ASSESSING MATERIALS RISK IN PURCHASED ELECTRONIC COMPONENTS DURING PRODUCT DESIGN

by

Jennifer A. Rigoni

B.S. Industrial and Systems Engineering, University of Southern California, 1996

Submitted to the Sloan School of Management and the
Department of Mechanical Engineering
In Partial Fulfillment of the Requirements for the Degrees of

Master of Science in Management and
Master of Science in Mechanical Engineering

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Signature of Author ____________________
MIT Sloan School of Management
Department of Mechanical Engineering
May 7, 2002

Certified by ____________________
Dr. Daniel E. Whitney, Thesis Advisor
Sr. Research Scientist, MIT Center for Technology, Policy, and Industrial Development

Certified by ____________________
Dr. Sara L. Beckman, Thesis Advisor
Sr. Lecturer, Management of Technology, Univ. of California Berkeley Haas School of Business

Certified by ____________________
Dr. Donald B. Rosenfield, Thesis Advisor
Sr. Lecturer, MIT Sloan School of Management

Accepted by ____________________
Margaret C. Andrews
Director of Master's Program, MIT Sloan School of Management

Accepted by ____________________
Dr. Ain Sonin
Chair, Committee on Graduate Students, MIT Department of Mechanical Engineering

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ABSTRACT

In the electronics industry, Design for Supply Chain principles are employed in an attempt to reduce the impact of component obsolescence. When a supplier discontinues a component, the costs to the customer are high. The customer can choose to redesign the product(s) the component is used in, or can purchase all of the components the customer projects needing to manufacture and support the product(s) for the remainder of its(their) lifetime (called a lifetime buy).

The goal of this thesis is to develop a risk analysis methodology and supporting tools to help design engineers reduce the use of parts at high risk for obsolescence in new products. This approach was developed in conjunction with the Design Chain Solutions Group at Agilent Technologies' Santa Clara, California site.

An algorithmically determined risk metric was developed to communicate the level of risk incurred by a printed circuit board design. A proof-of-concept level risk analysis application was also developed to compute the risk metric and display risk information to design engineers. The effectiveness of the risk metric and risk analysis application was tested in a pilot program.

Expected impacts of a successful materials risk analysis program at the design engineer level include a reduction in cost of sales, reduction in the time to market for new products, and reduction in inventory holding costs.

Thesis Advisors:

Daniel E. Whitney, Sr. Research Scientist, MIT Center for Technology, Policy, and Industrial Development
Sara L. Beckman, Sr. Lecturer, Management of Technology, Haas School of Business, University of California, Berkeley

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I wish to thank a host of people at Agilent Technologies' DCS group and Sonoma County EPSG group who provided time, expertise, and general support for this research. In particular I want to thank Pete Woodhouse, my project supervisor, for keeping my work on track and ensuring I had everything I needed to be successful. I also want to thank Ted Lancaster, the project sponsor, for understanding the importance of the project and finding funds when they were urgently needed. I want to give a special thank you to Mike Young, who dedicated an enormous amount of time to program the pilot application at the last minute when all other contingencies had been exhausted. There are many more people who were critical to the project success, and I want to mention a few of them: the pilot designers Gary Dooley, Uriel Fojas, Ben Starkey and Aaron Patton. Roy Helgevold and Mike Powers who were always willing to help, and also ensured we had third party data for the pilot program. Lastly, I appreciated the expertise and advice of Bill Walker, who is Agilent's guru of everything Supply Chain.

I also wish to thank my thesis advisors, Dan Whitney and Sara Beckman for their guidance and insights. The depth of their knowledge and experience ensured the quality of both the project and the thesis.

Lastly, I want to thank my husband Tony for his support and love through this very trying time. Thank you, dear, for helping me reach for the stars.

I wish to dedicate this thesis to my parents, Dean and Jeannette Fish, who have made deep sacrifices throughout my life to continually support my endeavors.

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1 BACKGROUND

This thesis is centered about an internship project performed with Agilent Technologies during the summer and fall of 2001. The internship focused on the new product development process, and specifically on the assessment of the components chosen by design engineers for their products. The organizational home for the internship was a corporate organization, Design Chain Solutions (DCS), but the target users of the work were the engineers in the product divisions.

This chapter provides some background on the importance of new products to Agilent, the organizational and cultural environment in which the project was performed, and the economic situation in which Agilent found itself at the time of the work. The internship project, problem statement, project parameters, and the project goals are also introduced.

1.1 COMPANY

Agilent's businesses date back to the beginnings of the Hewlett-Packard (HP) Company, which was founded in 1939. HP's first products were the ancestors of the test and measurement equipment that now make up Agilent's largest division. In 1999, HP decided to spin off some of its core businesses into an independent company. This independent company became what is now Agilent Technologies on November 1, 1999.

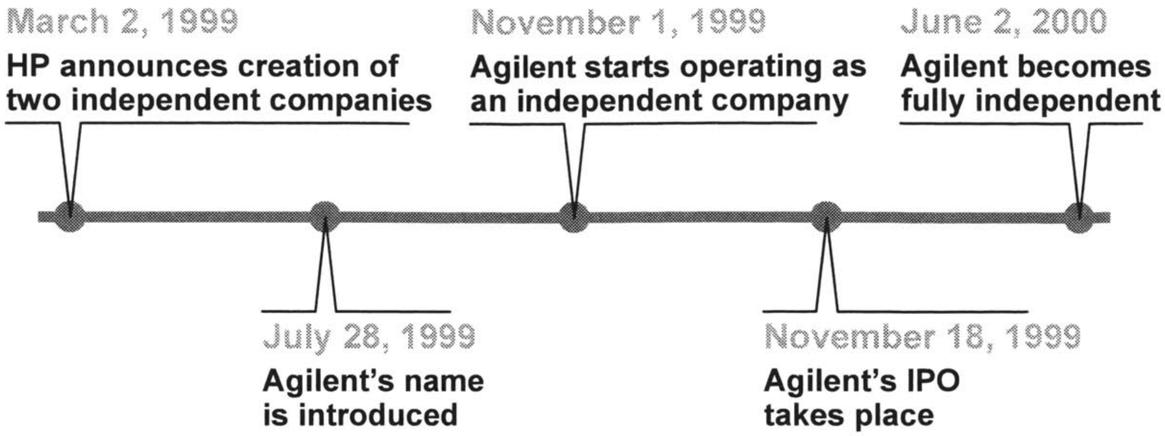

Figure 1: Agilent's Road to Independence[1]

1.1.1 Divisions and Products

Agilent is divided into three primary divisions: Test and Measurement, Semiconductor Products, and Chemical Analysis and Life Sciences. For each of these divisions, the rapid introduction of innovative new technologies and products has historically played a critical role in HP/Agilent's strategy.

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[1] Figure taken from Agilent Profile Slides, Agilent Technologies, Inc., 2001

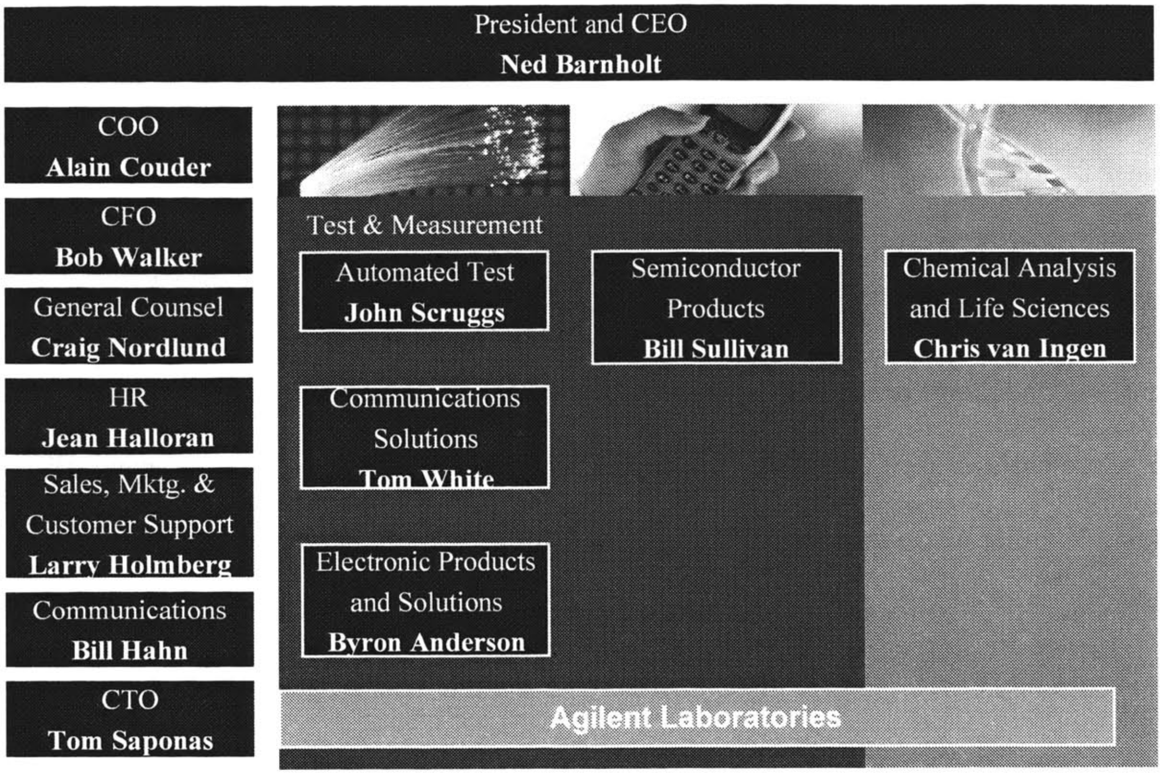

Figure 2: Agilent's Organization

1.1.1.1 Test and Measurement

The Test and Measurement division is the largest division, generating 65% of revenue. Test and Measurement has three subdivisions or groups: Automated Test, Communications Solutions, and Electronic Products and Solutions Group (EPSG). Agilent considers the core businesses of Test and Measurement to be communications test equipment, electronics test equipment, automated test equipment, and services. Opportunities for future development include optical broadband, data networking and wireless test equipment as well as broadband network monitoring and network management software. The semiconductor test group is working to develop systems-on-a-chip and high-speed memory test equipment.

The internship project, while designed to address all of Agilent's businesses, focused on EPSG. EPSG designs and manufactures electronic instruments such as Spectrum Analyzers and Component Test Devices.

1.1.1.1.1 Semiconductor Products

The Semiconductor Products division is the next largest in Agilent, accounting for 24% of revenue. Core businesses of this division include fiber optic communications, high-speed networking, RF/microwave devices, imaging devices, infrared components, ASICs (Application Specific Integrated Circuits) and optoelectronics. Some of the areas the Semiconductor Products division is currently developing are gigabit networking, cellular chipsets and wireless appliances.

1.1.1.1.2 Chemical Analysis and Life Sciences

While currently the smallest division in Agilent, contributing only 11% of revenue, the Chemical Analysis and Life Sciences division is probably the most exciting. This division is Agilent's emerging market investment, and is projected to grow astronomically in the coming years. The Chemical Analysis and Life Sciences division plays in the genetic solutions space, aiding drug discovery and diagnostics work. The core businesses are gas chromatographs, liquid chromatographs, mass spectrometers and services and supplies. Areas for opportunity include bioinstrumentation and microfluidics.

1.1.2 Structure

Agilent, as would be expected, retained much of the structure and culture of HP after the spin-off. A highly decentralized organization was the result. One of the motivations for having a decentralized organization is to increase the speed of innovation and decision-making, resulting in a fast-moving and flexible organization. A common disadvantage of decentralized organizations is lack of shared learning and best practices across divisions. Agilent is representative of decentralized organizations on both fronts.

Sharply contrasting with my previous experience at Intel, Agilent's decision-making structure seems to be somewhat of a "free market" model. While Intel urges teams to make use of the "disagree and commit" policy, a decision at Agilent will remain unmade until all decision makers agree. Another sharp contrast is Agilent's lack of cross-functional management committees that are endowed with top-down decision-making authority. The decentralized structure lends itself to an adoption-oriented model of implementation. For example, at Intel I would have developed the Early Materials Risk Analysis (EMRA) tool, and tested it in a group designated by a Steering Committee. I would then return to the Steering Committee to present my results, and with their buy-in, would begin an implementation and training program in which the users had no choice but to use the tool. The Steering Committee would expect to see frequent reports on the metrics, therefore requiring a certain frequency of tool use. Conversely, at Agilent I worked at the lower levels of the organizational chart, using influencing skills to garner support for my project. I reported my findings and progress to Design Chain Solutions (DCS) management, but they were not empowered to dictate the participation of a pilot group or the usage of the EMRA tool.

During interviews in an effort to generate project support and a list of requirements for the EMRA tool, interviewees stated repeatedly "if the tool doesn't meet X requirement, no one will use it". This supports the thesis that Agilent is a free market model. If a user, or an entire group of users, doesn't want to adopt the EMRA tool, they simply won't. The only reason they will use it is if they find it to be useful to their business. Decentralization and lack of cross-functional management committees allows each division to make its own decision about which tools to use. Convincing groups to use a tool requires demonstrating the usefulness of the tool to that particular group, and customizing it to suit their needs.

There are, of course, pros and cons of the free market model. On the downside, anyone encouraging use of a new tool will need to put a huge amount of time and effort into convincing each and every group of its benefits. A lot of support will be required to provide customization required to encourage usage. And, of course not every group will end up adopting the system, so getting any kind of standardized tool to be used Agilent-wide is next to impossible. On the positive side, each group is empowered to do what's best for that group. A decision not to use a given tool may very well be the right decision for that group. We just need to beware of local optimization when global optimization may yield a larger overall benefit. Another positive aspect is that people who have a choice about adoption will tend to be more committed to the program. If they use the tool or support its use, it is because they truly believe it to be a valuable tool.

1.1.3 Culture

Agilent's documented values are:

1. Innovation and contribution
2. Trust, respect and teamwork

3. Uncompromising integrity
4. Speed
5. Focus
6. Accountability

The first in the list, innovation, is a take-away from HP culture. The HP slogan is "Invent". The Agilent slogan is "Innovating the HP way". Clearly there is a very strong focus on and respect for the creative innovation process at Agilent. Since the internship goal was to introduce operational focus during the innovation process, this first value played a big role in the project and learning.

Another observation of Agilent culture came during the discovery process – figuring out how to get things done. It quickly became clear that at Agilent, you get things done through people. The social contact and reliance on one's personal network to be successful is probably one of the reasons people love working there and tend to stay at Agilent for their entire careers.

Since the project was on a tight timeline and I was completely unfamiliar with the landscape, I required a lot of help, especially initially. My project mentors helped get me in touch with key players. I met with these people individually, to get their thoughts on my project and to begin to build relationships. They, in turn, gave me names of other people who had particular expertise or access to resources I would need to continue the project. I was very impressed with the knowledge and friendliness of everyone I met with. I truly enjoyed my experience at Agilent, primarily because of the great people I was privileged to work with.

However, someone objectively observing the situation may be concerned with the abundance of tacit knowledge within the company, especially given the recent and forthcoming employee cutbacks.

1.1.4 Economic Climate

At the time of the internship, several measures were being undertaken to mitigate the impact of the severe economic downturn. In March of 2001 a company-wide 10% pay cut was implemented, resulting in a $280 million annual savings. While the pay cut was unpopular, employees seemed willing to sacrifice a little bit personally for the better good of the company – to avoid layoffs. This offers strong evidence of the people-centric Agilent culture. "This was a matter of saving employees," says Stacy Yu, 25, who handles marketing for fiber-optic products. "It sounds hokey, but it's like a family. Everyone knows that we have to chip in to make sure that everyone else is okay."[2]

Another measure instituted was a push within the R&D ranks to get new products out the door. According to Agilent CEO Ned Barnholt, "We really have accelerated some of our most important R&D programs, because we know our secret weapon in downturns like this are new products. Even if our customers are in tough shape, if you can come up with a product that can save them money or help them grow their revenue, they are willing to look."[3]

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[2] Daniel Roth, "How to cut pay, lay off 8,000 people, and still have workers who love you", *Fortune,* 4 Feb 2002, 62-68

[3] Tim McElligott, "This way out: Ned Barnholt, Agilent Technologies", *Telephony*, 4 June 2001, 86-88

Despite these efforts, severe discretionary cost cutting, and the sale of Agilent's Healthcare Division to Philips Electronics for $1.7 billion, sales were plunging and Agilent was running out of cash. Ned Barnholt and the other Agilent executives came to realize that cuts in the workforce were the only remaining option.

The first round of layoffs, 9% of the workforce or 4000 employees, was announced in August, 2001 and was complete by mid-September. Barnholt and the management teams executed the layoffs with the utmost respect to employees. Barnholt himself announced the cuts over the company PA system before announcing to Wall Street. He wanted the employees to hear it straight from him before they read it in the news. In the address, he explained the rationale for the cuts and how the number of layoffs was determined. "This is the toughest decision of my career," he said, sounding fatigued. "But we've run out of alternatives."

The second round of layoffs, another 4000 employees, was announced on November and was completed by the end of January 2002. Even with significant workforce reductions, Agilent employees, including the ones losing their jobs, did not seem to resent the company. They seemed to understand that the cuts were an absolute last resort, and that they were necessary casualties of a depressed economy.

1.2 INTERNSHIP PROJECT

The project sponsors, managers in Agilent's corporate Design Chain Solutions (DCS) group, worked with the LFM administration for several months to develop the Early Materials Risk

Analysis (EMRA) project. Being in corporate group provided a different vantage point of the organization than that of a particular division.

DCS was formed to provide organization-wide focus on supply chain initiatives at the product design level. The mission of DCS' parent organization is: Through enterprise process leadership and world-class hosted services, Enterprise Supply Chain Services (ESCS) delivers investment flexibility to achieve financial goals, a segmented total customer experience and compliance with regulatory requirements together with our business partners to Agilent, customers, suppliers and partners.

DCS' Mission is: Provide Agilent Business Units with the competitive advantage to develop and deliver its products and services by creating and sustaining:

- The central product generation system
- Processes and tools that decrease time-to-volume and lower cost of sales
- Linking the design environment into order fulfillment processes
- Turning critical information into design expertise[4]

Both the ESCS and DCS organizations were formed from similar groups within HP.

1.3 PROBLEM STATEMENT

The impetus for the internship project came from a costly problem identified in EPSG, specifically an obsolescence risk with board-mounted commodity components. Although the result of the work was to be applicable company-wide, the scope of the internship was thereby focused on EPSG.

Each of the EPSG instrument designs consists of several printed circuit boards, with board-mounted electronic components. Teams of electrical design engineers in this group divide the work up by board, with each engineer developing 1-2 boards per project.

There are some existing tools and methods for assessing a new design's material risk in EPSG. These methods are manual, cumbersome, have a slow feedback time, and occur late in the product development cycle. Imperfections in current materials risk analysis methods allow inclusion of sub optimal components in new designs. Once these designs reach production, the manufacturing organization has to deal with component problems such as obsolescence, lengthy lead times, or disruptions in supply. Historically the manufacturing organizations have addressed the problems by purchasing and holding in inventory all of the projected parts requirements for the lifetime of a product, qualifying a replacement component, holding a large amount of safety stock for a long lead time item, or counteracting parts quality problems in assembly.

The goal of the internship was to develop a risk analysis methodology that can be applied by design engineers early in the design cycle to assess the materials risk of their designs. The effectiveness of the approach designed was to be tested in a proof-of-concept pilot program.

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[4] Source: Agilent ESCS and DCS websites

1.3.1 Proposed Solution

Before the internship officially began, it was clear that the project sponsors had a mental model of the results of the project. They envisioned an automated Bill of Materials (BOM) grading tool that would replace or supplement the existing risk analysis methods and inform the design engineers of risky components included in their designs. This new tool would provide real-time risk analysis to designers, and could be used very early in the product design cycle.

1.4 CONCLUSION

The internship was undertaken during a difficult time for Agilent, making it difficult to get financial and human resources for parts of the project. However, cost savings and reduction of time to volume are crucial to the organization. Consequently, the project was supported at high levels of the organization, and ultimately was successful.

2 PROBLEM DESCRIPTION

This chapter describes the specific problems that the internship project was initiated to address. It describes how the materials selection and risk analysis processes presently work, including which groups are involved and when in the new product development cycle these processes occur. Additionally, the information technology tools that currently support the materials selection decisions and risk analysis processes are described. Next, the problems with the current system are investigated, with focus on sub optimal outcomes such as lengthening time to volume and obsolete inventory, and poor processes such as decisions being made late in the process and evaluation output being unusable. The work undertaken by the DCS group to remedy the problems is discussed.

2.1 PROBLEM STATEMENT

The problems that initiated the internship project were twofold. First, problems with the current materials risk analysis process were becoming increasingly apparent. Risk analysis was being performed late in the design cycle, when design changes were difficult to make. Also, the turnaround time for risk analysis was much too long, delaying the feedback time to designers.

The second problem was a more immediate and urgent component obsolescence problem, caused when a manufacturer decides to discontinue a part currently included on a manufactured instrument. Component obsolescence was, and continues to be, very costly to Agilent, and has contributed to very large raw materials inventories.

Evidence of both of these problems, as well as an assessment of the magnitude of the problems is presented in the next sections.

The sponsors of the project saw that improving the materials risk analysis methodology could both improve the process and mitigate the component obsolescence problem. The Early Materials Risk Analysis (EMRA) internship project resulted.

2.2 MAGNITUDE ASSESSMENT

Since the economic downturn, many companies including Agilent found themselves with huge amounts of inventory on their hands. Production was fully ramped up when customers initially began canceling orders. Finished goods inventory and work in process (WIP) began rapidly piling up. The information lag between the order entry process and raw materials purchasing meant that raw materials inventories were building as well.

When times were good and Agilent could sell everything they made, emphasis was on output, not on inventory control. Consequently, a few bad inventory management techniques crept in and remained unnoticed during the boom economy. However, very shortly after the downturn it was very clear that Agilent had an inventory problem, and several task forces were initiated to identify and resolve it.

A first step was to identify what kinds of goods were in inventory. The results of the study indicated that a surprisingly large portion of all inventories were lifetime buy (LTB) parts. A description and discussion of LTB components is found in the following section. The exact valuation of the LTB inventory is confidential, but it was sufficiently sizable to command attention at the very highest levels of the organization. The inventory holding costs incurred from LTBs are significant. 60-70% of the total LTB inventory was owned by EPSG. Given the magnitude of the problem, especially the size of EPSG's contribution to it, it is easy to see why the problem was receiving so much attention.

2.3 OPTIONS FOR DISCONTINUED COMPONENTS

When Agilent becomes aware that a part has been discontinued, a discontinuation notice is issued by corporate procurement. Then each division using the part must assess their options: (a) find a drop-in replacement part, if one exists, (b) do a lifetime buy, (c) do a total redesign to qualify a new part, or (d) do a bridge buy which is a combination of (b) and (c).

2.3.1 Drop-in Replacement

If another part exists that has the same form, fit and function of the discontinued part, it can be substituted directly into the manufacturing line. Administrative costs, estimated at several thousand dollars, are still incurred to process the discontinuance, notify customers of the change, etc. In addition, a new part number must be set up in the systems, inventory systems initiated, and manufacturing processes adjusted if necessary. The drop-in replacement is the least costly option, but still has significant cost and resource impacts.

2.3.2 Lifetime Buy

When a drop-in replacement part is not available, performing a LTB is the next least painful solution, and for this reason is selected often. A LTB consists of estimating the total divisional demand for the discontinued part over the entire life of the products it is used in, and then purchasing that amount of the part before the manufacturer actually shuts down the line. Demand estimation is, to say the least, an inexact science. Underestimating this demand could be disastrous, as a shortage would force a redesign very late in the product's lifecycle when the cost of the redesign would not be recovered. Overestimating the demand results only in additional inventory, and hence is the preferred side to err on. As previously discussed, the inventory holding costs incurred from LTBs are significant, and have recently received a lot of attention from Agilent management.

2.3.3 Total Redesign

Sometimes a LTB is not a viable option, either due to the prohibitive expected costs, or the inability for a supplier to deliver the amount of inventory required for a LTB. In these cases, a major redesign is required. Potential replacement parts must be thoroughly investigated, tested, and qualified. The time and materials costs that go into a major redesign can easily cost 10-20 times more than a drop-in replacement.

2.3.4 Bridge Buy

A bridge buy occurs when the decision is to perform a redesign, but the expected duration of the redesign effort exceeds the current inventory stock for the discontinued part. So, a mini-LTB is ordered to supply the manufacturing line while the redesign efforts are underway.

2.3.5 Summary

Clearly none of these options are without cost, and some of them have a high impact on Agilent's cost structure. Finding a way to minimize component discontinuances would be very valuable.

2.4 OBSOLESCENCE MANAGEMENT OUTSIDE AGILENT

Component obsolescence is not isolated to Agilent – it is a significant global problem for corporations and government organizations. The problem is of such magnitude for the US military and its contractors that a joint organization, the Government-Industry Data Exchange Program (GIDEP), was formed to address it.

Additionally, a couple of companies have undertaken predictive obsolescence initiatives. The goal of these initiatives is to assess the likelihood of component discontinuance over a given timeframe, or to predict the time at which a component will be discontinued.

2.4.1 GIDEP[5]

GIDEP is fully managed and funded by the U.S. Government. It provides an automated mechanism for the military and industry to share critical design and manufacturing information. Subscribers find information in six primary categories: (1) engineering data on parts, components, materials and processes, (2) failure experience data as a result of ALERTs, Problem Advisories, etc., (3) metrology data such as calibration procedures and technical manuals, (4) product information data including product discontinuance notices, product change notices (PCNs), and Diminishing Manufacturing Sources and Material Shortages (DMSMS), (5) reliability and maintainability data on failure rates and replacement data, and (6) urgent data request, which allows subscribers to query the GIDEP community for urgent problem resolution assistance.

GIDEP subscribers, and DMSMS subscribers in particular, are all facing similar problems with component obsolescence. They meet annually to discuss the year's progress, share best-known methods, and set goals for the future. Presentations from the conferences generally have three common themes. One is the need for avoiding designing in components that are known to be "bad" (the goal of the EMRA project). Another is the need to reduce the impact of component obsolescence, realizing that it is an inevitability given the comparative lifecycles of products vs. components. And the last is the need for a way to predict during design when a component is likely to be discontinued, a.k.a. predictive obsolescence.

In December of 2000, the Department of Defense adopted the DMSMS management practices, which prescribe the following eight-step proactive approach to managing component obsolescence[6]:

1. Before introducing a new product, verify the obsolescence status of all designed-in components as early as possible in the design process.

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[5] Information via the official GIDEP website at http://www.gidep.corona.navy.mil/data_inf/faq.htm

[6] Mark Husey, "Avoiding Component Obsolescence", September 2001, *Printed Circuit Design*, 28-30

2. Avoid designing-in sole source components and be sure to look beyond a single vendor's line card when evaluating options.
3. Select packaging adopted by multiple manufacturers, drop-in equivalents are the easiest alternative to redesigns when faced with an obsolete component.
4. When testing a board, include potential drop-in replacement components from different manufacturers and sources in the testing process to pre-qualify potential alternates.
5. New technology is always subject to revisions; consider this risk and weigh it carefully against the relative value of the new capabilities offered by such technology.
6. Assess the risk of a given component going obsolete in the future by studying how many manufacturers are picking up and dropping that technology or packaging.
7. Establish a method for tracking products and their components and regularly verify the obsolescence status of all components for all projects throughout the product lifecycle.
8. When using 5-volt devices, consider using a voltage regulator (or providing alternate power sources near high risk components) that can adapt to the different current requirements of manufacturers' components.

One of the methodologies employed to address the component obsolescence problem by large government agencies and contractors, as well as large companies, is a partnership of sorts with suppliers. A well-designed partnership can ensure that a supplier knows the criticality of, and expected demand lifetime for, a component in their portfolio. It can ensure that suppliers notify key customers when they are considering discontinuing a product. It can also ensure suppliers collaborate with customers to replace discontinued components with components that are easy drop-in replacements. HP has recently experimented with a “portfolio” technique of contracting with suppliers. "Under the portfolio model, HP enters into a structured contract with suppliers. Anticipating future component pricing trends and evaluating what its longer-term requirements will be, HP agrees to buy a set amount over a period of time. The OEM assumes the risk for that volume, regardless of changes in market conditions or fluctuations in supply or demand. In return, suppliers will likely provide better pricing, know up front what HP's commitment will be over an extended period, and be able to plan resources accordingly.[7]" Agilent, due to its relatively low volumes and high mix of products, does not have sufficient power with its suppliers to form this kind of partnership. Figure 3 demonstrates alternative supplier strategies based on degree of risk and amount spent for each supplier. Agilent's supplier strategy is shown in the lower right hand quadrant of the matrix; clearly this is not an optimal place to be.

$ Spent with Supplier	**HI**	Corporate Contract	Partnership
	LO	Commodity Mat'ls	BAD - supplier has all power (Agilent here too much due to low volumes)
		LO	**HI**
		Risk Associated with Supplier	

Figure 3: Agilent's Supplier Strategy

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[7] Jennifer Baljko Shah, "HP Focuses On Procurement Risk-Sharing ", 29 October 2001, *EBN*, 52

2.4.2 Predictive Obsolescence

There are at least two firms that are attempting to predict when a component will be discontinued. Both are targeted at the early design phase, in an attempt to inform of the expected remaining lifetime of a component under consideration for new design.

i2, as part of their extensive software suite, offers customers a subscription to their component database. One of the fields maintained for certain categories of components is Years to End of Life (YTEOL). YTEOL can be < 1 year, 1-4 years, 4-8 years, or > 8 years. i2 considers the YTEOL algorithm to be a very valuable piece of intellectual property, and hence did not disclose the detailed formula. They did list the primary attributes that are included in the calculations:

- Information directly from suppliers – when the supplier anticipates discontinuing the part
- Sales volumes
- Manufacturer-specific history – conditions under which they tend to discontinue parts
- Adoption rate
- Agencies' technical roadmaps
- i2's own technical roadmap
- PCN (part change notice) alerts
- Agencies' market trend analysis
- Component lifecycle analysis expertise gained from the acquisition of Tactech

The company obtains and maintains much of this information from suppliers via telephone and e-mail, coordinated through a large call center in India. i2 was unable to provide validation to indicate the historical accuracy of the YTEOL metric.

Many companies are concerned about the legal ramifications of offering such a metric, because if potential customers do not purchase a component because of its short YTEOL, that directly affects the manufacturer's bottom line. If the manufacturer believes the prediction to be unfair, they may take legal action.

The second company that has taken an approach to predictive obsolescence is R. Morley Inc. (RMI). RMI is a consulting firm specializing in leading edge manufacturing technologies. InvisiTech, an RMI affiliate has proposed using the theory of Loosely Coupled Sets (LCS) to attempt to predict component obsolescence.

LCS, roughly defined, describes the relationship between the number of measurements and the accuracy of those measurements. Calculated accuracy of the result increases linearly as one increases the accuracy of any one of the measurements. However, calculated accuracy of the result increases exponentially as one increases the number of measures. The key is that as the number of measurements increases, the necessary accuracy of those measurements can decrease significantly and still maintain the desired calculation accuracy. Putting it into predictive obsolescence terminology, instead of requiring a very accurate component lifecycle metric, one could theoretically use several less-accurate measures such as volume, number of customers, and sales margin and obtain the same, or better, level of predictive accuracy.

RMI proposed a development effort for LCS as applied to predictive obsolescence to a software company and several industry partners. The partners would provide the necessary funding for the project in exchange for a limited-term exclusive license for the fruits of the project. However, as the economy and the proposed partners' profits continued to deteriorate, the project was, and remains, tabled.

RMI is only one of the organizations working on predictive obsolescence initiatives, but the LCS approach is unique to RMI. Thus far, i2 is the only company to market a predictive obsolescence metric.

2.5 PRODUCT DESIGN PROCESS

This section first describes who is involved in making materials selection decisions, and the computer support systems they make use of. Next, the new product development process is introduced, with emphasis on when in the process materials decisions are made.

2.5.1 Sonoma County EPSG

The project scope was confined to a focus on the Electronic Products and Solutions Group (EPSG) division in Sonoma County, California. Therefore, most of the descriptions of current process below refer to this specific group. The functions in the Sonoma County EPSG group that played a role in the EMRA project are: (1) R&D Engineers across three Product Generation Units (PGUs) – Signal Sources, Spectrum Analyzers, and Component Test, (2) divisional

Materials Engineers who support the PGUs and are generally assigned by commodity, (3) divisional procurement group, (4) NPI planners, who manage materials, new part setups, and potential manufacturing issues on the design teams, and (5) an Order Fulfillment (OF) site that manufactures many of the instruments designed at the PGUs.

R&D electrical design engineers primarily design in one of two Computer Aided Design (CAD) programs – Mentor or Electrical Engineering Design Program (EEDP). Mentor is a widely used sophisticated commercial CAD program. EEDP was designed in-house many years ago, and has survived several attempts to phase it out. It appears that EEDP is still used because it supports some mechanical geometries and properties that Mentor does not, and some designers simply have not learned Mentor and are more comfortable and faster at using EEDP.

2.5.2 Design Phases

EPSG has a well-defined Product Lifecycle Process to "provide a common 'roadmap' of expectations across organizations" and "provide a standardized model for product development efforts around which improvements may be identified". After each phase, a checkpoint review is held with PGU management to ensure that all phase deliverables have been met before moving into the next phase. The length of each phase varies significantly by product, but the entire product development cycle is generally on the order of one to two years. The table in Figure 4 summarizes the new product development process and the role of materials risk analysis in each. Note that the proposed EMRA process will have materials risk assessment done much earlier in the product development process than it is currently done, and once started will happen on an ongoing basis throughout development.

	Concept	Investigation	Definition	Development	Qualification	Manufacturing
Purpose	Does idea warrant further investigation?	Technical and market feasibility assessment	Specifications and parameters set	Complete design work	Verify goals met and production ready	Begin production life
Design Work Done	Minimal	Technology-enabling components included	Spec-meeting components selected	Completed	Changes made if problem found	
Current Risk Analysis	None	Rarely done	Rarely done	Full review(s)	Rarely done	None
EMRA Proposal	None	Risky parts highlighted	Full review(s)	Full review(s)	Continuing review	Review as desired

Figure 4: New Product Development Process

2.5.2.1 Concept

The purpose of the Concept phase is to determine whether or not the potential product is worthy of further investigation. Usually there is little to no design work done in this phase, since the goal is simply to determine if the idea has merit.

2.5.2.2 Investigation

The purpose of the Investigation phase is to determine feasibility of the product idea, both from a market and a technical standpoint. Technical feasibility can only be effectively assessed if some degree of design work has been done. Design engineers verified in interviews that a good portion of the initial design work is completed as part of the investigation phase, although it is generally only a couple of months long. This is a very "fun" time for designers, since they are fully utilizing their extensive creative and problem solving skills. The focus of the Investigation phase is technology – designing a new capability or making a substantial performance enhancement. An effective materials risk analysis methodology will give designers a tool to avoid using risky materials during this critical phase that will not detract their focus from the technology.

2.5.2.3 Definition

The purpose of the Definition phase is to assess the development and testing requirements for each of the boards in the instrument. The product specifications and technological parameters are defined during this phase.

2.5.2.4 Development

The purpose of the Development phase is to design the product according to the specifications set in the Definition phase. This is the phase in which the design work is the most intensive, when prototypes are created and tested, when designs are refined. Currently, most materials risk analysis and changes to components are made during the Development phase.

2.5.2.5 Qualification

The purpose of the Qualification phase is to verify that the specifications and goals set in the Definition phase have been met, and to confirm that manufacturing and the supply chain are ready to support production.

2.5.2.6 Manufacturing

There are several sub-phases of the manufacturing process, but in essence the product begins its production life. Once the product passes the Qualification checkpoint, production engineers become responsible for the product design. If a component is discontinued, production engineers are responsible for any redesigns required.

2.6 PARTS SELECTION PROCESS

The last section described when, in the larger product development process, materials selection takes place. This section describes how it occurs, both historically and presently. The current parts selection process for new designs makes use of Agilent preference codes (described below) and standardized part search mechanisms. Throughout the years, EPSG materials engineering has provided design engineers with many tools to allow effective parts selection.

2.6.1 Lab Stock Evolution

Twenty years ago, a large depository of components called Lab Stock was maintained at each development site. When a designer needed a component, he or she went to Lab Stock, got a component and plugged it into his or her board. If he wanted to utilize a component that was not kept in Lab Stock, he had to fill out several forms and wait for the part to be ordered. Given the pain of this process compared to the ease of grabbing something out of Lab Stock, all incentives were aligned to ensure designers used the Lab Stock as much as possible. Therefore, to ensure the maximal use of preferred parts in new designs, materials engineering and procurement simply needed to limit the Lab Stock to preferred parts.

As technology developed, designers made increasing use of computers to complete their designs, rather than physically building breadboard models. By the time the first prototype was developed, many of the components had already been selected electronically. Control over use of preferred parts began to diminish. To combat this trend, materials engineering and procurement developed some tools to assist the designers in making the right choices while designing electronically.

2.6.2 Part Preference Determination

Agilent preference code is the existing system through which components are rated, and that rating is communicated company-wide. The preference code is determined by the Materials Engineering organization at the enterprise level and the division level. Preference codes are 1, 2, 3, or 4, in descending order of preference. Code 1 parts are considered to be "recommended for new design", while Code 4s are not to be used. Some Code 3s and 4s also have a secondary alphanumeric coding to indicate why the part is coded this way. For example, a Code 4X is a part that has been discontinued by the supplier. In addition, sometimes a # or a ? are used to indicate a changing or unknown preference code. These are intended to throw a "red flag" for the designers. A sampling of preference codes that may be encountered and their associated meanings are shown in Figure 5.

Code	Interpretation
1	Recommended for new design
2	Recommended for new design, but less ideal than Code 1
3	Not recommended for new design, but OK if no other option
3A	Sole source
4	Not recommended for new design
4X	Part has been discontinued by the supplier
#	Preference code is changing
?	Preference code is unknown (may be new part)

Figure 5: Sample Preference Codes

2.6.3 Parts Selection Mechanisms

Each year, an internally generated Parts Selection Guide (PSG), with a listing of the parts that are "recommended for new design" is published in hard copy and soft copy. Given the ease of grabbing a PSG off the shelf and finding a part, this remains a popular method of parts selection. This practice is somewhat concerning, because part preference can change quickly – more quickly than the PSG is updated.

The latest and greatest parts selection tool in EPSG is the internally developed CAD Data Store (CDS). CDS permits part searches on parameters, partial part number, etc. When search results are displayed, they are displayed in order of Agilent preference code. Therefore, a designer selecting the first part in the list is necessarily selecting the "best" part. CDS also has the capability to drag and drop the component geometry directly into Mentor. CDS is clearly superior to the hardcopy PSG, but not all designers have yet converted to using it.

2.6.4 Leveraging

"Leveraging" or "reuse" is another common, and highly encouraged, practice among the design community. This refers to the practice of utilizing a board, or portion of a board, from a previous design in a new design. Leveraging speeds up the product development cycle because designers can begin their project with a portion of the design already complete. It also improves manufacturing flexibility since more products make use of some of the same components.

A common misconception among the design community regarding leveraging is that leveraged boards, since they went through the Materials List Analysis Review process (described below) and were approved at some point, do not have materials issues. In fact, it is quite the opposite. It is highly likely that some of the components were discontinued in the intervening time between when the leveraged board was designed and the new board was designed.

2.7 MATERIAL LIST ANALYSIS REVIEW

The Material List Analysis Review (MLAR) is the existing system for assessing the materials risk of new designs before they are sent to Order Fulfillment. The process begins when a designer uploads his material list file to an automated system, usually at the encouragement of his NPI planner. As discussed in the previous section, this occurs most frequently during the Development Phase, and occasionally during the Investigation or Definition Phases.

The system runs a query of the Materials Specification Master (MSM) database, and outputs a very long, complex, difficult-to-interpret pipe-delimited ASCII text file. The file lists all of the parts in the design (usually hundreds of parts), in order of preference code. Information included in the file is Agilent part number, preference code, reference designator (location on the board), part description, part performance parameters, and category code. Since all of the information is in text, with little formatting, it is not easy to read. In addition, the Code 3 and 4 parts are listed at the bottom of the file, so one must scroll all the way to the bottom to get to the risky parts. In general, the MLAR output is not user-friendly.

The next step in the MLAR process is for divisional Materials Engineers to follow up on the Code 3 and Code 4 parts, and find recommended replacements for them. Once they have determined which part to recommend as a replacement, they will fill this information into the "notes" section in the MSM database. When all Materials Engineers are finished making their recommendations, the MLAR report is returned to the designer. This process typically takes about two weeks. The final report the designer sees is the same complex, difficult-to-read output that was originally generated, but with the recommended replacement notes added to the Code 3 and Code 4 parts.

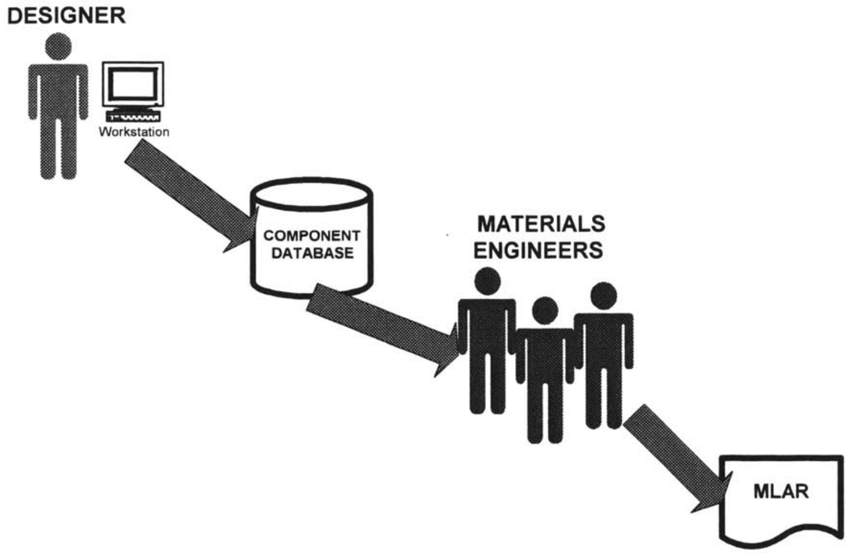

Figure 6: Material List Analysis Review Process

According to designer interviews and a pre-pilot survey, the MLAR is run 1-2 times per board, most frequently during the development phase.

Figure 7 demonstrates a general framework for understanding the increased relative costs of making changes later in the design cycle. In this particular case, discovering a component problem later in the design cycle causes more pain to make the change than if it were discovered right up front. This diagram makes the case for the sub optimality of the existing materials risk analysis process, because it is undertaken so late in the development process.

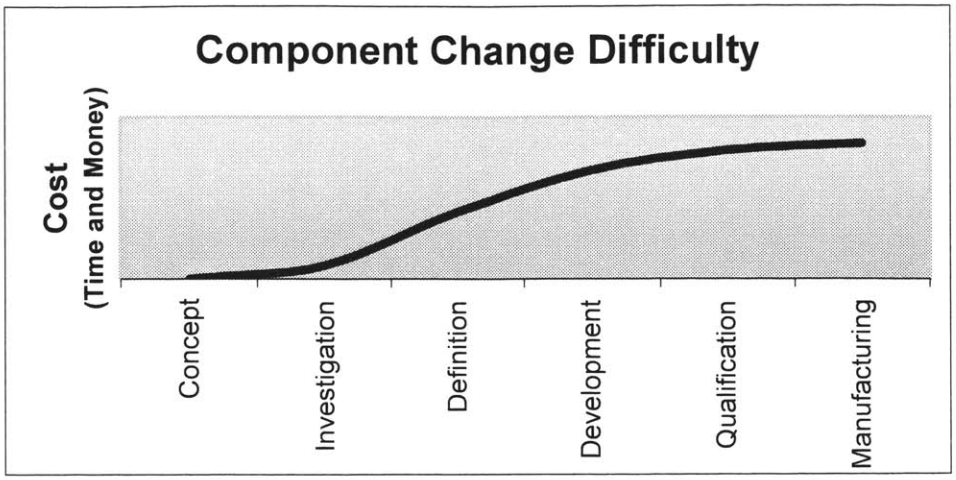

Figure 7: Relative costs of making component changes late in the product development cycle

In summary, the current MLAR process is sub optimal on several levels, most notably the lack of usability and the delay time between submission of the materials list and completion of the report. The impact of being difficult to read and interpret is that designers dislike having to sift through the file to get to the relevant information. This may lead to avoidance of the process altogether, resulting in the current situation where designers often wait to run the process until they are urged to do so by their NPI planner.

The impact of the two-week cycle time is more significant. The designers are often on a very tight time schedule, and in the space of two weeks they can be on to a new project phase, with new goals. They will have further developed the design, adding other components that are sometimes dependent on, or complementary to, a part that is discovered to be risky. Going back to replace a risky part at best is frustrating, since the designer must essentially return to the parts selection process that he thought he had completed. Worse, an entire chain of components must be changed out to eliminate the risky part, costing the designer precious time and potentially impacting the time to volume. In the most costly scenario, a new prototype must be built and tested to verify that the new, non-risky part(s) will perform as desired. In this case, significant direct cost is incurred to build and test the new prototype, and the schedule will likely be impacted as well. It is not surprising, then, to find that sometimes designers choose not to change out a risky part when it is discovered too late in the process. By making this choice, the designer trades off the cost of a redesign or lifetime buy in favor of schedule.

2.7.1 Design Engineer Survey Results

Both of these problems were very clearly happening at Agilent, as was verified after conducting a survey prior to designing and testing the new materials risk analysis tool. Two of the questions gauged the frequency with which the designers discover risky parts from the MLAR process. Responses indicated that they almost always find that they have inadvertently selected a risky part. Not surprisingly, they even more frequently find that a leveraged part of their design makes use of risky parts.

Probably the most poignant discovery from the pre-pilot survey was the fact that the designers do not always change out risky parts with the recommended replacement parts. Subsequent interviews indicated that often the reason is that the discovery is made too late in the process and the pain/cost level for making the change is assessed to be too high (refer again to Figure 7). This is a clear indication that the current process leaves significant room for improvement and that there is real cost savings to be obtained by providing the risk analysis earlier in the design cycle and improving the turnaround time.

2.8 DECISION SUPPORT SYSTEMS

This section describes the information systems that support the materials decisions. Although not officially part of the original problem statement, Agilent is undertaking a major revolution of their data/decision support systems. A transition to an Enterprise Resource Planning (ERP) platform complete with a Product Data Management (PDM) module is underway, with phased company-wide implementation beginning in the summer of 2002. Figure 8 demonstrates the decision structure of the current system. The integrity of decision support systems such as the internal component database are critical to the players' abilities to make decisions that positively affect Agilent's business.

Agilent's internal component database is called the MSM, for Materials Specification Master. The MSM is an Informix database that has one original instance and several local instances at most Agilent sites. It houses several fields of data for each of Agilent's parts, active and inactive, including part number, cost, leadtime, and preference code. The MSM is rarely accessed directly by engineers – instead, interfaces such as the CAD software, CAD Data Store or the MLAR process query the database and return relevant MSM data. Although the MSM has served Agilent well for many years, it has significant limitations, especially in the data structure. A proposal to replace the MSM is expected in the next year or so.

The "Decision Support Systems" referenced in the Figure include the MSM database, the ERP system and the PDM system.

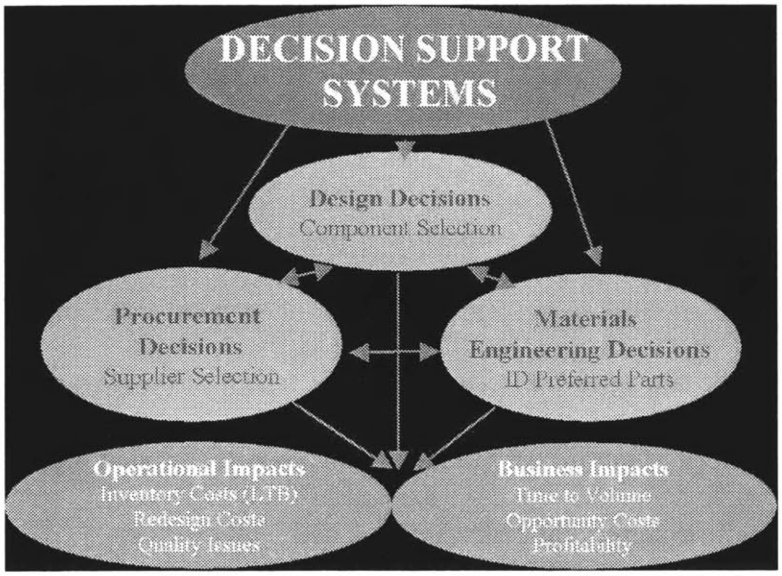

Figure 8: Agilent's Decision Support System Structure

2.9 COMPLEMENTARY PROJECTS

The Design Chain Solutions group has several other Design for Supply Chain (DfSC) projects currently underway. Materials Lifecycle Risk Analysis and Next Generation Preference Codes are two that are closely connected to the Early Materials Risk Analysis project.

2.9.1 Materials Lifecycle Risk Analysis

This project is an effort to assess the need for, test, and implement component risk assessment information purchased from a third party. Typical third party risk attributes include Lifecycle (where a part is in its lifespan), Availability (is the part kept in stock or not), Sourcing (sole-sourced vs. multi-sourced), and Breadth of Usage (how many customers are purchasing the part). Although the Agilent preference code is intended to be the sole assessment of materials risk, there may still be a need for third party data.

First, a third party may have information on a component that is not available in the MSM. This could help decide on selection of a new part. Next, the MSM has hundreds of thousands of components. It is unreasonable to expect that Materials Engineers can keep all of the preference codes up to date at all times. A key benefit of a third party database is expedited processing of Product Change Notices (PCNs) and adjustment of the risk ratings. Lastly, the third party systems provide more information to the viewer. While Agilent preference code indicates essentially “recommended for new design” or “not recommended for new design”, third party data indicates *why* that part is preferred or not preferred. Agilent currently has trial subscriptions to a third party database, and is assessing the viability of the information.

2.9.2 Next Generation Preference Codes

Closely related to both the Materials Lifecycle Risk Analysis and the Early Materials Risk Analysis is the Next Generation Preference Code project. The goal is to assess the possibility of creating an algorithm to dynamically determine the preference codes. This scenario would likely make use of a third party data source as input to the algorithm. The preference codes may be dynamically updated to the MSM, or may require approval of Materials Engineering or others before being updated.

2.10 PROBLEM DEFINITION

The magnitude and complexity of the project could easily occupy a lone intern for several years. In order to keep the scope under control, the project mentors limited the scope and dictated specific project tasks. These tasks were to (1) assess the requirements for a Bill of Materials grading tool, (2) execute a proof-of-concept level pilot program to test the viability of such a tool, and (3) make recommendations regarding the implementation of the tool. The scope was limited to board-mounted commodity components, and the focus group defined as the EPSG Sonoma County division.

It would be important to design the tool so that it could, and would, be used earlier in the design cycle than the MLAR process is employed.

2.10.1 Expected Impacts

Impacts of having materials risk information early in the design cycle include a reduction in cost of sales due to a reduction in lifetime buys and redesigns. Another expected impact is a reduction in the time to market for new products due to a reduction of design cycle iterations. Yet another is reduction in inventory holding costs due to selection of lower leadtime components. Lastly, and least measurable, is an improvement in design engineer effectiveness. Effectiveness will be improved when the designers spend less time on parts selection and redesign activities, and more time on the value-added creative design process. This improved effectiveness may result in increased competitiveness (technological capability and/or manufactured cost) of the products.

2.10.2 Risk Scoring Methodology and Risk Metric

A key goal of the internship was to determine how to score or grade a Bill of Materials (BOM) or materials list. The vision was to design a single metric that would communicate the risk level of a new design. A successful risk metric would communicate the overall materials risk to a designer, indicating how much materials improvement was required for his design. It would also communicate to management the level of materials risk being incurred by new designs.

2.11 SUMMARY

The challenge for the internship was thus set. The goal was to find a way to both streamline the process of component selection and evaluation during product development, and make the process more effective in identifying and eliminating high-risk parts. The next chapter reviews the approach taken during the internship to resolve the problems and improve the process.

The problem resolution approach was to first determine a risk metric(s) to measure the materials risk incurred by a particular design. Next, an automated application was developed, which took as input a material list and then output the risk score for the design. Finally, a small group of design engineers tested the application and the risk metrics in a pilot program.

3 RISK METRIC AND ALGORITHM DETERMINATION

3.1 RISK METRIC IMPORTANCE

To directly address the component obsolescence and lifetime buy inventory problems, the designers would need to be informed of risky components included in their designs and then replace them with less risky components. Developing an overall risk metric or risk score to assess the status of the board would not directly resolve the problems or improve the current process. However, a risk metric would serve several peripheral purposes, namely to measure materials risk and to provide an incentive for designers to use the EMRA tool.

First, the risk metric would provide a way to measure reduction in materials risk over time. At the project level, the risk score should improve over the product development cycle so that by the time the product is qualified for manufacturing the materials risk is as low as feasible. Additionally, risk scores should improve as designers become more accustomed to using the EMRA tool and designs that made use of the tool are leveraged (so that problems with leveraged designs occur only due to changes in component risk status instead of an accumulation of prior mistakes). In the absence of a risk metric, it would be difficult to demonstrate improvement in materials risk due to the EMRA tool.

An effective risk metric will also provide critical incentive for designers to use the risk analysis system. A risk metric can easily be reported and tracked through the management chain. Without a risk metric it would be difficult for project managers and designers to be evaluated based on their materials risk reduction efforts. The only way a metric can be reported and tracked is if the system generating the metric (in this case, the EMRA tool) is used. Of course, the extent to which the risk score is linked to designer and project manager performance evaluations will determine the strength of the incentive to use the EMRA. This dynamic is investigated in more detail in the last chapter[8].

3.2 CURRENT APPROACHES TO RISK ASSESSMENT

Working with a set of companies that offered supply chain management software made it clear that there were two viable approaches to risk scoring. One was a deterministic approach – taking a set of risk parameters, weighting each appropriately, and summing the result to determine an aggregate risk score. Another was a probabilistic approach along the same vein as R. Morley Inc.'s attempt at predictive obsolescence. A probabilistic scoring method would assess the probability of a component being discontinued, and multiply by the expected cost of the discontinuance to assess the expected cost of the design decision.

As discussed in the last section, i2 has also attempted to predict when a component will be discontinued, in their Years To End Of Life (YTEOL) metric. YTEOL is offered as part of their component database, to which customers subscribe. R. Morley Inc. has also investigated a predictive obsolescence approach, suggesting the use of Loosely Coupled Sets to determine risk of obsolescence. Both of these approaches differ from the methodology used by most supply chain software companies.

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[8] It should be noted that there might be other metrics that would be equally valuable. For example, measuring component obsolescence rate, or the cost of the LTB inventory are other ways to get people focused on this problem. A broader metric might involve more people (e.g., materials engineers and procurement personnel) than just the design engineers.

The other software companies investigated as part of the internship offer customized risk scoring by a deterministic method. This means that the customer selects which risk categories represent the highest degree of risk, and the amount of weighting that each category should get. A customer-determined algorithm then assesses a material risk metric or score, and uses the metric to grade a Bill of Materials or filter components for selection in a new design.

Selecting which type of risk scoring should be employed for the pilot program was a difficult choice since each has benefits and drawbacks. Most notably, the deterministic score is simpler and more easily maintained than the probabilistic score, but does not incorporate an aspect of cost to the organization. The pros and cons of each score are summarized in Figure 14. Eventually it was decided that there was sufficient time allotted for the pilot to allow evaluation of both methods. The pilot participants could then assess which score was preferable, and the preferred method would then be used for the full implementation of the EMRA tool. Details regarding the development of the two metrics as well as the pros and cons of each are described in the following sections.

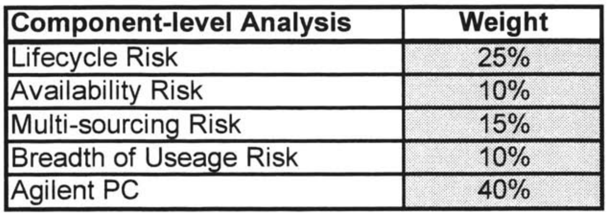
3.3 DETERMINISTIC RISK SCORE

Deterministic risk scoring involves taking a set of risk parameters, and then weighting each of the parameters to determine a final score. For the purposes of the EMRA project, relevant and available input parameters were the Agilent preference code (scale of 1-4), and four industry-level risk assessment attributes from a third-party source (Lifecycle, Availability, Multi-Sourcing Profile, and Breadth of Usage), each on a scale of 1-3 (low risk, medium risk, high risk). The third-party provider that Agilent was working with on a test subscription basis supplies these metrics. This provider is a very large distributor of board-mounted electronic components, and hence has visibility into statistics such as average lifetime, number of customers for a given component, and whether or not the part is kept in stock. The metrics and their sources are described in the table in Figure 9.

Metric	**Description**	**Basis**
Lifecycle	Risk of discontinuance	Average lifetime of similar components, compared to current component age
Availability	Whether component is kept in stock	For this distributor, is the component kept on hand or ordered as needed
Multi-Sourcing Profile	Number of alternate sources for the component	Multiple sources for identical components reduces the risk of total obsolescence
Breadth of Usage	Number of customers for the component	If Agilent is the only customer, the manufacturer may be more likely to discontinue

Figure 9: Third-Party Component Metrics

Discussions were held with several managers in DCS and Sonoma County, as well as the thesis advisors for this paper in an attempt to assess the appropriate weighting scheme. Opinions varied widely as to how much weight should be given to the Agilent preference code compared to the third-party metrics. A Materials Engineering manager felt particularly strongly that the third-party metrics should not be included at all, since the Agilent preference code should already incorporate the third party data, and it is the Materials Engineer's job to do so and to keep it current. Design engineers and their managers, on the other hand, were excited about the prospect of having information in addition to the preference code with which to make risk assessment decisions. After much discussion, the general consensus appeared to be that although the Agilent preference code is intended to include the third party risk assessment, it is not practical to presume that it does. Realistically, Materials Engineers cannot keep up with the thousands and thousands of parts and their related preferences, especially given the rapid pace of change in the status of the parts. Further, their time might be better used in helping engineers identify and use alternate, less risky parts. The exact weightings to be used were never agreed upon by all of the managers. Eventually I made an executive decision, and used the weighting scheme shown below for the pilot. Agilent preference code and Lifecycle were weighted most heavily, given that they were likely the strongest indicators of component obsolescence, the largest of the problems the EMRA project was formed to address.



Component-level Analysis	Weight
Lifecycle Risk	25%
Availability Risk	10%
Multi-sourcing Risk	15%
Breadth of Useage Risk	10%
Agilent PC	40%

Figure 10: Weighting scheme for deterministic risk score

The weighting scheme should be adjusted as business conditions change and as more data is gathered on apparent causes of discontinuance. When the EMRA project is fully implemented, the third-party metrics as well as the deterministic risk rating should be recorded in a database by component over time. As these components are discontinued, multiple regression analysis could determine which of the metrics tends to be the stronger predictor of the timing of obsolescence. An example of business conditions changing is the completion and implementation of the Next Generation Preference Code project. This project will make use of third-party data, and may eliminate the need for the weighting scheme altogether. Perhaps an aggregate Preference Code for the board is all that will be required. Annual evaluations of the weighting scheme should be sufficient given the rate of business condition change and the resources likely to be available to analyze the data.

The risk assessment scheme described above was performed at the component level, meaning each component in the material list was assigned a score based on that component's attributes and the weighting of each attribute. After the component risk score was computed, the score was multiplied by the component cost and dubbed the "dollar-weighted component risk score". This practice ensured that the more expensive components (which invariably have higher LTB and redesign costs) were considered more risky. The dollar-weighted component risk was then summed up across all components in the materials list. This was dubbed the "aggregate dollar-weighted risk score".

The question then became how to normalize the score so that it could be compared across boards, products and projects. Dan Whitney, a thesis advisor, suggested that a reasonable approach was to employ a standard Boothroyd Design for Assembly[9] technique of using a percentage score equal to the actual score divided by the ideal score. In this case, the ideal score would be obtained if the Agilent preference code was 1, and each of the third party categories were rated low risk. That equates to a component risk score of 1, and an aggregate dollar-weighted risk score of the raw materials cost. Therefore, the deterministic risk score utilized in the pilot was a percentage score of the raw materials cost of the board divided by the aggregate dollar-weighted risk score.

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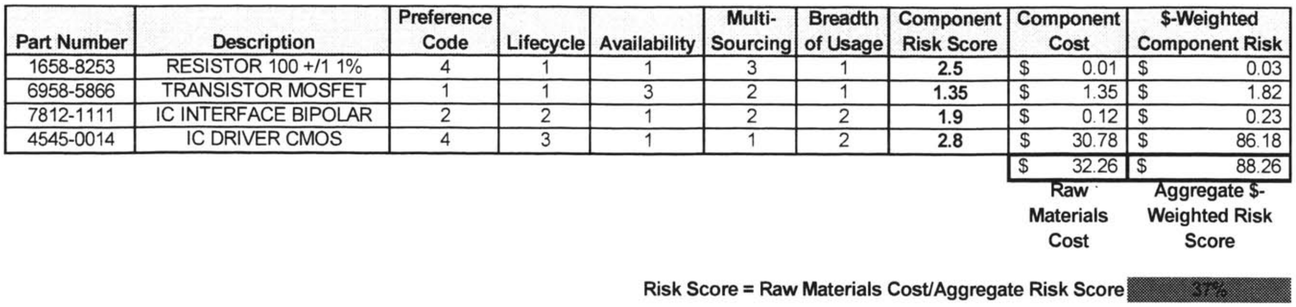
[9] Geoffrey Boothroyd, Peter Dewhurst, and Winston Knight, *Product Design for Manufacture and Assembly*, (New York: Marcel Dekker, Inc. 1994).

An example calculation of the deterministic risk score for a fictitious 4-component board using the weighting scheme in Figure 10 is shown in Figure 11 below.



Part Number	Description	Preference Code	Lifecycle	Availability	Multi-Sourcing	Breadth of Usage	Component Risk Score	Component Cost	$-Weighted Component Risk
1658-8253	RESISTOR 100 +/1 1%	4	1	1	3	1	**2.5**	$ 0.01	$ 0.03
6958-5866	TRANSISTOR MOSFET	1	1	3	2	1	**1.35**	$ 1.35	$ 1.82
7812-1111	IC INTERFACE BIPOLAR	2	2	1	2	2	**1.9**	$ 0.12	$ 0.23
4545-0014	IC DRIVER CMOS	4	3	1	1	2	**2.8**	$ 30.78	$ 86.18
								$ 32.26	$ 88.26
								Raw Materials Cost	**Aggregate $-Weighted Risk Score**

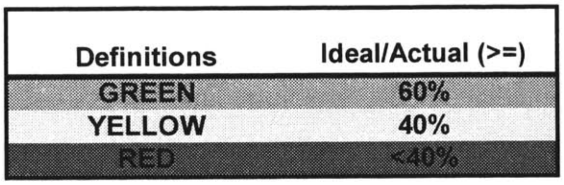
Risk Score = Raw Materials Cost/Aggregate Risk Score 37%

Figure 11: Board-Level Deterministic Risk Scoring Methodology

The next challenge was to determine what represented a "good", "medium" and "poor" risk level at the board level. Ideally the risk score would be color-coded green, yellow or red so that the designer could see at a glance how high the risk level was. It would also provide the designer with a baseline – for example, is a 65% score good or bad? The answer is that it depends on the type of design. Revolutionary designs may score lower than evolutionary designs due to the high usage of new, unknown materials. A board that does not leverage a previous design may include fewer older components and may score higher than a heavily leveraged board. In addition, designs in one PGU might score differently than in another.

After running several test material lists, the scoring levels shown in Figure 12 were determined to be reasonably applicable to all designs. This scheme should not be considered absolute, and should definitely be adjusted once the EMRA tool has been in use for several months. Specifically, risk scores should be recorded for many different types of boards, and statistics calculated to assess significant differences between the scores based on the differences among boards.

When the tool is first introduced, it is probably best to set one scheme, and let project managers decide if a score is too low for the type of product that is being designed. In time, they will learn through experience what types of scores to expect for their teams. Trying to maintain a separate color scheme for each type of product that might be designed would be a maintenance headache, the value of which is unclear.



Definitions	Ideal/Actual (>=)
GREEN	60%
YELLOW	40%
RED	<40%

Figure 12: Color-coding scheme used for deterministic risk scoring

3.4 PROBABILISTIC RISK SCORE

As the efforts of R. Morley Inc. and i2 make clear, existing technology regarding predictive obsolescence is very new and largely not validated, expensive and of limited value. In addition, the amount of data Agilent currently tracks regarding discontinuances is insufficient to make an informed analysis of the probability of discontinuance. The attempt at a probabilistic risk score for the pilot was made to ascertain how the pilot designers would react to having the risk score quantified in terms of dollars.

A high-level R&D manager mentioned in an interview that ideally, all risks would be related back to cost. The designers have a lot of things to think about while they are designing, and are evaluated on many fronts. He felt that an effective risk metric would be related back to one of the existing metrics that designers already care about, cost being foremost amongst them.

Further development of this suggestion resulted in the concept of "expected materials penalty cost of this design". It seemed it would be beneficial to give the designers a dollar figure that assessed the expected cost that Agilent would incur due to the sub-optimal portions of their materials selection. Ideally, this metric would represent the sum of expected component penalties across all components in the design. The expected component penalty would be assessed by multiplying the probability of that component being discontinued over the next 5 (or whatever) years, by the expected cost of that discontinuance.

In reality, assessing this probability during the pilot was very difficult to do accurately without purchasing the i2 YTEOL metric or doing extensive statistical analysis on data that Agilent does not currently track. Figure 13 represents a probabilistic scoring scheme that seemed reasonable based on discussions with the third party data provider and several managers in DCS and EPSG. Parts that are considered high risk (by the third party database) in the lifecycle risk category were given 100% chance of being discontinued over the following 5 years. Parts considered high risk in the availability risk category, however, were given only a

10% probability of being discontinued or otherwise incurring risk due to availability. Although these parts could clearly cost the company some money (i.e., by not being readily available when needed), from a component obsolescence perspective, they were less critical. The third party data provider was selected for testing as part of the Materials Lifecycle Risk Analysis project in DCS. Designers were not informed that the cost was a poor approximation of the actual cost. If they did not trust the output, that they would have a hard time assessing it fairly.

Component-level Analysis	Weight	Probability of Incurring Costs if "High Risk"	
Lifecycle Risk	25%	100%	
Availability Risk	10%	10%	
Multi-sourcing Risk	15%	10%	
Breadth of Useage Risk	10%	20%	
Agilent PC	40%	100%	25%
		PC = 4	PC = 3

Figure 13: Probabilistic Risk Scoring Calculations

	Deterministic Metric	Probabilistic Metric
Pros	• Simple • Easily understood by users • Easily maintained	• Links materials risk to cost to the organization • Allows users to readily assess tradeoffs based on cost
Cons	• Does not tie risk directly to cost to the organization	• Complex • Difficult to maintain • Accuracy may be questioned by users

Figure 14: Comparison of Deterministic and Probabilistic Risk Metrics

4 PILOT

4.1 APPLICATION DEVELOPMENT

To communicate the materials risk score and the supporting detail to the design engineers during the pilot, an application to read in a materials list, process the risk algorithm, and display the results of the analysis would be required. Figure 15 maps out the systems view of the EMRA pilot application. Since the pilot was intended to be only a proof-of-concept, the pilot application could be very rough and have some manual steps. In the long term, however, any risk assessment application would have to be completely automated and very user-friendly.

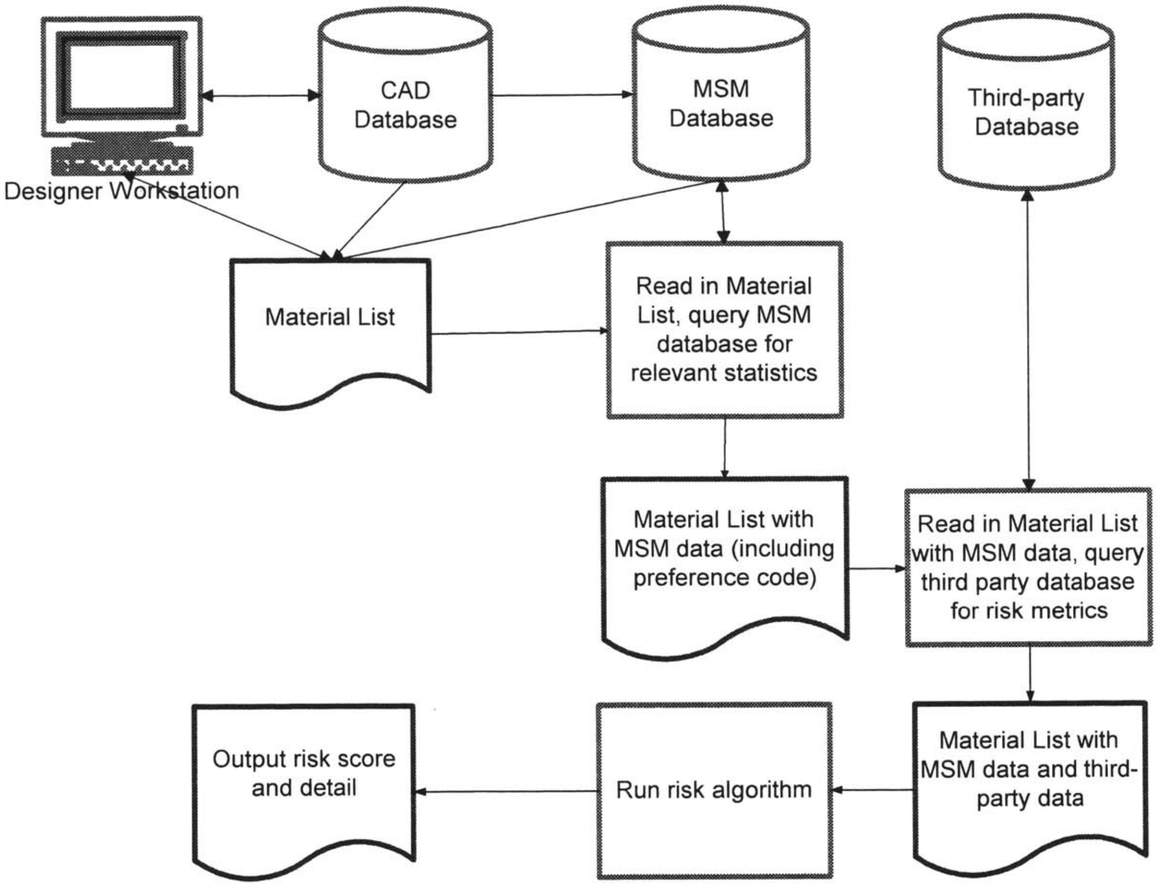


Figure 15: EMRA Pilot Application Flowchart

4.1.1 Process

It was clear very early on that IT resources would be critical to the success of the project, and be exceptionally difficult to come by. The ERP and PDM implementation projects were usurping all of the IT resources the company had to give. In addition, the IT group was centralized, and therefore the EMRA project proposal had to compete with every other IT project proposal in Agilent for the minimal amount of available additional resources.

Agilent's IT group has standardized the resource request process, by requiring certain forms to be filled out to initiate the process. The forms included a description of the project, expected amount and duration of IT resources required, and project ROI. Understanding the criticality of IT resources to the project, the proper forms were submitted in the first three weeks of the internship. The status of the request was checked on at least once a week. Ten weeks into the internship IT management finally made a decision that they would not be able to support the EMRA project. Immediately a contingency plan was enacted in which a contractor was hired to do the application programming. To keep the cost at a minimum, I agreed to program the user interface in Excel. The user interface took a comma-separated value file as an input, and then, through a series of macros, crunched the data and displayed it to the user.

Unfortunately, the process of using the contractor was not as easy as originally anticipated. The contractor was located in Oregon, had difficulty accessing Agilent's systems remotely, and required Agilent IT assistance to gain access. She did not have an understanding of the MSM data structure, and therefore required an Agilent employee to write the SQL script to query the database. Due to delays in gaining access and finding someone to write the script, she ran out of time to do much in the way of programming. At this point another contingency plan was enacted, and a senior IT person in the DCS group was talked into doing most of the programming after the contractor's departure. He ended up scrapping much of what she had done.

Another issue encountered was the incorporation of third party component risk data into the pilot. Shortly before the pilot was scheduled to kick off, the Materials Lifecycle Risk Analysis project began an alpha test with a third party to allow a few Agilent test users to access their Risk Manager database. Incorporation of third party data was critical to the success of the pilot, since without it the risk metrics would have only Agilent Preference Code as an input. Ideally, the Risk Manager data would be automatically pulled into the pilot application. The third party and the consultant worked to identify ways in which this might be feasible, but it was determined that it would be too time-consuming and resource-intensive to complete this functionality in time for the pilot. It was determined that the pilot users would each have to go to the third party's web site, upload a file of Manufacturer Part Numbers (MPNs), run the risk manager, and then download the resultant file back to the application environment.

4.1.2 Result

The original plan to use Agilent IT resources was reworked when the central IT group determined that they had insufficient resources to support the project. The learning came when it turned out that supporting the external contractor required significant use of internal resources, very likely more resources than the original plan would have required.

Regrettably, in the end, the pilot tool was not user-friendly. Running it required the following set of steps:

1. Extract materials list from design
2. Type in a UNIX command line (runs MSM query, returns .csv file)
3. Go to PC, open Excel application
4. Hit one button, get prompted to point at correct .csv file
5. Hit another button, filter MPNs

6. Highlight MPN column, save as new file
7. Open Arrow website and login
8. Upload file from step 6 to Arrow
9. Hit "get cost and availability" button
10. Hit "risk manager" button
11. Download file with Arrow risk data now included
12. Paste results of file into Excel application
13. Hit another button to generate pivot tables of high risk parts
14. View results

This turned out to be very painful and confusing to the pilot users. To help encourage use of the tool, I volunteered to run the Excel part of the application (steps 3-13) for them. All of them took me up on this offer. The process from then on out was that after they did steps 1 and 2, they would send me a note or call me to let me know the .csv file was ready. 10-20 minutes later I would have the results, and e-mail the Excel output to them. While not ideal, and certainly not real-time, 10-20 minutes is a much better turnaround time than the two weeks they are accustomed to waiting for the MLAR. Note that they did not get the full output of the original MLAR process, as they did not receive suggested alternatives for the risky parts.

The setup and results of the pilot program are discussed in detail in the following sections. The result of the application development was the multi-step process described above, with the MSM query followed by the third-party query followed by the algorithm churn.

4.1.3 Lessons Learned

As stated previously, the biggest learning was that support of an external contractor required a significant amount of internal IT resource support. The support requirements probably completely eclipsed the value of going externally for programming resources.

Another learning was how critical the ease-of-use of the application was in order to encourage designer use. The pilot participants were very supportive, and gave it their best effort, but got frustrated easily and made it clear that the final version of the tool absolutely must be very easy to use. Along these lines, it was not a good idea to split the application between UNIX and Windows. Since the material list was in UNIX and the application was in Excel, it required toggling back and forth adding unnecessary confusion. Having access to an internal Agilent IT resource to program all steps of the application probably would have resolved the problem.

4.2 PILOT EXECUTION

The pilot project itself lasted four weeks, and was executed by four designers. The designers used the application, which displayed the risk score as an output. The deterministic risk score was used for the first two weeks of the pilot and the probabilistic risk score was used for the remainder. Also output was a list of Code 4 parts, Code 3 parts, long leadtime parts, and parts for which the third party data indicated at least one category to be high risk. A sample output screen is demonstrated in Figure 16.

4.2.1 Pilot Participants

Four electrical design engineers, who design printed circuit (PC) boards, participated in the pilot. They were working on a total of twelve boards, across various phases of the design cycle. Although ideally all of the boards tested would have been in the initial stages of design (Investigation Phase or earlier), only two of the boards met this description. The remainder of the boards were in the late stages of the process – Definition Phase or later. All of the boards were evolutionary in nature and leveraged other designs to some degree.

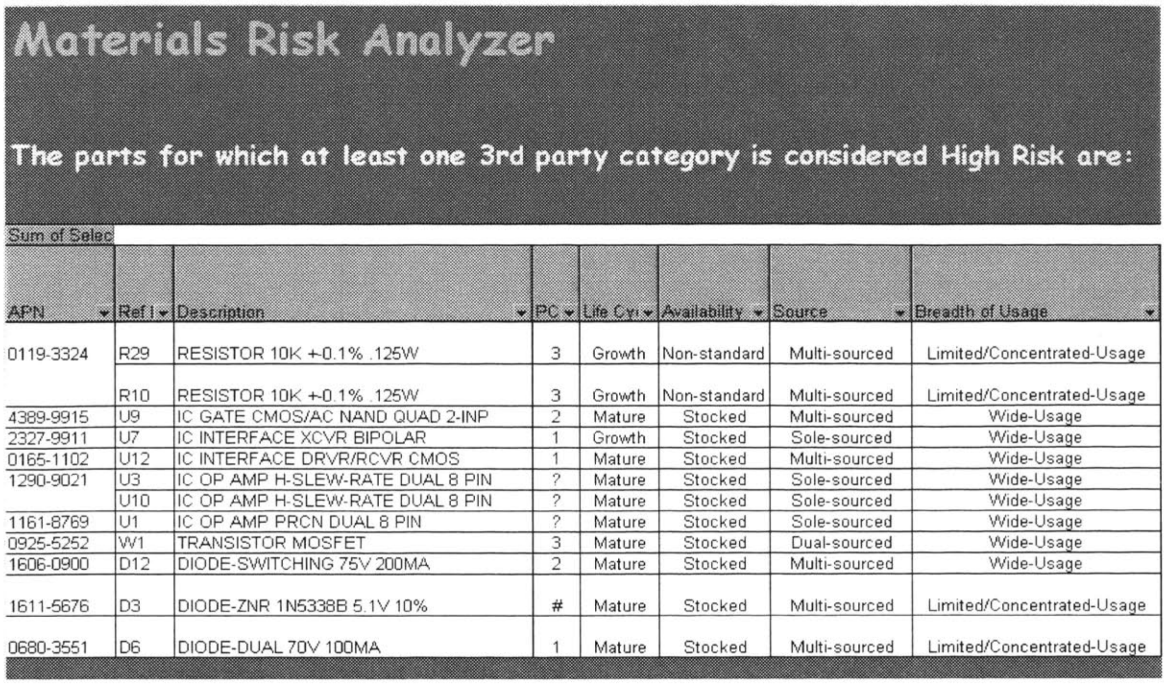
The designers also utilized different CAD programs to design their boards. Mentor is the de facto standard in Sonoma County, but several engineers still use the internally developed program called EEDP. The difference in CAD programs was inconsequential to the pilot, as both programs produce a pipe-delimited material list that was read by the EMRA tool. However, future development efforts should be sure to include functionality to support both programs.

4.2.2 Desired Outcome

The key problems with the current methodology, discussed previously, were usability of output, and speed of assessment or cycle time. The desired outcome of the EMRA pilot was to improve upon both usability and cycle time, which should result in designers applying the knowledge from the risk assessment. This application of knowledge would manifest itself if the designers made component changes to their designs based on the identification of risky parts. Therefore, action taken after receipt of information was the key desired result. Some of the identification and replacement of risky parts would have occurred as part of the MLAR process. It would be difficult to ascertain which changes were made exclusively as a result of the EMRA tool. Interviews with designers helped to determine an estimated percentage of the changes that they would have been hesitant to change later in the design cycle when the MLAR is typically performed.

Additionally, it was anticipated that designers would initiate earlier communication with the Materials Engineering organization. The EMRA application did not provide recommended replacement information, a key disparity between the output of the EMRA tool and the output of the MLAR. Hence, when a designer became aware of a risky part after running the EMRA, he could either select a replacement based on the parts selection tools available to him, or contact the proper Materials Engineer to assist in the selection of an ideal replacement. Since the designers were all running designs that had not yet been through the MLAR process, any contact with Materials Engineering could be classified as earlier contact than otherwise would have occurred.

Lastly, it was hoped that the designers would not attempt to "game" the process. To reduce the likelihood of gaming, the risk algorithms were closely inspected to check for points of leverage to improve the risk score. It appeared that the methods of improving the risk score all legitimately reduced the materials risk of the design. However, post-pilot interviews were used to determine if the pilot participants discovered any mechanisms to game the system.



Materials Risk Analyzer

The parts for which at least one 3rd party category is considered High Risk are:

Sum of Selec

APN	Ref I	Description	PC	Life Cy	Availability	Source	Breadth of Usage
0119-3324	R29	RESISTOR 10K +-0.1% .125W	3	Growth	Non-standard	Multi-sourced	Limited/Concentrated-Usage
	R10	RESISTOR 10K +-0.1% .125W	3	Growth	Non-standard	Multi-sourced	Limited/Concentrated-Usage
4389-9915	U9	IC GATE CMOS/AC NAND QUAD 2-INP	2	Mature	Stocked	Multi-sourced	Wide-Usage
2327-9911	U7	IC INTERFACE XCVR BIPOLAR	1	Growth	Stocked	Sole-sourced	Wide-Usage
0165-1102	U12	IC INTERFACE DRVR/RCVR CMOS	1	Mature	Stocked	Multi-sourced	Wide-Usage
1290-9021	U3	IC OP AMP H-SLEW-RATE DUAL 8 PIN	?	Mature	Stocked	Sole-sourced	Wide-Usage
	U10	IC OP AMP H-SLEW-RATE DUAL 8 PIN	?	Mature	Stocked	Sole-sourced	Wide-Usage
1161-8769	U1	IC OP AMP PRCN DUAL 8 PIN	?	Mature	Stocked	Sole-sourced	Wide-Usage
0925-5252	W1	TRANSISTOR MOSFET	3	Mature	Stocked	Dual-sourced	Wide-Usage
1606-0900	D12	DIODE-SWITCHING 75V 200MA	2	Mature	Stocked	Multi-sourced	Wide-Usage
1611-5676	D3	DIODE-ZNR 1N5338B 5.1V 10%	#	Mature	Stocked	Multi-sourced	Limited/Concentrated-Usage
0680-3551	D6	DIODE-DUAL 70V 100MA	1	Mature	Stocked	Multi-sourced	Limited/Concentrated-Usage

Figure 16: Sample EMRA Output (fabricated data)

4.2.3 Lessons Learned

The key lesson learned from the pilot process was that the application absolutely must be very easy to use to get designers to use the tool at all. The pilot designers, given their level of commitment to the project, were more patient with a difficult-to-use application than they or their peers would be under normal circumstances. The final product, therefore, must be very easy to use to encourage maximal designer usage.

4.3 PILOT RESULTS AND ANALYSIS

Despite the hurdles, the pilot was undoubtedly a success. The success metrics for the project are summarized in Figure 17.

Success Metric	How Measured	Goal Value	Actual Value
Designer Usage	% of designers participating by using the EMRA tool	100%	100%
Frequency of Use	Average runs/designer/board over pilot period	>1	1.6
Risk Reduction	% improvement in total risky parts	no goal set	1%
Designer Action	% of designers changing out some of the identified risky components	100%	100%
Designer Vote of Confidence	% designers indicating they would use the tool when implemented	100%	100%

Figure 17: Pilot Success Metrics

All goals were met or exceeded, with the exception of the improvement in total risky parts, for which a goal percentage was not set prior to the pilot. It is difficult to directly compare these metrics with the MLAR process because usage and action indicators are not currently tracked. It is believed that 100% of designers use the MLAR process; the same usage observed during the pilot. According to the pre-pilot survey, designers perform the MLAR process an average of 4 times per board over the entire design cycle. The 1.6 times per board the designers used the EMRA during the weeks of the pilot is certainly a greater rate, the exact magnitude of which depends on the length of the design cycle, but probably was influenced by the fact that the designers were compelled to use the tool during the pilot.

A post-pilot survey administered in individual interviews and a pilot group discussion session were key indicators of the success of the program. Every pilot participant indicated that he liked having the risk information, and even more importantly, made changes to his designs after viewing the results. While simple, these two conclusions are quite powerful. The fact that the designers liked having the risk information indicates that they have some motivation to use the EMRA tool. The fact that designers changed their designs to improve the component selection indicates that real cost savings will be realized when designers are informed of risky components. In other words, we can safely conclude that when the EMRA tool is rolled out to designers, they will use it and they will consequently reduce the materials risk incurred by their designs.

4.3.1 Third Party Data

Some specific feedback was that the third party data was particularly useful. Designers primarily used Agilent preference code as the identifier of risky parts, but they appreciated having visibility to the specific risk areas. Interviews both before and after the pilot indicated that designers are frustrated with the current preference coding system because it tells them only that a part is "ok to use" or "not ok to use"; it does not indicate why it may not be recommended for new designs.

One designer related the following vignette: The EMRA tool indicated that one of the technology-enabling components on his board was a Code 3 (not recommended for new design). He then looked at the third party data and saw that it was a sole-sourced part. Since the component was critical to the design and there were no other choices for suppliers, he knew that the sole-sourcing was inevitable. But he was comforted somewhat by the other information the third party provided, namely that there were several other customers for the component, it was in its "maturity" stage, and the third party kept the component stocked. The detailed third party data provided this particular designer with much more information than the Agilent preference code and gave him the confidence to continue designing the board with the Code 3 component included.

4.3.2 Risk Metric

The pilot participants did not pay much attention to the overall risk score. Several of them mentioned that it might be useful information for their managers, but they went straight for the detail. This finding is consistent with the original concerns related in the last chapter, namely the desire to align incentives with the risk metric. Specifically, if the designers are not being held accountable for their risk scores, they do not have any incentive to improve the score, or in this case, even take notice of it. It is important to note that the designers behaved in the right way during the pilot, despite the lack of use of the metric, emphasizing the importance of the component-level detail. Unfortunately, the design of the pilot program did not make room for involvement of the project managers or even higher levels of management. The full implementation of the EMRA tool must carefully consider the best way to get management to buy into the value of the tool and set expectations for designers to score highly with their designs. There are many alternative metrics to achieve the reduced LTB inventory objective, only one of which is to measure the risk metric. The most obvious of these alternatives is to measure levels of LTB inventory and set and expectation that LTBs will go down. This would put pressure on the organization to think through the designs and to use the EMRA tool.

In the first two weeks of the pilot, all of the designs that were evaluated with the EMRA tool were assessed with the deterministic method. During the remainder of the pilot, designs were assessed with the probabilistic method. Before the pilot ended, all of the designs were re-evaluated using the other method so that designers could directly compare the results of both methods on the same design and provide feedback.

According to the post-pilot feedback, the designers slightly preferred the deterministic risk scoring to the probabilistic method. The reasons given for this preference were that the score was easier to interpret, and was based on a more limited, straightforward set of assumptions. The designers did like seeing the expected cost penalty shown with the probabilistic score, but were wary of the number of assumptions that went into assessing it. In short, they preferred simplicity.

4.3.3 Cost Savings

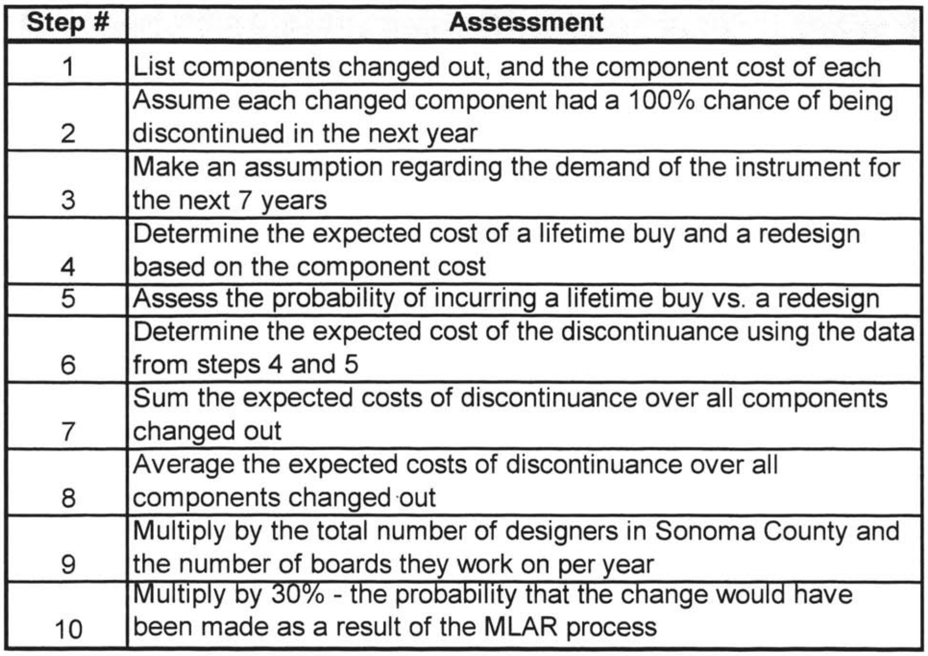
Figure 18 gives some statistics on the 12 boards that were evaluated by the EMRA tool. These statistics represent the status of the boards before component changes were made. MPNs = Manufacturer Part Numbers, and TPHR = Third Party High Risk Items. With very few exceptions, there should be zero Code 4 parts in new designs, yet up to 4% of the components in these pilot designs were Code 4, very likely due to the leveraged portions of the boards. On average, for 17% of the components in the pilot designs, at least one of the categories reported by the third party was deemed to be high risk. These statistics indicate that on the initial run of these boards, there was room to improve the component selections.

Board	# MPNs	Code 4's	% Code 4	Code 3's	% Code 3	# Third Party High Risk	% TPHR
1	81	3	4%	11	14%	19	23%
2	420	0	0%	27	6%	79	19%
3	107	1	1%	7	7%	23	21%
4	271	0	0%	21	8%	93	34%
5	521	10	2%	14	3%	127	24%
6	352	1	0%	55	16%	101	29%
7	88	1	1%	5	6%	4	5%
8	195	4	2%	12	6%	14	7%
9	283	0	0%	26	9%	14	5%
10	610	7	1%	48	8%	88	14%
11	166	6	4%	60	36%	3	2%
12	209	1	0%	41	20%	4	2%
TOTAL	**3303**	**34**	**1%**	**327**	**10%**	**569**	**17%**

Figure 18: Statistics on Boards Evaluated During the EMRA Pilot

Figure 18 suggests that the third party data identifies a greater number of parts as high-risk (17%) than the Agilent preference codes (11%). The causes of this are outside the scope of this paper, but are being actively addressed by the Next Generation Preference Code project.

During the pilot, designers made changes to eight of the 12 designs assessed with the EMRA tool. Figure 19 indicates how the cost savings during the pilot were calculated, and how the potential savings in all of Sonoma County were conservatively extrapolated.



Step #	Assessment
1	List components changed out, and the component cost of each
2	Assume each changed component had a 100% chance of being discontinued in the next year
3	Make an assumption regarding the demand of the instrument for the next 7 years
4	Determine the expected cost of a lifetime buy and a redesign based on the component cost
5	Assess the probability of incurring a lifetime buy vs. a redesign
6	Determine the expected cost of the discontinuance using the data from steps 4 and 5
7	Sum the expected costs of discontinuance over all components changed out
8	Average the expected costs of discontinuance over all components changed out
9	Multiply by the total number of designers in Sonoma County and the number of boards they work on per year
10	Multiply by 30% - the probability that the change would have been made as a result of the MLAR process

Figure 19: Pilot Cost Savings Assessment Methodology

The projected cost savings of the EMRA tool cannot be disclosed, however a sense of the magnitude of the savings can be determined by comparing the projected annual savings in Sonoma County with the estimated annual holding costs for the lifetime buy inventory attributed to EPSG. At current levels, the expected annual EMRA cost savings is approximately 10% of the annual LTB inventory holding costs for all of EPSG. As LTB inventories are reduced (the denominator decreases) and more EPSG groups utilize the EMRA tool (the numerator increases), this percentage should increase significantly. Recall that the cost savings from Step 9 was extrapolated only to the Sonoma County EPSG group, so further penetration can be expected with a full implementation.

5 IMPLEMENTATION

Interviews conducted throughout the internship with engineers and managers within the R&D, Materials Engineering, Procurement, Order Fulfillment and ESCS groups resulted in the gradual development of a vision for the EMRA tool. The vision, here referred to as the "Ideal Situation", is essentially a wish list for a perfect materials risk assessment system. Although there are many barriers and challenges that currently impede achieving the Ideal Situation, it is useful to begin with the ideal, and then relegate to practicality.

There are four primary components to the Ideal Situation vision: (1) the use of Total Cost of Ownership as the risk assessment metric, (2) system functionality and user interface, (3) suggested alternate components, and (4) the software platform upon which to execute the application.

5.1 TOTAL COST OF OWNERSHIP AS RISK ASSESSMENT

One of the pilot designer concerns was that the EMRA, while important, represented only one of the Design for X (DfX) initiatives. The EMRA puts materials issues in front of the designer, and ideally will also be integrated with his CAD environment. If the designers have higher visibility to the EMRA than other DfX tools, it is foreseeable that the design teams may focus on optimizing for materials, and consequently inadvertently sub-optimize another DfX principle.

An example of this is the use of leveraged designs. If several of Agilent's products use an identical PC board, Agilent gains manufacturing flexibility. If the demand for one product drops off while the demand for the other product is on the rise, the common PC board volumes do not have to change. Inventories of that PC board do not experience wild swings. However, now imagine that the first product to utilize the common PC board made use of a component that became a high risk for discontinuance before the second product made use of the board. When the designer for the second product decided to leverage the common PC board, he ran the EMRA and discovered the component had a high lifecycle risk. So he swapped it out to a "good" component. Now this common PC board is no longer identical for the two products. Is the manufacturing flexibility gained by leveraging identically more beneficial to Agilent than incurring the cost of using a LTB part in a new design? Should the designer attempt to swap out a common part on all boards on which it is used at the same time to maintain commonality? It is hard to answer these questions without doing some sort of tradeoff analysis. In an ideal world, the designer would be able to answer these exact questions at the push of a button.

A good way to assess tradeoffs is to develop a common metric by which all decisions are analyzed. In EMRA's case -- in fact for all of product design -- Total Cost of Ownership (TCO) is a good candidate. In the previous example, the risk assessment tool would know which other products were utilizing the identical board, and make a value assessment based on manufacturing flexibility and the probability of stock outs and overstock situations. It would also be able to assess the expected cost of using the board as-is, without changing out the risky components. It could then compare the two and make a recommendation regarding whether or not to change out the components.

It is important to remember that materials risk extends to all boards that make use of a risky component, not just the ones currently being analyzed. A TCO perspective requires consideration of impacts to all products making use of a risky component.

Another tradeoff example is landed cost considerations[10]. Factoring in logistics expenses, such as the costs of shipping overseas, could lead Agilent to conclude that the expected TCO is lower for a riskier domestic component than a less risky recommended alternate manufactured overseas.

Yet another conventional designer tradeoff consideration is price vs. performance. Simply graphing the two attributes and plotting the candidate parts can assess this tradeoff. Parts that fall below the mean line (Parts B and C) are considered a better value. Figure 20 demonstrates a typical price vs. performance tradeoff analysis. A total cost of ownership approach would go a step further by attempting to assess the increased market value of improved performance, and compare it to the increased product cost necessitated by the higher raw material cost.

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[10] Agilent's Bill Walker has been directing the landed cost effort, and published materials internally and externally in this regard.

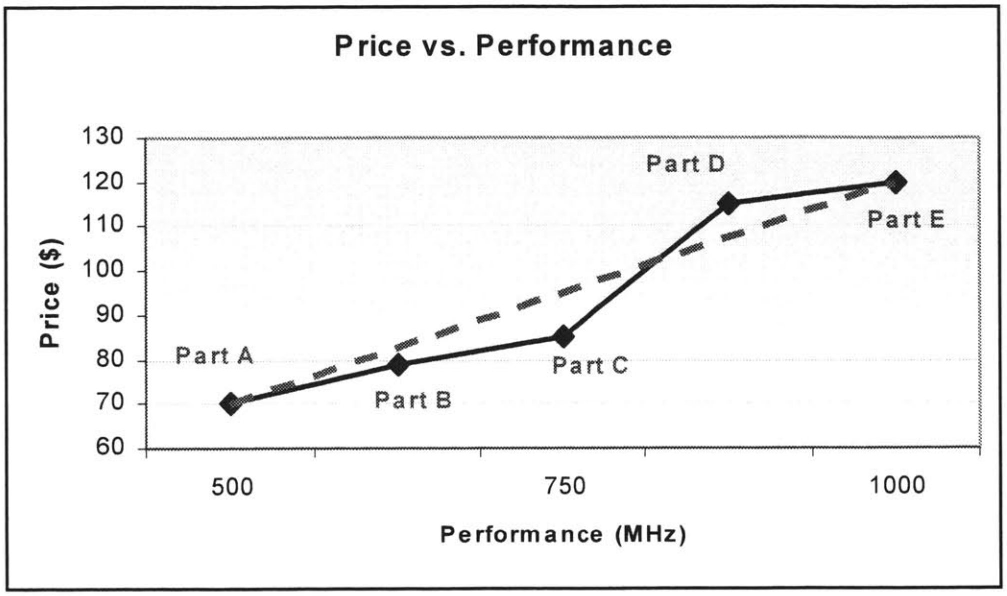

Figure 20: Sample Price vs. Performance Tradeoff Analysis

There are plenty of examples of tradeoffs that ideally would be assessed at a designer level. In the end, "The Goal"[11] of Agilent is to make money. One way to make more money is to minimize the total cost of ownership for Agilent's products, signaling the importance of the TCO metric.

Even simply from a discontinuance perspective, some kinds of discontinuances cost more than others. For example, when a product is sole sourced, a costly major redesign is much more likely to be the outcome of a discontinuance than a LTB.

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[11] Goldratt, Eliyahu M., *The Goal*, (Great Barrington, MA: North River Press, 1992).

Looking at TCO can be very beneficial to product planning at a strategic level. Decision support systems could be used to predict when, in a product's lifecycle, Agilent will incur costs associated with discontinuance (or anything else). This forward-looking capability would allow product managers to look at the total instrument cost curve, and make product lifecycle decisions such as when to phase in next generation products or when to discontinue old products based on it. This view can be expanded to whole instrument family lifecycle planning. An example of expected rate of component obsolescence over an instrument's lifecycle is shown in Figure 21. Mapping the associated cost curve would allow the company to identify the point at which the cost of component obsolescence exceeds the value of continuing to manufacture the instrument, at which point a new product should be phased in.

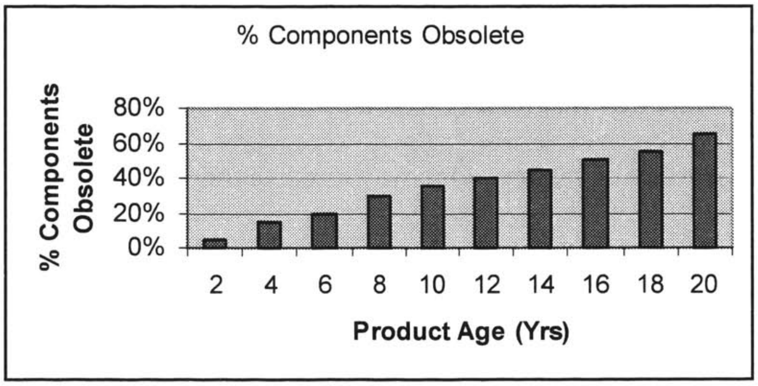

Figure 21: Sample Instrument Lifecycle Planning Input

Although it is the ideal way to assess tradeoffs and understand the bottom line impact of decisions, there are several issues with the use of TCO as the primary metric. One problem, of course, is that determining TCO is an incredibly complex task. Maintaining cost assumptions used to determine TCO is also a complex and time consuming task. Given the complexity and difficulty of maintaining this information, the likelihood that it will fall into a state of disrepair is high. And, as has been discussed, if the data feeding the system is no good, the system itself is worthless. Garbage in, garbage out. For a TCO based system to be successful, the cost assumptions and calculations would have to be agreed upon by all groups, with clear owners and business processes to ensure the cleanliness of the data.

5.2 SYSTEM FUNCTIONALITY

The vision for the EMRA user interface was developed with (and for the most part, by) the pilot designers. The ideal user interface would be a live decision support system, accessed from within their CAD design environment, whether that be Mentor, EEDP, or another platform. Any required connections to third party data systems would be live and transparent to the user. The designer would select a menu function to "turn on EMRA highlighting". All parts deemed to be high risk would be highlighted in red, directly on the schematic. All parts deemed to be medium risk would be highlighted in yellow. Any redlines that a Material Engineer has suggested would be obvious, whether or not the highlighting is turned on. A right mouse click on a highlighted part would pop up a small window indicating why the part is considered risky (e.g. "Part is Sole Sourced"), and then list the recommended replacement parts. Clicking on a recommended replacement would take the designer to the manufacturer's data sheet to verify the parametric data and ensure the part is a worthy replacement. A double click would replace the risky component on the schematic with the improved component, and the highlighting would then disappear.

The above describes the user interface for the design. However, many of the users of the EMRA tool will be others such as Materials Engineers or NPI Planners. Interfaces for these users will function primarily through a reporting function of the software and a collaborative design environment. For example, the Materials Engineering interface would allow the engineer to select any design from the design vault, and filter for his or her commodity. The report would list all components in the design (in list format, not the schematic view) in order of risk rating. This would allow him or her to focus on the most critical items first. One click on a risky part would pull up the list of recommended replacements. If the engineer wants to look for more parts that didn't pop up, he could do a part search right there. Once the engineer decides on a recommendation, he or she would click a button that says "submit redline". Then, when the designer next opens up the file, the recommended redlines will be in place and the designer can decide whether or not to accept the recommended change.

5.3 SUGGESTED ALTERNATE COMPONENTS

Every single pilot designer identified the need for a system that provides real-time equivalent and suggested alternate components. They indicated that identifying problem parts is only half the process. They then need to know what to do to fix them. This would significantly increase the probability that they will actually make changes to the risky parts, especially on leveraged designs. The ideal solution would include a system that allows the designer to have access to recommended replacement parts immediately after discovering that a component is "risky" as described in the last section.

One way to address the need for suggested alternates is to assign some tolerances around parameters and do a replacement part search based on them. For example, if someone is looking for a replacement for a 20-microfarad capacitor, the alternate part search engine could be set up to look for all capacitors with the exact same parameters except +/- 10% on the capacitance. Then all capacitors that meet that specification would be displayed as alternates for the designer. This is essentially the same way they search for original parts when they use one of the automated search engines, so a translation into the EMRA tool should be relatively simple. Some of the software suppliers investigated (details in the following section) also include a link to the manufacturer's data sheet from the alternate parts list. The specifics regarding which parametric data and the tolerances to search on for alternate parts should be designed, approved, and supported by Materials Engineering.

5.4 SOFTWARE PLATFORM

The final version of the EMRA tool, especially as defined by the vision in the previous sections, will require a significant investment in software. Agilent can either choose to develop a system in-house (not recommended), or purchase and customize an existing software suite.

Developing the final EMRA system internally would require starting from scratch, because the pilot tool would need to be almost completely replaced. Development efforts would require a live third party data feed, live MSM data feed, multiple user interface designs, and schematic capture integration. Using a commercial software system is certainly not without internal IT resource requirements, but the resources required to develop an in-house system are likely to be an order of magnitude higher.

The second argument against developing an internal system is the non-standard end result. Instead of having a software package that is supportable by the software company and thoroughly documented, Agilent would end up with another homegrown solution that requires significant long-term application support and revisions. Any customization required by the different divisions within Agilent must be supported internally. For these reasons, I do not recommend pursuing an internal solution.

As part of the research described in the Approach section for an off-the-shelf, long-term software solution, I investigated four software companies. Two of them, Company 1 and Company 4, also offer third party component risk assessment data sets. The four companies have a wide range of product offerings and functionality. They also have a wide range of price points. All of them were asked to assess the ballpark cost of doing the Beta test in Sonoma County, as well as the cost of a full implementation. Company 1 and Company 4 consider their databases to be a big part of their value proposition, and the Beta test would require full access to these databases. For this reason, they are not able to offer reduced pricing for the MSM data cleansing and mapping to their own systems just because it is part of a "Beta" test. They did consider price reductions for the software (BOM grading) part of their packages. Company 2 and Company 3 offer a BOM grading tool, as well as other component management modules. They do not offer a third party component database.

Figures 22 and 23 compare the software companies on functionality and cost.

Function	**Company 1**	**Company 2**	**Company 3**	**Company 4**
Industry component database	X			X
Data cleansing service	X			X
BOM grading tool	X	X	X	X
Schematic capture		X		X
Procurement analysis	X			
Preference management	X	X	X	X
Configurable risk scoring	X	X	X	X
Ability to incorporate third party data	X	X	X	X
Auto datasheet link	X			X
CM collaboration	X			

Figure 22: Software Functionality Checklist

The functions considered and compared were:

- *Industry component database:* offers a third-party data set with industry-level risk assessment, very similar to the third-party data tested in the pilot.
- *Data cleansing service:* ensuring that the component data in the database is "clean"; in other words, data in all fields is consistent and correctly formatted. This avoids errors and mistakes when processing risk algorithms.
- *BOM grading tool:* the basic EMRA functionality – the ability to identify risky components and display the risk score to the user at both the component level and the board level.
- *Schematic capture:* integration with CAD design environment.
- *Procurement analysis:* tracking and subsequent optimization of procurement strategies. Credited for huge cost savings at Company 1's customers, but outside the scope of this project.
- *Preference management:* ability to define and maintain a part preference scheme.
- *Configurable risk scoring:* permits Agilent to initialize and maintain the algorithm used to determine component-level and board-level materials risk.

- *Ability to incorporate third party data:* ability to either include third party data in the reference database, or to query a third party system on a case-by-case basis to obtain the requisite information.
- *Auto datasheet link:* automatic link to the manufacturer's datasheet on the web. Datasheets include specific performance specifications that would allow designers to determine if the component is a suitable substitute for a risky part.
- *CM collaboration:* ability for procurement teams to collaborate online with design engineers. An example would be a procurement engineer redlining a design with suggested changes.

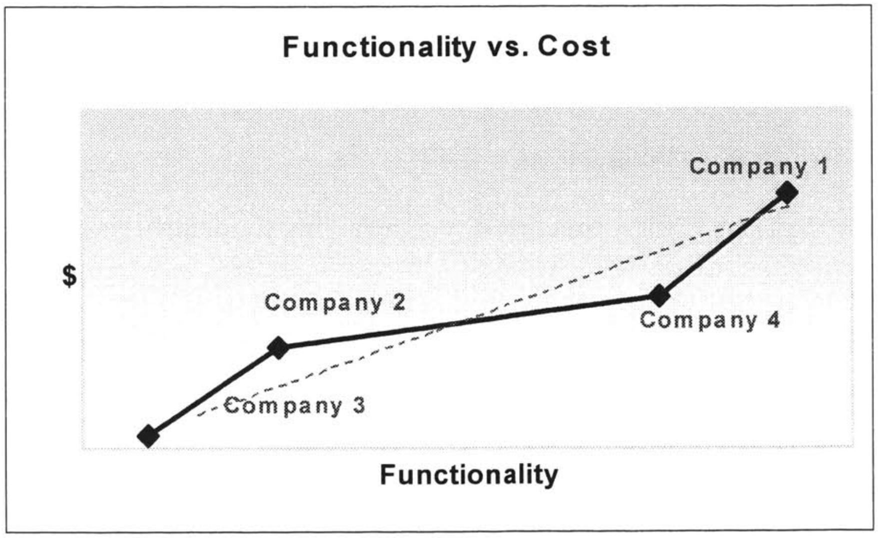

Figure 23: Functionality vs. Cost Software Comparison

Using this framework for assessing the software companies helped to compare them on a fairly objective basis and eliminate some ambiguity. It is clear from Figure 23 that Company 1 offers the most functionality, with Company 4 next. Performing a tradeoff analysis as described in the previous section shows that from a value standpoint, Company 4 has a desirable cost/functionality ratio, while Company 2 is comparably overpriced for the functionality offered. Based on this analysis, the final recommendation at the end of the internship suggested working with Company 4 to develop detailed requirements for the Beta test as well as the full implementation. A final decision on whether to approve funds for the software purchase should be made based on the outcome of these detailed negotiations. In general terms, the cost of the systems varied from about six months of expected savings (when implemented Sonoma County wide) to two years of savings initially with a recurring cost of one year of savings. Clearly, if the recurring annual costs exceed the annual savings, the project is not worthwhile. The value of the project will increase as the EMRA is implemented more widely. The negotiations should consider the implementation, and hence expected savings, timeline.

5.5 CHALLENGES AND BARRIERS

The biggest barrier to wide implementation of the EMRA tool is Agilent's structure. The tool must be effectively sold to all divisions, each of which has a unique set of requirements, expertise, and systems. The ERP implementation will help reduce the disparity in IT systems, but some legacy systems will remain.

Another important barrier is the amount of resources that will be required to fully develop the tool interface and functionality as described in the vision. Some of the existing software companies can accommodate many of the requirements, and are willing to do further development work to optimize the software for Agilent's operating environment. However, as discussed above, the software has a very hefty price tag, and custom development work will be even more costly. In addition, most companies charge an annual service fee for database subscription and data maintenance. If Agilent chooses to do the development and support work in-house, the total investment will probably be similar. Despite the huge value proposition to Agilent of the system, the large system expenditures are difficult to disburse given the current climate.

To dig into the details, a couple of potential issues may arise with respect to the suggested alternates. For one, the MSM parametric data integrity is not currently up to par. This would either need to be cleaned up, or Agilent would need to primarily rely on the third party component data for the parametrics. Secondly, Materials Engineering is different in each division. Some organizations may feel differently about how the alternate part search is set up. One potential solution would be to have the enterprise Materials Engineering organization own the alternate part search setup.

5.6 LESSONS LEARNED

The project and the internship were successful. However, there were some hurdles to overcome, as well as mistakes made along the way. The key lessons learned involved driving change from a corporate group in a decentralized company, working with centralized groups (specifically IT) in a decentralized company, obtaining funds and resources for a project in tight economic conditions, the value of metrics tightly linked to incentives, and the challenges in valuing a new system.

5.6.1 Driving Change from a Corporate Group

The EMRA project has provided a data point for the following argument: in a decentralized company, the best way to obtain support for a corporate project is to work from within the divisions. By contributing to the design and development of the EMRA pilot tool, pilot designers felt some ownership for it. They, therefore, will likely be champions for its implementation.

5.6.2 Centralized IT in a Decentralized Company

Many decentralized companies encounter somewhat of a quandary when they attempt to consolidate or centralize certain functions. This is essentially an attempt to have the best of both worlds – the flexibility and quick decision-making expected from a decentralized organization, and the cost effectiveness of centralized functions. Agilent has attempted to do this by centralizing the IT group, and is encountering many of the same problems that other companies have.

There appears to be a few necessary elements present for a centralized IT organization to function efficiently:

- *An effective methodology for prioritizing projects to ensure that the highest-value projects are being resourced.* This would require all divisions submitting project requests to use the same set of assumptions when objectively assessing the value of their project. It would also require that the decision makers in IT have a good understanding of the various divisions' goals and active projects so that they can do a sanity check on the value assessment.

- *All IT employees who may be assigned to a project should have the skills necessary to take on almost any project.* This is very difficult to accomplish in a decentralized organization, since the divisions are likely to have many different systems, languages and platforms resulting in an infinite combination of requisite skill sets. When this condition is not met, projects with low value get resourced simply because employees with the required skill sets are available, while high-value projects wait in line for certain high-demand employees to become available.

It appears that neither of these conditions is currently met at Agilent. When a project with a high value proposition does not get resources, it can be very frustrating for the project manager. The only effective solution, as occurred with the EMRA project, is to "shop around" at the division level for qualified technical resources that may be convinced to help. Resorting to this solution effectively reverts to the model of decentralized IT.

Another potential area for improvement is Agilent's current IT resource request process. It currently is not sufficiently responsive to meet the needs of the IT customers – internal project managers. IT by definition is fast moving. And just about every project, especially in DCS, is going to require IT resources of some sort. One solution may be for DCS (as well as other customers) keep a project roadmap and review it regularly in staff meetings so that the IT representative can stay abreast of upcoming resource requirements. To close the loop, the IT representative should present back to DCS management regarding which projects he or she foresees being unable to resource. Whether or not the IT POR Resource Request process has been followed yet for all the projects, the representative should still be able to make an educated assessment. The projects not able to be resourced need management support and involvement to ensure the formulation and success of contingency plans.

5.6.3 Project Challenges in Tight Economic Times

The most frustrating part of attempting to drive change in a tough economic climate is that a positive ROI (return on investment) is not sufficient to justify a project. In this economic downturn, Agilent reacted as most other companies did – by tightening expenditures company-wide. A hiring freeze was enacted. Travel was severely restricted. All divisions saw their budgets cut.

Spending restrictions impacted the EMRA project in the pilot phase, and will certainly impact the speed and effectiveness of implementation. When IT resources were unavailable for pilot application development, the funds necessary to procure an external contractor were difficult to obtain. Funding for the contractor was secured primarily because the contracting company does a significant amount of business with Agilent, and the existing contract was slightly (in terms of percentage) expanded to accommodate the EMRA development.

Because recommendations for implementation include spending millions on software and/or internal development and support for the application, implementation likely will not proceed immediately. Very likely, implementation will proceed slowly until the economy improves and funding and resources become more readily available.

5.6.4 Alignment of Metrics and Incentives

The fact that the designers did not take much notice of the risk metric was a clear indication that the metric was not valuable to them. This behavior is understandable; the designers want to know what is broken and how to fix it. They are not particularly interested in gauging their designs. During the pilot, this disconnect was not a problem because I was actively encouraging the designers to use the EMRA, and keeping track of their progress. However, when the EMRA is implemented on a wider scale, it is not practical to have someone constantly persuading the designers to use the tool early and often. This is essentially the current model, with NPI planners often the catalyst for the MLAR process. To be effective, the incentive to use the tool must be systematic.

Incentive to use the tool should be tightly tied to the designers' performance evaluations. And to make this link, a performance measure must exist for the materials risk incurred by or avoided by the designer. The risk metric is this performance measure, and should be overtly used by project managers to evaluate designers' performance. The designers themselves suggested that this could best be accomplished if each designer reported his latest risk score at regular project team meetings. The raw scores would inform the project manager of a potential materials risk problem, and the rate of improvement over time would indicate the action being taken to reduce materials risk problems. To further increase the visibility of the metric and accountability of the project managers to reduce the materials risk of the instrument, the project manager should report the risk scores during project phase reviews.

5.6.5 New System Valuation

As indicated by the number of assumptions that had to be made to get a cost savings estimate, it was very difficult to assess the value of the EMRA project. A new system is, by definition, unproven. Although the EMRA pilot provided some hard data regarding the projected usage of the tool, a lot of ambiguity remained even after the pilot. First, the awkwardness of the pilot application made it difficult to assess how the designers would really behave if they had a sleek, user-friendly system. Secondly, since EMRA would replace the MLAR process, it was necessary to assess the degree to which EMRA contributed to materials risk reduction above what would be accomplished with the MLAR process. Lastly, since the internal data systems did not catalogue costs incurred due to discontinuance, it was difficult to assess the exact expected costs of discontinuance and therefore the expected cost savings when discontinuance is avoided.

To summarize, it is very difficult to assign a value to a new system. Under this kind of ambiguity, it is difficult for decision makers to dedicate human and financial resources to a project, the payoff of which is uncertain. For the EMRA project, this dynamic was further compounded by the economic climate.

CONCLUSION

This thesis described the development of a risk analysis methodology and supporting tools to help design engineers reduce the use of parts at high risk for obsolescence in new products. Some key takeaways from the project development, pilot program execution and pilot results are summarized below.

Design engineers, in general, are aware of supply chain risks and honestly want to contribute to design for supply chain (as well as other DfX) efforts. However, their primary job is to design circuits and boards, so they cannot spend a significant amount of time getting the data and information they need to participate in DfX efforts. If they had the data readily at their fingertips, they could more easily and quickly make DfX decisions. To be successful, a materials risk analysis system must be very quick and easy to use. It must not only inform designers of risky components present in their design, but also recommend actions to improve the selections.

The second takeaway regards execution of a project requiring significant IT resources in an environment where these resources are in very high demand. An interesting twist at Agilent was assessing the structural conflict of a centralized IT group functioning in a highly decentralized organization. A contingency plan that was executed during the internship was the use of an external contractor to provide programming support. Interestingly, the contractor required significant internal IT support to complete the project, and in the end Agilent probably expended more IT man-hours supporting the contractor than they would have by supporting the project entirely internally.

Lastly, metrics will only drive behavior if the metric is closely linked to performance evaluation. During the pilot project, the risk metric was not being used to evaluate the designers in any way. This permitted them to objectively assess the value of the information that was being provided. They valued the detailed component data, and hardly acknowledged the risk metric itself at all. In contrast, project managers and materials and supply chain groups would likely use the risk metric exclusively to track performance and trends. In order to properly align goals and incentives, the interests between the two groups need to be closely synchronized.