewhat effective</b>	<b>Somewhat ineffective</b>	<b>Ineffective</b>	<b>Rating Average</b>	<b>Response Count</b>
Effectiveness	4	20	13	3	1.63	40
<b>answered question</b>						<b>40</b>
<b>skipped question</b>						<b>1</b>

**Section: Communication and Collaboration with Suppliers**

**In general, assuming executed Non-Disclosure Agreements, Non-Compete Agreements, and Confidentiality Agreements, and notwithstanding any significantly proprietary or legally protected data, does your organization trust your supplier base to:**

<b>Answer Options</b>	<b>Any supplier</b>	<b>Most suppliers</b>	<b>Some suppliers</b>	<b>No suppliers</b>	<b>Rating Average</b>	<b>Response Count</b>
share related subassembly/ assembly drawings with them?	4	22	13	1	1.73	40
share the identity of your organization's customer?	1	8	22	9	1.03	40
share the drawings of your organization's customer?	1	9	16	13	0.95	39
share the specifications of your organization's customer?	1	9	17	12	0.97	39
involve them in conversations with your organization's customer?	1	2	21	14	0.74	38
involve them in conversations with other suppliers?	0	6	24	8	0.95	38
ask them to provide objective estimates for design alternatives, when the design alternatives may mean less revenue for them?	6	10	17	6	1.41	39
provide them with cost targets for quoting purposes?	2	8	22	8	1.10	40
<b>answered question</b>						<b>40</b>
<b>skipped question</b>						<b>1</b>

**How often do you personally communicate with suppliers about:**

<b>Answer Options</b>	<b>Relatively frequently</b>	<b>Relatively infrequently</b>	<b>Never</b>	<b>Rating Average</b>	<b>Response Count</b>
RFQs	34	7	0	1.83	41
Placing orders	25	13	3	1.54	41
Order status	23	14	3	1.50	40
Design issues/DFMA	19	19	3	1.39	41
Strategic collaboration	19	19	3	1.39	41
<b>answered question</b>					<b>41</b>
<b>skipped question</b>					<b>0</b>

**Are you satisfied with the degree of integration of your suppliers within your organization's operations?**

Answer Options	Response Percent	Response Count
Yes	47.4%	18
No	52.6%	20
<b>answered question</b>		<b>38</b>
<b>skipped question</b>		<b>3</b>

**Section: Suppliers and Supplier Selection****Does your organization have an approved supplier list?**

Answer Options	Response Percent	Response Count
Yes	95.1%	39
No	4.9%	2
<b>answered question</b>		<b>41</b>
<b>skipped question</b>		<b>0</b>

**Has your organization reduced its supplier base recently?**

Answer Options	Response Percent	Response Count
Yes	41.5%	17
No	58.5%	24
<b>answered question</b>		<b>41</b>
<b>skipped question</b>		<b>0</b>

**In making decisions about which suppliers to purchase from, please choose a relative level of importance that suppliers:**

<b>Answer Options</b>	<b>Critical/ Imperative</b>	<b>Very important</b>	<b>Somewhat important</b>	<b>Low importance</b>	<b>Un- important</b>	<b>Rating Average</b>	<b>Response Count</b>
are an approved supplier	21	13	4	2	1	3.24	41
have a quality management system	20	14	6	0	1	3.27	41
have a registered quality management system, such as ISO9001	8	17	11	2	3	2.61	41
understand engineering requirements	19	17	2	3	0	3.27	41
can provide design assistance	3	12	19	4	3	2.20	41
are willing to participate in supply chain initiatives	6	17	8	5	3	2.46	39
practices C = 0 or other Zero Acceptance Number Sampling Plans	1	11	13	5	7	1.84	37
will never knowingly deliver non-conforming product without an advance waiver	27	12	1	1	0	3.59	41
meet delivery commitments	30	10	1	0	0	3.71	41
can be trusted with limited design authority	10	11	9	7	4	2.39	41
<b>answered question</b>							<b>41</b>
<b>skipped question</b>							<b>0</b>

**To what extent does your organization rely on its suppliers for a competitive advantage based on the following areas:**

Answer Options	Completely relies	Heavily relies	Somewhat relies	Barely relies	Does not at all rely	Rating Average	Response Count
delivery	11	19	9	1	1	2.93	41
price	8	20	12	1	0	2.85	41
quality	19	19	2	1	0	3.37	41
specialized knowledge	5	16	16	3	1	2.51	41
<b>answered question</b>							<b>41</b>
<b>skipped question</b>							<b>0</b>

**Section: Functional Integration**

**How involved are each of the following organizational functions in strategic supply initiatives?**

Answer Options	Research/ data collection	Influencing	Decision making	Implementation	None	Response Count
Accounting/finance	11	10	4	4	9	38
Engineering/design	3	15	13	5	0	36
Manufacturing/ manufacturing planning	4	13	9	8	3	37
Operations	2	11	9	9	5	36
Procurement	1	4	19	13	0	37
Quality	3	15	16	3	0	37
Sales	5	11	3	2	15	36
Upper management	2	12	16	1	5	36
<b>answered question</b>						<b>38</b>
<b>skipped question</b>						<b>3</b>

**In the last year, how often have the following functions within your organization collaborated on strategic supply initiatives?**

Answer Options	Much of the time	Some of the time	Rarely	Never	Rating Average	Response Count
procurement and engineering	19	12	6	1	3.29	38
procurement and manufacturing	17	17	3	1	3.32	38
procurement and quality	17	17	2	1	3.35	37
procurement and sales	4	12	14	7	2.35	37
<b>answered question</b>						<b>38</b>
<b>skipped question</b>						<b>3</b>

**Are you satisfied with the degree of collaboration regarding supply chain initiatives within your organization?**

Answer Options	Response Percent	Response Count
Yes	40.0%	14
No	60.0%	21
<b>answered question</b>		<b>35</b>
<b>skipped question</b>		<b>6</b>

**In the last year, how often have the following functions within your organization collaborated on NPI (new product introduction)?**

Answer Options	Much of the time	Some of the time	Rarely	Never	Rating Average	Response Count
procurement and engineering	25	10	3	1	3.51	39
procurement and manufacturing	20	15	3	1	3.38	39
procurement and quality	16	19	3	0	3.34	38
procurement and sales	10	12	10	6	2.68	38
<b>answered question</b>						<b>39</b>
<b>skipped question</b>						<b>2</b>

**Are you satisfied with the degree of collaboration regarding new product introduction within your organization?**

Answer Options	Response Percent	Response Count
Yes	54.3%	19
No	45.7%	16
<b>answered question</b>		<b>35</b>
<b>skipped question</b>		<b>6</b>

**How effective do you feel your organization is regarding:**

Answer Options	Very effective	Somewhat effective	Somewhat ineffective	Not at all effective	Rating Average	Response Count
internal collaboration	9	25	7	0	3.05	41
supply chain integration	5	26	9	0	2.90	40
new product introduction collaboration	7	26	7	1	2.95	41
<b>answered question</b>						<b>41</b>
<b>skipped question</b>						<b>0</b>