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A MODEL FOR MAKING PART SOURCING DECISIONS FOR LONG LIFE CYCLE PRODUCTS

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ABSTRACT

Long life cycle products, commonly found in aviation, medical and critical infrastructure applications, are often fielded and supported for long periods of time (20 years or more). The manufacture and support of long life cycle products rely on the availability of suitable parts, which over long periods of time, leaves the parts susceptible to a number of possible supply chain disruptions such as suppliers exiting the market, counterfeit part risks, and part obsolescence. One solution to mitigating the supply chain risk is the strategic formulation of suitable part sourcing strategies (optimally selecting one or more suppliers from which to purchase parts over the life of the part's use within a product or within an organization). Strategic sourcing offers one way of avoiding the risk of part unavailability (and its associated penalties), but at the possible expense of qualification and support costs for multiple suppliers.

Existing methods used to study part sourcing decisions are procurement-centric where cost tradeoffs focus on part pricing, negotiation practices and purchase volumes. These studies are commonplace in strategic parts management for short life cycle products; however, conventional procurement-centric approaches offer only a limited view when assessing parts used in long life cycle products. Procurement-driven decision-making provides little to no insight into the accumulation of life cycle cost (attributed to the adoption and use of the part), which can be significantly larger than procurement costs in long life cycle products.

This paper presents a new life cycle modeling approach to quantify risk that enables cost effective part sourcing strategies. The method quantifies obsolescence risk as "annual expected total cost of ownership (TCO) per part site" modeled by estimating the likelihood of obsolescence and using that likelihood to determine the TCO allowing sourcing strategies to be compared on a life cycle cost basis. The method is demonstrated for electronic parts in an example case study of linear regulators and shows that when procurement and inventory costs are small contributions to the part's TCO, the cost of qualifying and supporting a second source outweighs the benefits of extending the part's effective procurement life.

Keywords: Total cost of ownership, part sourcing, supply chain, obsolescence, electronic parts

1 INTRODUCTION

Products can be categorized into long life cycle and short life cycle products. Popular consumer electronics, such as computers, mobile phones, GPS (global positioning systems), etc., have relatively short procurement lives and are replaced with newer products within a few years of their market introduction (usually 5 years or less). Long life cycle products, such as those used in aerospace, military, communications infrastructure, power plants, and medical applications, remain in use for significantly longer (often 20 years or more). However, long life cycle products, because of their relatively low volume requirements, often do not control their own supply chains and must draw their parts from the same supply chain as high-volume products. Electronic parts are a good example where all products, regardless of their market, must draw parts from the same supply chain; the outcome is a relatively high frequency of involuntary part obsolescence [1]. As a result, the assessment and management of parts used in long life cycle electronic products differs significantly from their short life cycle counterparts.

Sourcing strategies (e.g., sole, single, second, dual, and multi sourcing) may be adopted to mitigate supply chain disruptions as well as reduce procurement cost by promoting competition between suppliers. Although, supply chain risk and sourcing strategy has been extensively studied for high-volume, short life cycle products (e.g., [2,3]), the applicability of existing work to long life cycle products is unknown. Existing methods used to study part sourcing decisions, especially for high-volume consumer oriented applications, are procurement-centric where cost tradeoffs at the part level focus on part pricing, negotiation practices and purchase volumes [4-7]. These studies are commonplace in strategic part management for short life cycle products; however, conventional procurement-centric approaches offer only a limited view of the assessment of parts used in long life cycle products providing little to no insight into

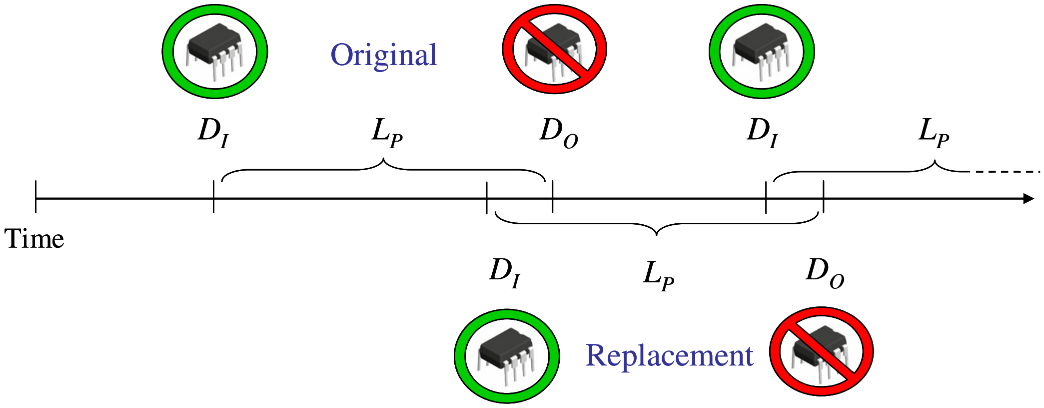


Figure 1 – Procurement life (L_P) as a measure for length of a part's procurement life cycle

the accumulation of life cycle cost (attributed to the adoption and use of the part over a long period of time), which can be significantly larger than procurement costs in long life cycle products [8]. For example, the procurement price of an electronic part has almost no correlation to life cycle cost of the part for small volumes of parts in products that are supported for long periods of time, [8]. In addition, like short life cycle products, the impact of supply chain failure has been recognized as a major concern in the manufacturing and sustainment of long life cycle products, however, the impact of the risk and the cost of mitigating supply chain disruptions on long life cycle products have not been quantified. For example, obsolescence status and forecasts for electronic parts are available through commercial databases, however, the interpretation and application of the forecasted obsolescence characteristics to optimize the sourcing and inventory management for the parts has never been done.

This paper presents a life cycle modeling approach to quantify the risk that part sourcing strategies are exposed to as a result of supply chain disruptions for long life cycle systems. The comparison of various sourcing strategies for use in long life cycle systems provides application-specific insight into the cost benefits of each as a proactive approach to mitigate supply chain disruptions. An example case study to address obsolescence risk was performed using a complete dataset of historic obsolescence information for linear regulators.

2 OBSOLESCENCE RISK MODEL

Many technologies and parts have life cycles that are shorter than the life cycle of the product or system they are in. Life cycle mismatches caused by obsolescence can result in large life cycle costs for long field life or long life cycle systems. This section addresses DMSMS (Diminishing Manufacturing Sources and Materials Shortages) type obsolescence, which is defined as the loss of the ability to procure a technology or part from its original manufacturer [1]. Forecasting when technologies and specific parts will become unavailable (non-procurable) is a key enabler for pro-active DMSMS management and strategic life cycle planning for long field life systems. However, knowing when a disruption will occur is only part of the problem. The impact or consequence of a disruption is often related to the timing of the event and must be consider in the assessment of sourcing strategies.

This section describes the method used to assess the risk that a sourcing strategy is exposed to. The two components of this risk are: 1) the consequence or severity of a risk related event, and 2) the likelihood that the event will occur. Likelihood and consequence are combined to quantify risk as "annual expected TCO per part site," which is suitable for comparing various sourcing strategies over the part's life cycle (period of time that the part is used within an organization).

2.1 OBSOLESCENCE LIKELIHOOD

Sandborn et al. [9] predicts DMSMS obsolescence in terms of procurement life, L_p, determined from a database of past obsolescence data as described in (1) and Figure 1.

$$L_P = D_O - D_I \tag{1}$$

where,

L_P = Procurement life, amount of time the part was (or will be) available for procurement from its original manufacturer
D_O = Obsolescence date, the date that the original manufacturer discontinued or will discontinue the part
D_I = Introduction date, the date that the original manufacturer introduced the part

The distribution of procurement lives (L_P) observed for parts introduced in the past can be fit with a Weibull (2-parameter) using Maximum Likelihood Estimation (MLE). The shape (β) and scale (η) parameters obtained through MLE provide a Weibull distribution representative of the part's procurement life. The method has been demonstrated on a range of different electronic parts and for the trending of specific part attributes

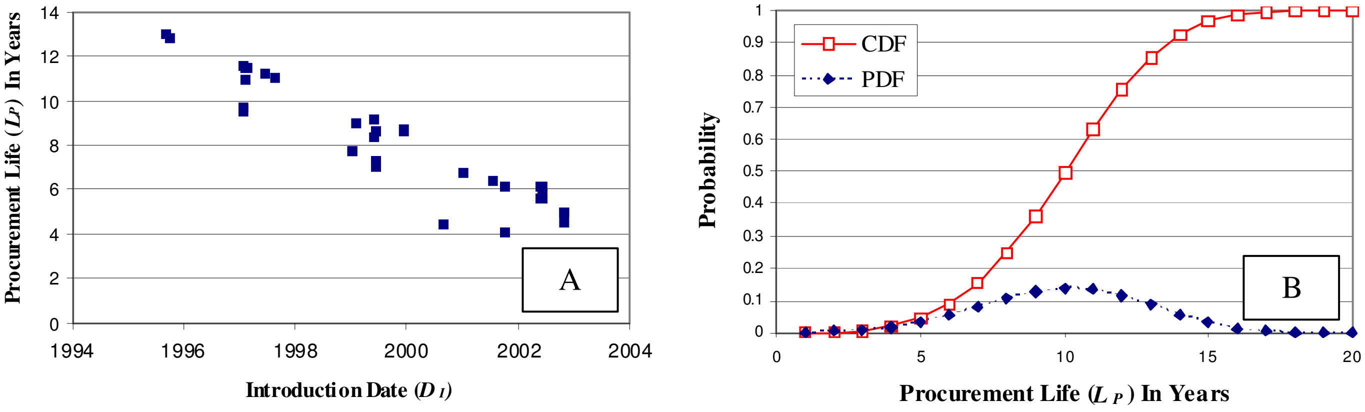


Figure 2 – Supplier-specific procurement life data for linear regulators (ON Semiconductor): (A) raw obsolescence data from SiliconExpert; (B) censored PDF and CDF of obsolescence risk likelihood over time

[9]. This method can also be applied to address the likelihoods of supplier-related part obsolescence events.

The obsolescence data used to estimate likelihood for the example that follows consists of a complete dataset of all the linear regulator parts introduced through 2008: 347 obsolete and 509 non-obsolete parts from 33 manufacturers. Censored PDF and CDF distributions for procurement life (L_P) shown in Figure 2B can be generated from raw supplier-specific data (data for ON Semiconductor is shown in Figure 2A) using MLE as described in [9]. Note, the Weibull distribution, like most parametric fits, evolves over time as more data is accumulated. The method in [9] generates censored Weibull distributions to account for the fact that the data is right-censored, i.e., the dataset used in this study contains introduction dates for all parts, 347 of which have obsolescence dates and 509 of which were not obsolete as of 2008.

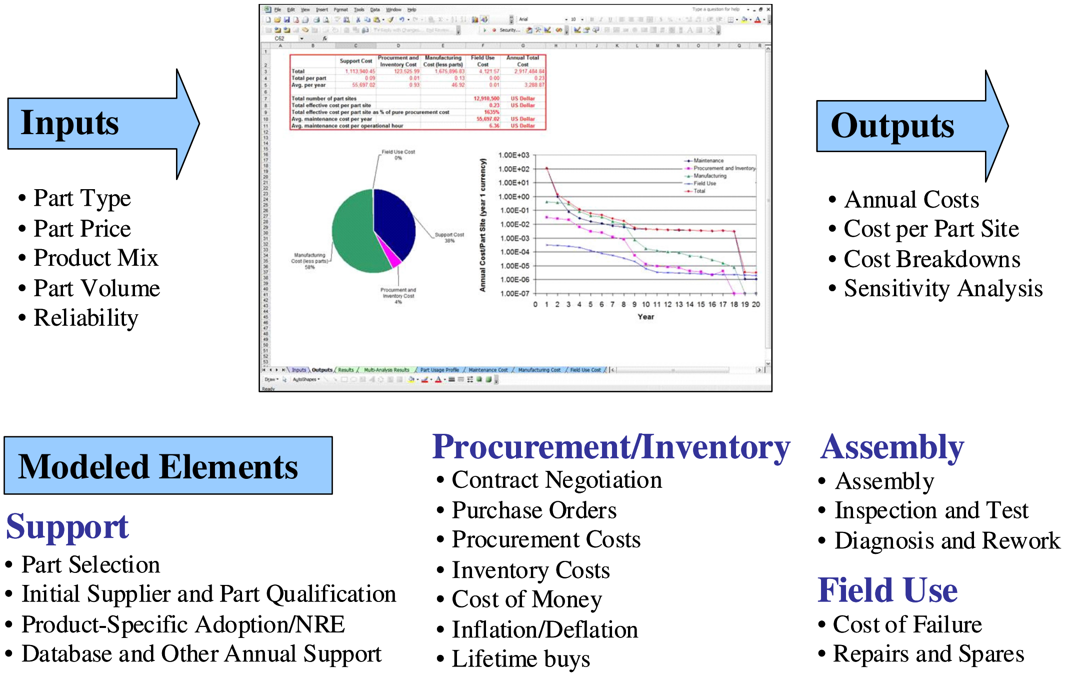
The censored CDF of L_P (Figure 2B) can be interpreted as the probability (likelihood) that a part will be obsolete L_p number of years after it is introduced. The supplier-specific CDFs will be used in Section 3.2 to estimate effective CDFs for second sourcing strategies. Similarly, the PDF of L_P is the probability (likelihood) that a part will become obsolete during specific intervals of time after it is introduced. PDFs are used in (3) in Section 2.3 to quantify obsolescence risk annually.

2.2 DISRUPTION CONSEQUENCE (PART TOTAL COST OF OWNERSHIP)

In this paper we consider the consequence of a supply chain disruption as a cost that is included in the total cost of ownership of the part. The total cost of ownership is a function of the timing of a disruption event and the impact the event has on the characteristic usage of the part within the OEM. This section presents a modification to the Part TCO model developed in [8] to assess the life cycle cost impacts of different sourcing strategies as a function of the date of supply chain disruptions.

The part total cost of ownership (TCO) model presented in [8] accounts for both assembly costs (including procurement) and life cycle costs associated with using the part in products, as calculated in the following four sub-models (Figure 3): procurement and inventory model, part support model, assembly model, and field failure model. The TCO model provides a basis for life cycle cost analyses and an environment within which to evaluate part selection and management tradeoffs. The model focuses on optimal part management from a part selection and management organization's viewpoint. This approach comprehends supply chain constraints that are associated with specific parts and their effects downstream at the product level. The model has been previously used to address design reuse of parts, part number reduction, retirement of parts from databases, organizational adoption of new parts, and part-specific long-term supply chain disruptions by influencing initial component selection and providing guidance on what actions taken at the component management level provide the maximum payback (or maximum future cost avoidance).

The model in [8] indicated that that the costs spent on qualification and approval (categorized as "support costs") are the largest contributors to the part's TCO in low-volume, long life cycle products; in high-volume products, these support costs would be distributed over higher volumes. The problem is exacerbated when these support costs are effectively multiplied with the addition of extra part sources or suppliers. For example, supplier qualification processes must be repeated for a second supplier if dual or second sourcing strategies are implemented before parts from a second supplier can be used. In addition, parts from multiple sources may need to be qualified for use in many (if not all) of the products that the part is designed into resulting in a duplication of product-related support costs; a



Inputs

- Part Type
- Part Price
- Product Mix
- Part Volume
- Reliability

	Support Cost	Procurment and Inventory Cost	Manufacturing Cost (less parts)	Field Use Cost	Annual Total Cost
Total	1,113,940.45	123,525.99	1,675,896.83	4,121.57	2,917,484.84
Total per part	0.09	0.01	0.13	0.00	0.23
Avg. per year	55,697.02	0.93	46.92	0.01	3,288.87
Total number of part sites				12,910,500	US Dollar
Total effective cost per part site				0.23	US Dollar
Total effective cost per part site as % of pure procurement cost				1635%	
Avg. maintenance cost per year				55,697.02	US Dollar
Avg. maintenance cost per operational hour				6.36	US Dollar

Outputs

- Annual Costs
- Cost per Part Site
- Cost Breakdowns
- Sensitivity Analysis

Modeled Elements

Support

- Part Selection
- Initial Supplier and Part Qualification
- Product-Specific Adoption/NRE
- Database and Other Annual Support

Procurement/Inventory

- Contract Negotiation
- Purchase Orders
- Procurement Costs
- Inventory Costs
- Cost of Money
- Inflation/Deflation
- Lifetime buys

Assembly

- Assembly
- Inspection and Test
- Diagnosis and Rework

Field Use

- Cost of Failure
- Repairs and Spares

Figure 3 – Part total cost of ownership (TCO) model for long life cycle electronic systems [8]

process that could potentially lead to expensive design changes if the alternative part is not a direct "drop-in" replacement.

The following describes a modification to the TCO model to address alternative sourcing strategies. A part's support cost for a given supply chain structure includes: initial approval, product-specific approval, annual database support, production support, purchase order generation, supplier setup, obsolescence resolution, etc. Cost changes for additional suppliers can be represented empirically as "learning curves," which reflect improvements in management, methods, processes, tooling, and engineering time. Learning curve models have been applied to relate production cost to the number of units produced for various industries and have also been applied to sourcing problems. Lyon applies learning curves to represent learning effects responsible for inducing collusion in dual sourcing [4]. Conditions for estimating learning curves using price data are discussed in [10]. However, the application of learning curves to support cost components has not, to the authors' knowledge, been previously done. An implementation of the Crawford or Boeing model [11] for supplier-related support cost is shown in (2). In (2), learning curves are applied to support cost components to maintain the "bottoms-up"[1] costing approach. Incorporating learning curves into the total cost of ownership offers a means to capture the decrease in cost to support multiple suppliers wherein information gathered on prior attempts reduces the time (or effort) needed for subsequent attempts of the same activity. The total cost of each supplier-related support cost component in year i can be calculated as follows,

$$C_{sup_i} = \sum_{p=1}^{N_{sup_i}} C_{x_i}\left(p\right)^{B_{x_i}} \tag{2}$$

where,

C_{sup_i} = support cost for year i

C_x = cost of support cost components x, i.e., initial approval, annual support, etc.

B_x = supplier learning index for corresponding support cost component x

N_{sup_i} = number of suppliers for which a support cost component is applicable in year i

i = year (starting at 1)

p = supplier count

In (2), if $B = 0$, then no learning occurs and all support activities are completely repeated for each subsequent supplier. If $B < 0$ then support activities (and thereby, support cost) decreases with the addition of subsequent suppliers. For example, when $B = -\infty$, then the addition of subsequent suppliers requires no support activities and therefore adds no support cost. Similarly, if $B > 0$ then support cost increases for all subsequent suppliers.

The number of suppliers, N_{sup}, is dependent on the type of sourcing structure used in year i. An example matrix of the

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[1] A "bottoms-up" approach to cost modeling assesses life cycle cost by the accumulation of cost components [12].

variable N_{sup} with respect to various sourcing strategies and support cost components C_x is shown in Table 1.

The part's total cost of ownership per part site[2] can be calculated over the part's life cycle within the organization as the sum of assembly, procurement, field failure and support costs divided by the total part usage (total part consumption as a result of all organization-wide activities, i.e., assembly, field replacements, etc.), as described in [8].

2.3 OBSOLESCENCE RISK

The OEM's total cost of ownership of introducing and supporting a group of suppliers, for parts in long life cycle products, can be combined with the estimated likelihood of disruption to quantify the risk of a part sourcing strategy as a function of time. An obsolescence risk, C_{exp}, can be calculated in year *i* as,

$$C_{exp_i} = \sum_{j=1}^{y} C_{TCO_{i,j}} \left(\frac{n_j}{N} \right) = \sum_{j=1}^{y} C_{TCO_{i,j}} f(j) \qquad (3)$$

where,

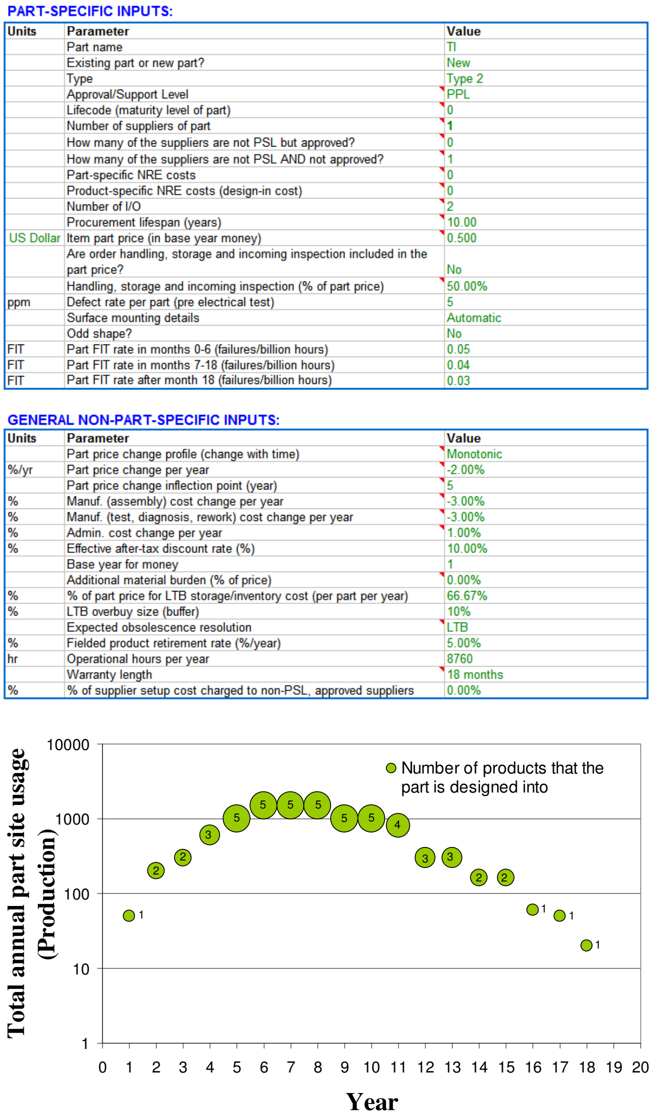
C_{exp_i} = average expected cumulative TCO per part site at year *i*
$C_{TCO_{i,j}}$ = cumulative total cost of ownership (TCO) per part site at year *i* subject to a procurement life of *j*
N = total size of a sampled population from a procurement life PDF
n_j = frequency of sample N with procurement life between *j-1* and *j*
$f(j)$ = PDF value of procurement life between *j-1* and *j*
i = year index of part usage
j = procurement life (in years)
y = longest procurement life in the population (in years)

3 EXAMPLE CASE STUDY

The examples in this section apply the methodology presented in Section 2 to study the sourcing of linear regulators. A linear regulator is a common electronic part that is a voltage regulator placed between a supply and the load and provides a constant voltage by varying its effective resistance. The case study focuses on three specific linear regulator manufacturers: Analog Devices, ON Semiconductor, and Texas Instruments (TI). The study quantifies the risk of single sourcing (from each supplier) and second sourcing (3 combinations of 2 suppliers) as

Table 1 – Example matrix for the number of suppliers (N_{sup}) for which support cost components (x) are applicable with respect to various sourcing strategies

Support cost components (x)	**Number of suppliers (N_{sup})**		
	Single	**Second**	**Dual**
Initial Approval	1	2	2
Part NRE Cost	1	2	2
Product-Specific Approval	1	2	2
Supplier Qualification	1	2	2
Annual Part Data Management	1	2	2
Annual Production Support	1	1	2
Annual Purchasing	1	1	2
Obsolescence Case Resolution	1	1	2



PART-SPECIFIC INPUTS:

Units	Parameter	Value
	Part name	TI
	Existing part or new part?	New
	Type	Type 2
	Approval/Support Level	PPL
	Lifecode (maturity level of part)	0
	Number of suppliers of part	1
	How many of the suppliers are not PSL but approved?	0
	How many of the suppliers are not PSL AND not approved?	1
	Part-specific NRE costs	0
	Product-specific NRE costs (design-in cost)	0
	Number of I/O	2
	Procurement lifespan (years)	10.00
US Dollar	Item part price (in base year money)	0.500
	Are order handling, storage and incoming inspection included in the part price?	No
	Handling, storage and incoming inspection (% of part price)	50.00%
ppm	Defect rate per part (pre electrical test)	5
	Surface mounting details	Automatic
	Odd shape?	No
FIT	Part FIT rate in months 0-6 (failures/billion hours)	0.05
FIT	Part FIT rate in months 7-18 (failures/billion hours)	0.04
FIT	Part FIT rate after month 18 (failures/billion hours)	0.03

GENERAL NON-PART-SPECIFIC INPUTS:

Units	Parameter	Value
	Part price change profile (change with time)	Monotonic
%/yr	Part price change per year	-2.00%
	Part price change inflection point (year)	5
%	Manuf. (assembly) cost change per year	-3.00%
%	Manuf. (test, diagnosis, rework) cost change per year	-3.00%
%	Admin. cost change per year	1.00%
%	Effective after-tax discount rate (%)	10.00%
	Base year for money	1
	Additional material burden (% of price)	0.00%
%	% of part price for LTB storage/inventory cost (per part per year)	66.67%
%	LTB overbuy size (buffer)	10%
	Expected obsolescence resolution	LTB
%	Fielded product retirement rate (%/year)	5.00%
hr	Operational hours per year	8760
	Warranty length	18 months
%	% of supplier setup cost charged to non-PSL, approved suppliers	0.00%

Figure 4 – Part TCO model inputs used in the example linear regulator case study (total production volume = 10,500 part sites)

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[2] A "part site" is defined as the location of a single instance of a part in a single instance of a product. For example, if the product uses two instances of a particular part (two part sites), and 1 million instances of the product are manufactured, then a total of 2 million part sites for the particular part exist. The reason part sites are counted (instead of just parts) is that each part site could be occupied by one or more parts during its lifetime (e.g., if the original part fails and is replaced, then two or more parts occupy the part site during the part site's life). For consistency, all TCO calculations are presented in terms of either annual or cumulative cost per part site.

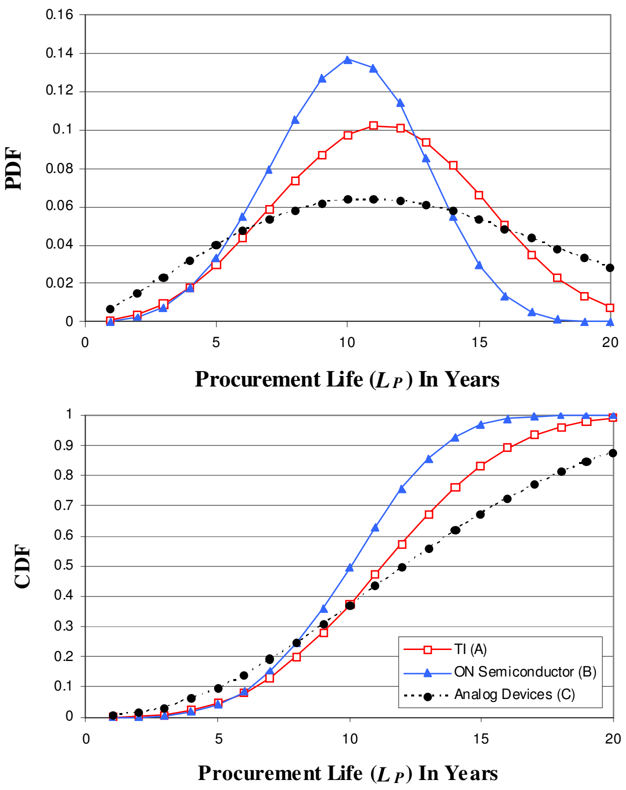


Figure 5 – Supplier-specific obsolescence likelihoods for linear regulators as (top) PDF and (bottom) CDF determined from historical data provided by SiliconExpert. The resulting Weibull fits are given in Table 2.

Table 2. Supplier-specific censored Weibull distribution parameters, β and η. *LKV* is the negative log-likelihood function (larger negative values indicate a better fit).

Weibull Parameters	Texas Instruments	ON Semiconductor	Analog Devices
β (shape)	3.3299	3.9668	2.1858
η (scale)	12.5831	11.0008	14.2503
LKV	69.917	113.246	39.424

well as compares the tradeoffs between each strategy. Using the method described in Section 2, the annual expected cumulative TCO per part site can be calculated. Part-specific inputs, non-part-specific inputs, and the characteristic part usage for the part within the OEM are shown in Figure 4 and are used in all the sourcing cases that follow. The example cases assume that when obsolescence occurs, the OEM performs a lifetime buy of the future projected demand plus a 10% buffer quantity. The lifetime buy is procured at the current price based on inflation and incurs inventory costs annually for the quantity kept in storage at the beginning of each year. The examples also assume that parts from all suppliers are introduced at year 0.

3.1 SINGLE SOURCING EXAMPLE

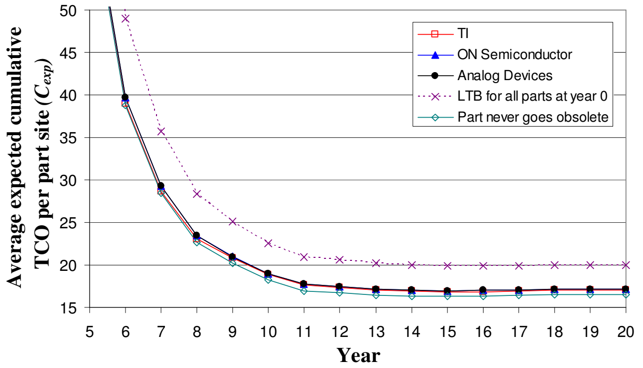
The right-censored PDF and CDF of single sourced linear regulators from the three suppliers considered are shown in Figure 5. The annual expected cumulative TCO per part site (C_{exp}) is plotted over time in Figure 6 and 7 for price independent and price dependent cases respectively.

Figure 6 and 7 each show C_{exp} plotted over time for two special cases: 1) lifetime buy (LTB) for all parts at year 0 – all the parts necessary to support all production forever are procured once at the beginning of the part's life cycle as a lifetime buy for all future production demand, and 2) the part never goes obsolete – the part never requires a lifetime buy and can be procured annually for the entire product life cycle. These two special cases describe bounding scenarios where life cycle cost is at extremes. When a lifetime buy is made at year 0, the total future production volume is stored in inventory from which parts for each year are drawn annually. Alternatively, when the part never goes obsolete, inventory cost is incurred only for the annual production quantity (assuming one purchase order is made every year for that year's production volume). Additional parts may be purchased to replace failed parts or defective parts that have been diagnosed during assembly. The difference in C_{exp} between these two bounding cases is \$3.53/part site after 20 years.

Figure 6 shows C_{exp} plotted over time for a price-independent single sourcing case where parts are procured at \$0.50/part from all suppliers in year 0 (includes deflation in part price of 2% annually). In this case, TI offers the lowest annual expected cumulative TCO (C_{exp}) based on the right-censored CDF of obsolescence risk as expressed in Figure 5. The maximum difference in C_{exp} between these suppliers is \$0.21/part site in 2010 dollars or 1.2% of C_{exp} of ON Semiconductor after 20 years.

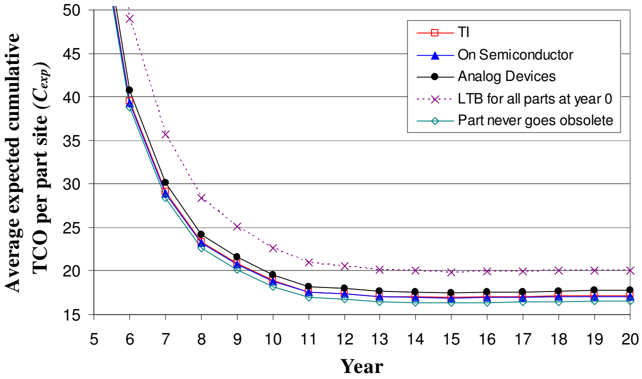
Figure 7 shows a price-dependent single sourcing case for specific linear regulator parts from each supplier. It is the same as Figure 6 except actual part prices are included. The maximum cost difference is \$0.64/part site in 2010 dollars or 3.7% of C_{exp} of ON Semiconductor after 20 years. TI's part, being a more expensive part than ON Semiconductor's by \$0.082/part, exceeds ON Semiconductor in C_{exp} by \$0.080/part site. The CDF value of ON Semiconductor's part is the smallest of the three suppliers until year 6; as a result, the benefit to the overall TCO, for a slightly lower CDF early in the part's life cycle, is almost equal to the cost of having a much higher CDF late in the part's life cycle (year 8 to year 20). Statistically, this indicates that procuring parts from ON Semiconductor offers life cycle cost benefits over the other suppliers as a result of the part site usage and its effect on lifetime buy inventory cost. The part site usage shown in Figure 4 assumes an increase in part sites until year 6, a plateau between year 6 and 8, and a decline that follows thereafter. ON Semiconductor's parts are least likely to go obsolete during periods of high part usage thereby reducing lifetime buy inventory cost.

The single sourcing examples (Figures 6 and 7) show that, if you are going to single source linear regulators, there is no significant difference even with relatively large procurement cost differences. When parts are consumed in low volumes, procurement and assembly costs play a small part in the overall



Suppliers	C_{exp} (at i = 20 years)
Texas Instruments	$16.99
ON Semiconductor	$16.99
Analog Devices	$17.20
LTB for all parts at year 0	$20.05
Part never goes obsolete	$16.52

Figure 6 – C_{exp} over time for single sourcing (price-independent case for linear regulator example)



Suppliers	Part Number	Price (per part)	C_{exp} (at i = 20 years)
Texas Instruments	TPS720105DRVR	$0.702	$17.19
ON Semiconductor	NCP699SN30T1G	$0.620	$17.11
Analog Devices	ADP130AUJZ-0.8-R7	$0.990	$17.75

Figure 7 – C_{exp} over time for single sourcing (price differences included for linear regulator example)

part TCO which are dominated by support costs instead. These examples show that low volume cases are insensitive to procurement price changes. However, for high volume part usage, price differences have a greater impact. An additional effect of high volume part usage is that large lifetime buys also lead to higher inventory cost, which enhances the benefit of selecting parts with longer procurement life. Therefore, for higher part production volumes, the procurement price of a part is expected to have an increasing role in sourcing tradeoffs.

3.2 SECOND SOURCING EXAMPLE

The potential advantage of second sourcing is that the parts can be purchased from two suppliers interchangeably. However, when second sourcing is used, both suppliers (and the parts they supply) are subject to approval and qualification processes within the OEM. The purpose of second sourcing is to ensure a continuous flow of parts and avoid "down-time" (and related penalties) in the event of supply chain disruptions by offering a redundancy in the supply of parts. Essentially, the effective procurement life of a part that is purchased from more than one qualified supplier is the longest procurement life of all the suppliers used.

Consider the following low-volume linear regulator case (shown in Figure 8) to demonstrate the tradeoff between single and second sourcing, as well as possible benefits in supplier selection based on obsolescence likelihood. The second sourcing example in Figure 8 assumes the following: 1) both suppliers are capable of supplying the total annual demand if necessary, 2) no competitive pricing or "split-award" auctions are conducted (procurement price = $0.50/part), 3) no cost to switch between suppliers (once they are qualified), 4) every supplier must be qualified before being used (qualification cost = $100,000/supplier), 5) parts from both suppliers have the same introduction date (D_I), and 6) learning indices, B_x, for support cost components x, are assumed to be 0 (no learning from supplier-to-supplier, i.e., worst case).

The effective probability of obsolescence or CDF of a part procured from two or more sources (N_{sup}) simultaneously at year i can be calculated as follows,

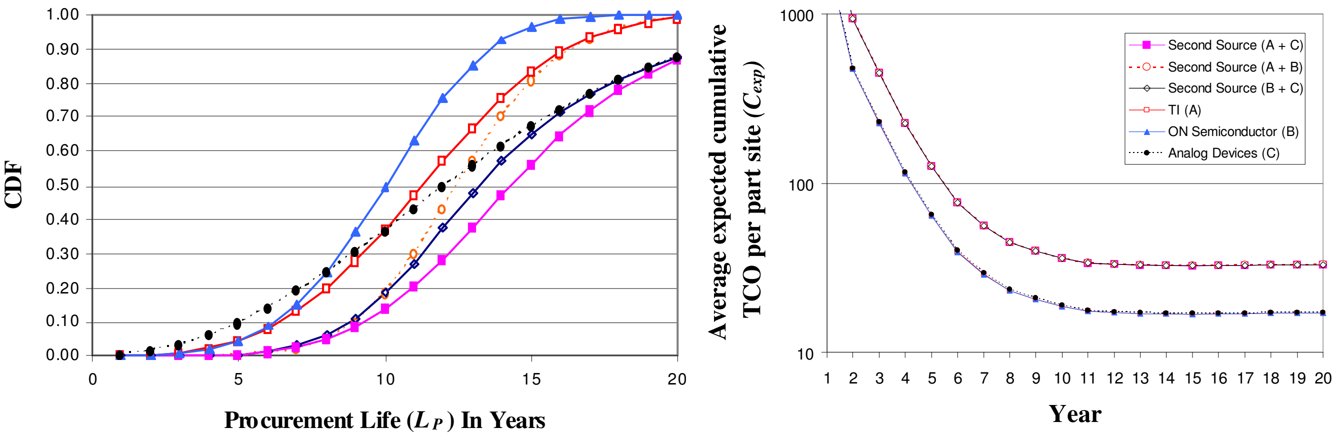
$$F\left(i, N_{\text{sup}}\right) = \prod_{s=1}^{N_{\text{sup}_i}} F\left(i, s\right) \tag{4}$$

where,

$F\left(i, s\right)$ = supplier-specific CDF value at year i for supplier index s

Figure 8 shows the calculated CDF distributions (left) and the corresponding obsolescence risk (right) over time to compare results between single sourcing (from Section 3.1) and their second sourcing combinations. C_{exp} after 20 years, for the second sourcing combination of TI and Analog Devices, is $32.92/part site. This combination is marginally lower than the combination of ON Semiconductor and Analog Devices, which yields a C_{exp} of $32.98/part site, due to the similarities between their second sourcing CDFs. However, the margin between C_{exp} is larger when second sourcing TI and ON Semiconductor due to consistently higher CDF values.

In this case study, the savings (over single sourcing) associated with extending the effective procurement life of the part through second sourcing is negated by the high qualification and support cost related with utilizing a second supplier.



Annual expected cumulative TCO (C_{exp}) after 20 years @ \$0.5/part:
TI + ON Semiconductor = 33.01 per part site
TI + Analog Devices = 32.92 per part site
ON Semiconductor + Analog Devices = 32.98 per part site

Figure 8 – (left) CDF of obsolescence likelihood by sourcing strategy and (right) annual expected cumulative TCO per part site over time by sourcing strategy (price independent case for linear regulator example)

4 DISCUSSION AND CONCLUSIONS

This paper presents a method to quantify obsolescence risk in order to compare sourcing strategies of electronic parts used in long life cycle products and systems. Existing methods used to address sourcing for high volume, short field life products are procurement-centric focusing on procurement pricing, negotiation practices and purchase volumes. The method described in this paper adopts a life cycle approach utilizing a part total cost of ownership model and historic obsolescence data to quantify obsolescence risk, which is suitable for comparing sourcing strategies over long life cycles. This paper presents a calculation for "annual expected cumulative TCO per part site," which can be used as a metric to assess part risk. The methodology is applied in a comparison of single and second sourcing linear regulators from three suppliers: Texas Instruments, ON Semiconductor, and Analog Devices.

The single sourcing cases for linear regulators show that the particular supplier parts are procured from (if the only difference is procurement life and procurement cost) does not make a significant difference even for relatively large procurement cost differences. It was also found to be difficult to make a business case for second sourcing linear regulators based only on maximizing procurement life (if the second source requires qualification). However, the method can be implemented to identify the ideal combination of suppliers, from a life cycle perspective, if second sourcing is predetermined.

A further issue in the management of long life cycle (low volume) electronics caused, in part, by single sourcing policies is the emergence of excessively long delivery lead-times causing disruptions that are albeit temporary yet recurring throughout the part's life cycle. For example, parts bought up by large high-volume OEMs exhaust available commodities causing a back-order for lower-volume purchases. Procured parts may take several weeks and sometimes as long as a year to be delivered to product manufacturers and system sustainers. Therefore, inventory management may be critical to protect against short-term supply chain disruptions for selected parts. This problem is compounded when organizations have chosen to follow "lean inventory" and "just-in-time delivery" management strategies that aim to minimize excess inventory. The trend toward "lean" has been traditionally driven by high inventory cost and limited storage space but variability in lead-times leave organizations susceptible to part unavailability. Future work involves assessing the effects of sourcing and inventory management strategies on the TCO of parts used in long life cycle products to determine when multiple sources should be used and when (and how much) inventory should be held to avoid lead-time problems.

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