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Lifetime Buy Optimization to Minimize Lifecycle Cost

Dan Feng, Pameet Singh, Peter Sandborn
CALCE, Department of Mechanical Engineering
University of Maryland

Abstract

Mismatches between electronic part procurement lifecycles and the lifecycles of the products that they are used in cause products with long manufacturing and/or support lives to incur significant obsolescence management costs. Lifetime buy is one of the most prevalent mitigation approaches employed for electronic part obsolescence management. Making lifetime purchases of parts when they go obsolete involves managing many interacting influences and multiple concurrent buys for multiple parts. The focus of this paper is optimizing lifetime buy quantities by minimizing lifecycle cost. There are multiple factors that contribute to the lifecycle cost associated with a lifetime buy: procurement cost, inventory cost, disposal cost, and penalty cost.

The Life of Type Evaluation (LOTE) tool was created to optimize lifetime buy quantities and minimize lifecycle cost. LOTE requires component and system data. With the given data, LOTE uses stochastic analysis to determine the lifetime buy quantity per part that minimizes the lifecycle cost for the system. LOTE was used to determine the optimum lifetime buy quantities for a Motorola communications system.

Introduction

A significant problem facing many “high-tech” sustainment-dominated systems[1] is technology obsolescence, and no technology typifies the problem more than electronic part obsolescence, where electronic part refers to integrated circuits and discrete passive components. Driven by the consumer electronics product sector, newer and better electronic components are being introduced frequently, rendering older components obsolete. Yet, sustainment-dominated systems such as aircraft avionics are often produced for many years and sustained for decades. Sustainment-dominated products particularly suffer the consequences of electronic part obsolescence because they have no control over their electronic part supply chain due to their relatively low production volumes. This problem is especially prevalent in avionics and military systems, where systems often encounter obsolescence problems before they are fielded and always during their support life.

Many part obsolescence mitigation strategies exist for managing obsolescence once it occurs, including [2]: lifetime buy (also referred to as final order or Life Of Type - LOT buy), last-time buy (also referred to as bridge buy), part replacement, aftermarket sources, emulation, re-engineering, salvage, and design refresh/redesign of the system. The opportunity to make lifetime buys is usually offered by manufacturers of electronic parts prior to part discontinuance (usually in the form of a published “last order date”). Lifetime buys play a role in nearly every electronic part obsolescence management portfolio no matter what other reactive or pro-active strategies are being followed.

The management strategy associated with lifetime buys of electronic parts is to determine the number of parts to purchase prior to the last order date. Lifetime buys are risky, as forecasting demand and sparing requirements for potentially 10-20 years into the future is not an exact science, especially in today's dynamic technology and market atmosphere. Lifetime buys also assume that the system design will remain static, which is seldom the case. Even if the product didn’t change and the number of parts needed in the future could be accurately estimated, stockpiling parts for the future may incur significant inventory and financial expenses. In addition, the risk of parts being lost, un-usable when needed, or pilfered by another program, all of which are very real occurrences for electronic part lifetime buys that may need to reside in inventory for 10 years or more, increases the risk associated with the lifetime buys in the inventory. Figure 1 shows an influence diagram associated with lifetime buys of electronic parts.

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[1] In the context of this paper, “sustainment-dominated” refers to systems whose sustainment (lifecycle) costs exceed the original procurement costs for the system. In this paper, sustainment refers to all activities necessary to, [1]:

- Keep an existing system operational (able to successfully complete its intended purpose),
- Continue to manufacture and field versions of the system that satisfy the original requirements
- Manufacture and field revised versions of the system that satisfy evolving requirements.

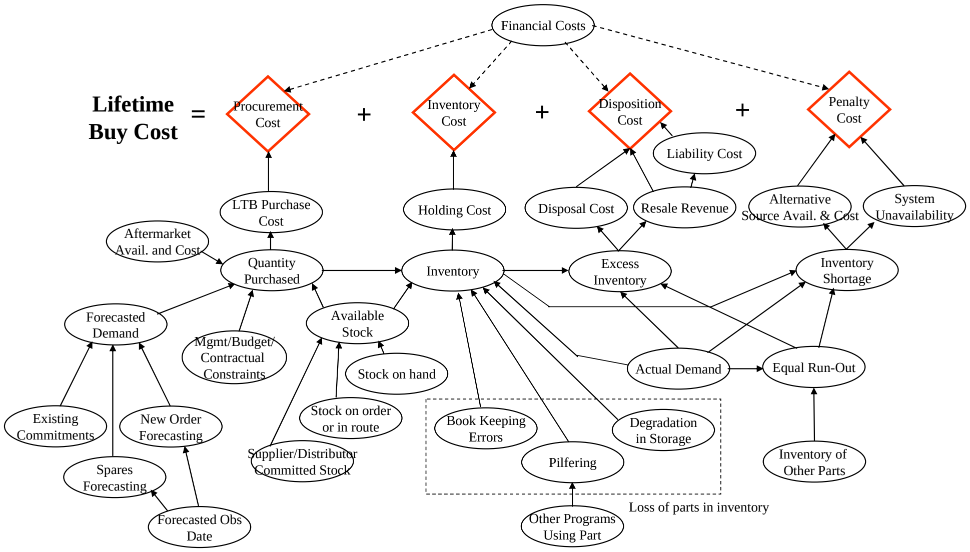

Figure 1 - Cost factors affecting electronic part lifetime buys.

The lifetime buy problem has two facets: 1) demand forecasting, and 2) lifetime buy quantity determination. Demand forecasting is the process of predicting how many parts are going to be needed in the future. The forecasted demand depends on sales forecasts and sustainment expectations for fielded systems. The second part of the problem is the determination of how many parts should be purchased (lifetime buy quantity). This paper focuses on the second part of the problem – the determination of optimum lifetime buy quantities based on uncertain demand forecasts and the other factors expressed in Figure 1.

Existing final order models [3,4], are intended for systems like complex manufacturing machinery that have long-term service contracts. To be able to provide long-term service, a manufacturer must be able to supply parts throughout the service period. However, the duration of the service period is typically much longer than the production period for the machine. The period after the machine has been taken out of production is called the end-of-life service period (EOL). To avoid out-of-stock situations during the EOL, an initial stock of spare parts is produced at the beginning of the EOL. This initial stock is called the final order. Existing models, address both the seller's perspective [3], and the buyer's perspective [4]. The electronic part obsolescence problem addressed in this paper is applicable to the seller's perspective, where the seller stores the parts in the inventory for future use, whereas, the buyer deals only with line replaceable units (LRUs) and systems.

The lifetime buy problem for electronic systems differs somewhat from that for maintaining a piece of equipment. Organizations that make lifetime buys of electronic parts generally have little or no control over the supply chain for the parts and cannot manufacture the parts themselves. These organizations can purchase parts until the part manufacturer discontinues the part at which time they must place a final order or implement some other mitigation strategy. In many cases, a substantial portion of an electronic system's content is obsolete before manufacturing of the system concludes (for avionics and military systems, it is not uncommon for 70-80% of the electronic part content of systems to be obsolete prior to the first system being fielded), and sustainment may continue for 10-20 years or more after that. Final order quantities for electronic parts range from a few thousand to 50,000 or more of a single part in a system that may be composed of hundreds of parts (a substantial portion of which may have lifetime buys). Under-buying at a lifetime buy by a few parts can be accommodated via secondary market sources or the use of salvaged parts,[2] however, under-buying by a significant quantity cannot be easily rectified and may require a design refresh to replace the part. Design refreshes for avionics and military systems may be prohibitively expensive due to re-qualification/re-certification requirements. While many of the mitigation approaches in [2] are practical options for small production volume systems, the only viable alternatives for large volume problems are lifetime buys or bridge buys until planned design refreshes.

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[2] Use of the secondary brokers and/or salvaged parts is in general not a recommended practice. A strict reliability and quality oversight is required before using such options.

This paper presents a model that extends the final order model for machine equipment [3] and applies it to the electronic part obsolescence problem (see the Appendix for the detailed calculations). The only other known quantitative treatment of lifetime buy optimization for electronic parts is by Rugina [5], which discusses various models for lifetime buy quantity determination without implementation. The model presented in this paper includes the major influences in Figure 1, but does not contain explicit details of everything shown in the figure.

Life of Type Evaluation (LOTE) Tool Overview

The Life of Type Evaluation (LOTE) tool is an extension and transformation of the Teunter and Fortuin model (see Appendix) into a usable form for electronic part lifetime buy analysis. The LOTE tool is capable of calculating optimum lifetime buy quantities and bridge buy quantities that will provide the minimum lifecycle cost. As input, LOTE requires component and production information, including:part obsolescence dates, number of instances of a part in the system, part cost/unit, part holding cost/unit, part penalty type (available/unavailable) and penalty costs, part disposal cost/unit, system demand and supply, refresh dates, and discount rate.

The LOTE software uses Monte Carlo analysis to represent the stochastic nature of the lifetime buy problem. The uncertainties lie with the forecasted demand/supply, part obsolescence date, and various cost factors. As previously mentioned, the demand forecasting aspect of this the lifetime buy problem is out of the scope of this paper. It is assumed that demand forecasts are supplied from another source. Likewise, parts obsolescence dates are not always certain. System unavailability penalty and system availability penalty are difficult to predict and at times hard to quantify. The uncertainties involved with part demand, obsolescence dates, and penalty costs justify the stochastic nature of the solution.

The sequence of steps that LOTE follows to optimize the lifetime buy or bridge buy quantities and minimize lifecycle cost (sustainment cost) are shown in Figure 2. For lifetime buys, all parts with obsolescence dates within the sustainment period are arranged in order of increasing obsolescence dates (earliest to latest). LOTE starts with the first part to become obsolete and assumes there is no future view of the system past the current time. It assumes either all parts in the future do not go obsolete or lifetime buys for all future parts are perfect and result in a constant increase in overall cost to the system. Using this assumption and the Monte Carlo sampling of input data distributions, LOTE determines the lifetime buy quantity that gives the minimum lifecycle cost for the first part.

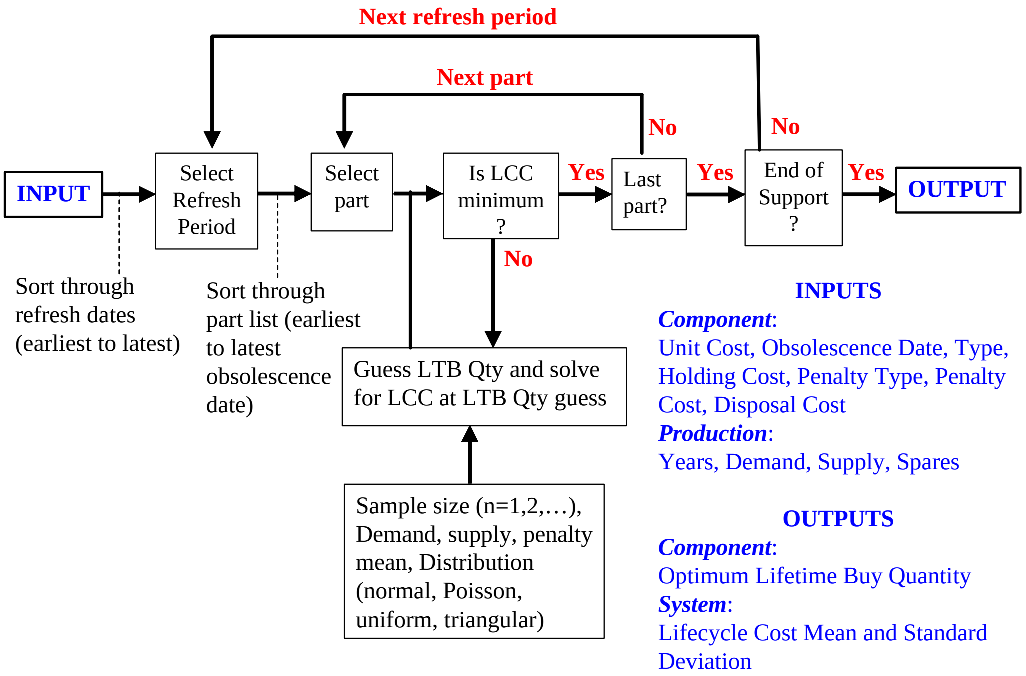

Figure 2 - Life of Type Evaluation Tool sequence of events with refresh insertion.

The search for the lifetime buy quantity that gives the minimum lifecycle cost is conducted through a gradient search algorithm. The solution to this optimization problem is a single minima (lifecycle cost) at the optimum lifetime buy quantity. To search for the minimum lifecycle cost, LOTE varies the lifetime buy quantity from 0 to m (default maximum lifetime buy quantity value) and calculates the lifecycle cost at each of these quantities. It uses the solutions (lifecycle cost) and slopes at these lifetime buy quantities to determine the next estimate search lifetime buy value until it finds the minimum lifecycle cost and the associated lifetime buy quantity. The minimum lifecycle cost is found at m-1, where the slope at that point becomes positive. For each of the lifecycle cost calculations, the demand and penalties are sampled from distributions using Monte Carlo analysis. The distribution values are used to find a mean lifecycle cost at the lowest non-negative lifetime buy quantity where the slope of the lifecycle cost curve is positive.

Upon finding the lifetime buy quantity that gives the minimum lifecycle cost for part one, the second part to go obsolete undergoes the same analysis with the same assumptions and one additional factor. It also considers the previous part's obsolescence date and lifetime buy quantity. If the first part runs out before the end of the system lifecycle, the second part will make a more conservative lifetime buy than if part one was not considered. The subsequent parts follow this same procedure to determine lifetime buy quantities and lifecycle costs. Ideally these steps are embedded within another Monte Carlo loop for the obsolescence dates.

For bridge buys when design refreshes are involved, LOTE first sorts all the refresh dates into ascending order. Rather than purchasing enough parts to last until the product end-of-life, within each refresh period enough parts are purchased until the refresh point or the end-of-life. After each refresh all parts that became obsolete and were purchased until the refresh date have their lifetimes (obsolescence dates) reset based on the type of part (LOTE assumes that all parts that become obsolete prior to the refresh are replaced at the refresh). The new replacement part is treated like other original parts, and may become obsolete again in the proceeding refresh periods.

It is often the case at redesigns that engineers will look ahead a predetermined time period for parts that are expected to become obsolete and design out those parts in addition to the previously obsolete parts. This predetermined time is known as the look-ahead time [1]. With the re-design date insertion, LOTE offers users the option to insert a look-ahead time in years. LOTE adds this quantity to the designated redesign dates and essentially pushes the redesign date ahead by the look-ahead period. All other analyses are the same.

To simulate the lifetime buy and bridge buy problem faced in industry, the demand is varied yearly, e.g., Figure 3. In addition, the demand in each year is independently distributed without consideration of the distribution of the demand in other time periods.

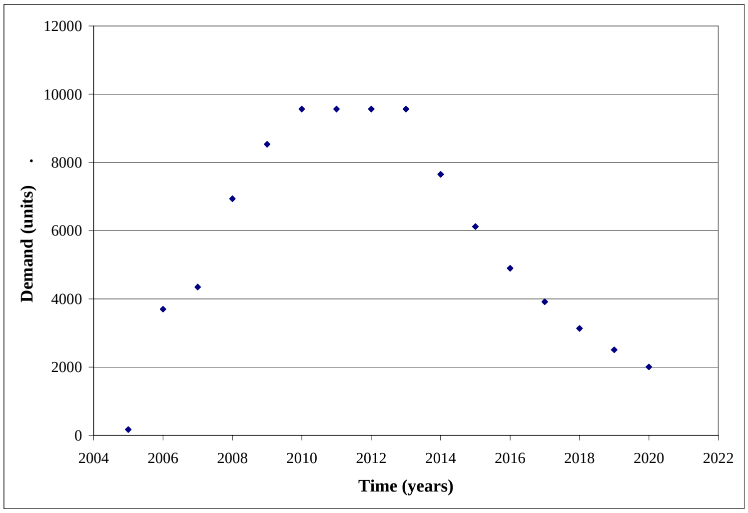

Figure 3 - Production profile for Motorola Infrastructure Base Station.

Single Part Motorola Infrastructure Base Station Case Background

The Motorola Infrastructure Base Station is a commercial off-the-shelf RF base station communications system. The Infrastructure Base Station program provides a radio frequency hardware platform for a variety for systems and communication modes. It also replaces several older base station products that Motorola offered. Over its 16 years planned manufacture and sustainment lifetime, more than 115,000 systems will be manufactured. It is comprised of 1218 components total, of which 249 are unique components. Its production period started in 2005 and is planned to complete in 2020. The end of support date for this product is at the end of the year in 2020. The forecasted demand for each production year is depicted in Figure 3. Figure 4 shows the number of forecasted electronic part obsolescence events throughout the system lifetime.

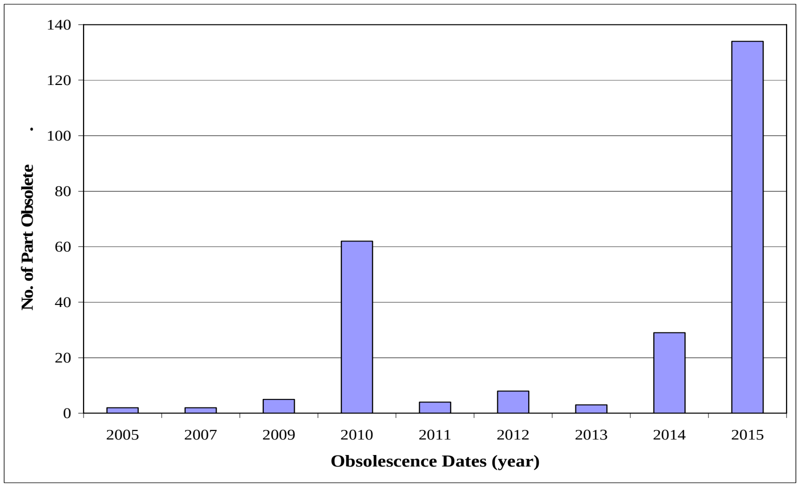

Figure 4 - Number of obsolete parts vs. obsolescence dates.

The Infrastructure Base Station program data was previously analyzed using the Mitigation of Obsolescence Cost Analysis (MOCA) software, [1]. MOCA results were instrumental in recommending an optimum refresh plan to Motorola. The recommended optimum refresh plan was a single refresh in the year 2011. The LOTE analysis performed in this paper assumes the MOCA determined 2011 refresh date and optimizes the lifetime buy quantities.

Based on inputs from Motorola, the following default data was assumed:

- Non-recurring Cost: $200,000 per part (available after obsolescence, but requires a resurrection fee)
- Availability Penalty: 3 times the original Unit Cost/Part
- Unavailability Penalty: $2,000/System
- Holding Rate: 5% Unit Cost/Part/Year
- Cost of Money (discount rate): 10%
- Net Present Value Baseline Date: 2005
- Demand Distribution: Poisson Distribution
- Refresh Date: 2011

In order to express the LOTE solution we define a quantity called Lifetime Buy Ratio given by,

$$\text{Lifetime Buy Ratio} = \frac{\text{Optimum Buy Quantity}}{\text{Expected Demand Quantity}} \tag{1}$$

where:

Optimum Buy Quantity = optimum lifetime buy quantity of a part predicted by LOTE
Expected Demand Quantity = quantity of a part predicted by the mode of the demand.

When the Lifetime Buy Ratio is 1, the optimum solution is purchased at exactly the expected demand quantity. When the Lifetime Buy Ratio is greater than 1, the optimum solution is purchasing greater than the expected demand quantity, and when the Lifetime Buy Ratio is less than 1, the optimum solution is purchasing less than the expected demand quantity.

Figure 5 shows the lifetime buy ratio for all parts purchased versus their purchase dates (there are 277 separate buys for each case shown, many buys overlap on the plot). The figure takes into account a refresh date in 2011. Holding cost was determined from data analysis to have a small affect, and is thus fixed at the Motorola specified 5% of unit cost per part. Figure 5 plots results for several availability penalty scenarios. The three results are for zero non-recurring costs and varied availability penalty multipliers of 1, 3, and 300 times the unit cost per part. The lifetime buy ratio for availability penalty equal to unit cost are very close to zero and are not visible in this figure. The penalty is so small that the system would rather run short of inventory after lifetime buy and pay for penalties than purchase more parts, i.e., he system is purchasing much below expected demand. As availability penalty increases to 3 times the part unit cost, the lifetime buy ratio for each part jumps to very close to, but below 1 for most parts. In these situations, the penalty cost becomes a significant factor in the lifecycle cost equation and pushes the lifetime buy quantity close to but still below expected demand to reduce penalties.

One other case graphed in Figure 5 has an additional non-recurring (resurrection) cost with the availability penalty of 3 times part unit cost. It is common when inventory becomes short for product suppliers like Motorola to request part resurrections from manufacturers. Part resurrection refers to requests that manufacturers receive to restart manufacture of an obsolete part. The cost estimate from Motorola for a non-recurring resurrection is $200,000 per part as shown in Figure 5. For the $200,000 non-recurring cost cases, the penalty is so high that the system purchases more than expected demand for all parts to avoid incurring the penalty. In fact, these results are very similar to results for zero non-recurring cost with high availability penalty of 300 times the part unit cost. Regardless of how penalties are allocated, once they become very high in comparison to all other costs in the system, the system behaves very similarly for all cases. LOTE purchases greater than expected demand consistently for all parts. It purchases just enough parts that penalties are very unlikely to occur and purchases not many more parts above that quantity. Figure 5 shows that all lifetime buy ratios hover between 1.01 and 1.07. These systems purchase between 1% and 7% more than expected demand.

There are a small number of parts that have lifetime buy ratios much greater than other parts at the same analysis. It was found that these parts have very low unit costs. Purchasing significantly above the expected demand quantity for these low unit cost parts has approximately no negative affect on the lifecycle cost ratio. Therefore it is beneficial to over-estimate their lifetime buy quantities greatly.

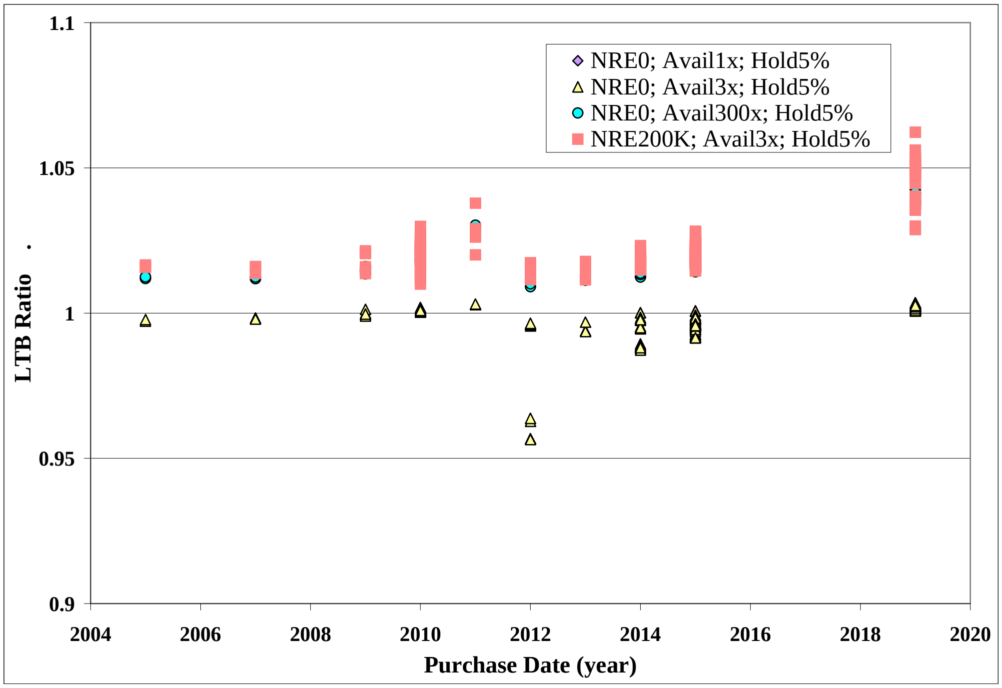

Figure 5 - Lifetime buy ratio for variations in availability penalty (refresh = 2011, holding rate = 5% unit cost/part).

Historical Motorola Lifetime Buy Buffers

Motorola has been collecting lifetime and bridge buy quantity information since the late 1990s. Based on information provided from their business and engineering departments about product demands, persons at Motorola who make lifetime buys often add a “buffer” to the demand prediction. The buffer is a percentage of parts to purchase above the demand prediction provided. It is the equivalent of the lifetime buy ratio in percentage format. It is a qualitatively determined estimated based on a number of variables such as product size, lifetime, and technological complexity.

Figure 6 shows 181 lifetime buys and bridge buys that Motorola has recorded for all systems that require lifetime buys and/or bridge buys (not exclusive to the Infrastructure Base Station case considered in this paper). The data is divided into 3 sets, lifetime buys, bridge buys, and buys made without a buffer (at demand) before 2004. In 2004, the buffer was formally introduced at Motorola. Prior to this date, although some buffers may have been added to demand predictions, there was no formal process to insert a buffer based on the part specifications.

For lifetime buys, the average buffer size Motorola uses is approximately 39% (lifetime buy ratio = 1.39). Bridge buys have average buffer sizes of about 23%. These are significantly larger than the LOTE recommended lifetime buy ratios of 7% at most for the Infrastructure Base Station (Figure 5).

LOTE’s analysis of the infrastructure base station indicates maximum lifetime buys of approximately 7% over expected demand. Figure 6 indicates that Motorola is over purchasing on its lifetime buys. There are a number of possible explanations for the discrepancy between the LOTE optimized results and the Motorola’s historic practices. When making lifetime buy decisions, Motorola does not emphasize the cost of inventory and the cost of money. They primarily emphasize avoiding part shortages. Engineers feel the short-term pain associated with running short of parts and overcompensate by buying too many parts at lifetime buys without a view to all the actual lifecycle costs. Equal attention is not placed on all costs that contribute to lifecycle cost. This result suggests that organizations should consider the entire cost associated with a lifetime buy, not just the penalties, when making overbuy decisions, paying closer attention to all lifecycle costs (especially the inventory costs and cost of money) rather than just focusing on the penalties of under-buying.

Another explanation for the smaller optimum lifetime over-buy sizes predicted by LOTE may lie with the input data to the model. The Monte Carlo analysis used in LOTE distributes uncertainties based on a user specified distribution model. All of the results generated from LOTE presented in this paper assumed a Poisson distribution for the demand. This distribution is commonly used to generate stochastic values for demand and inventory predictions at companies such as Motorola, however, the Poisson distribution may not adequately account for the risk of life extensions that occur for some products. The Poisson distribution variation percentage from the input

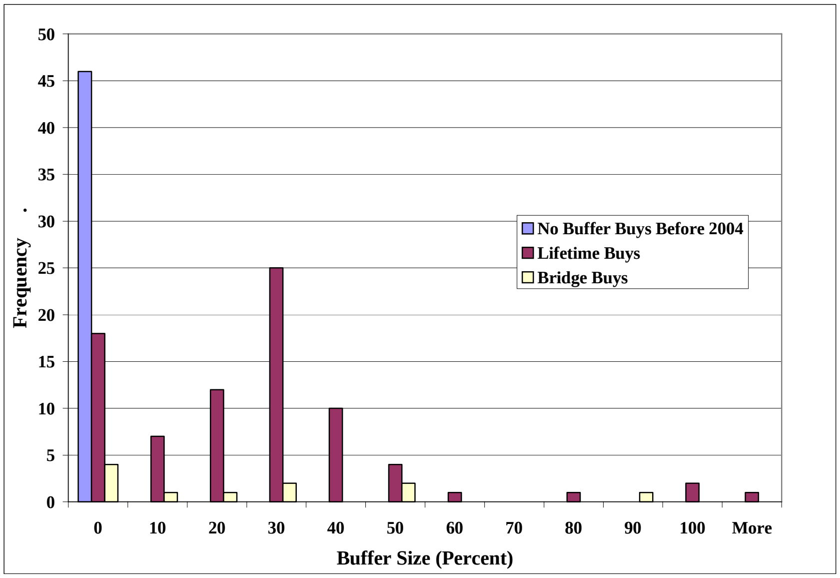

Figure 6 - Historic Motorola lifetime buy buffer sizes (181 buys are included).

mean is on average 4%, whereas the expected demand could be low by substantially more if a life extension situation is encountered.

Figure 7 plots the results for a triangular distribution with 30% variation on either side of the mean (expected) demand values provided by Motorola. At 30% variation with the triangular distribution, the lower limit of the distribution is 30% less than the mean, and the upper limit of the distribution is 30% greater than the mean. This allows for greater uncertainties in the lifecycle cost calculations than the Poisson distribution, which only had about 4% variation on either side of the demand mean. As speculated, the triangular distribution with 30% variation has higher lifetime buy purchases than the Poisson distributions. However, even at 30% variation the lifetime buy purchases are still only 10% - 20% above the demand quantities.

These results indicate that even if the LOTE implemented Poisson distribution is a tighter distribution than used by Motorola, the lifetime buy buffer sizes from the Triangular distribution at 30% are still lower than those used at Motorola currently. Currently Motorola uses on average a 39% buffer above their forecasted demand values to make lifetime buys.

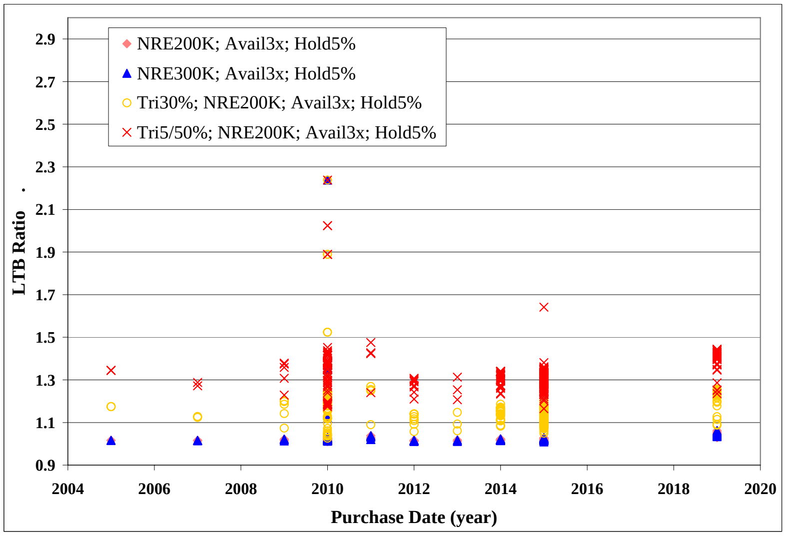

Figure 7 - Triangular distribution results of lifecycle cost ratio versus purchase date.

Also shown in Figure 7 are results for a life extension simulation. Often times, product lifetimes may be extended at the end of its life for various reasons (i.e., requirements from the customer to continue support). The risk of life extension is simulated by the results for the triangular distribution with -5% and 50% variation. The high uncertainty to the right of the mean demand value is modeled by the 50% variation. The results show that even with the risk of life extension LOTE still only suggests lifetime buy buffer sizes of approximately 30% (LTB ratio = 1.3), 10% less than the average buffer size Motorola is currently using. Additionally, the 50% variation is a generous assumption of the uncertainty. The results from Figure 7 support the assertion that the average buffer sizes Motorola is currently using are larger than optimum and are not minimizing the lifecycle cost of the system.

Summary

This paper describes a solution to lifetime buy quantity optimization implemented within the Life of Type Evaluation (LOTE) tool. It has also shown LOTE's capability to analyze complex, multi-part systems with refresh dates, changing demand profiles, and modified demand distributions. The results for the Motorola Infrastructure Base Station case indicate that demand distribution plays an important role in the results obtained. The LOTE results have also revealed that organizations making lifetime buys may be placing more emphasis on the short-term under-buy penalty costs and less on the inventory and procurement costs that contribute as much or more to the lifecycle cost, and as a result organizations may be consistently overbuying their lifetime buys.

APPENDIX – Final Order Model

The basic model used for this body of research extends the work of Teunter and Fortuin [3]. Their research models the lifetime buy (also known as final order or life of type) purchase problem faced in industry. As described in the introduction, lifetime buy purchasing is a popular solution for dealing with part obsolescence. Lifetime buy purchases are made at the risk of purchasing either more or less than demand. In either situation, there are unwanted costs that contribute to the lifecycle cost of the system. Teunter and Fortuin model this problem using various cost factors (procurement, inventory, disposal, and penalty) and analyze the problem to minimize lifecycle cost by balancing all cost factors through optimizing the lifetime buy quantity of parts upon obsolescence. The model iterates through the product lifecycle by user specified time periods and accumulates costs that contribute to sustainment at each time step.

The Teunter and Fortuin model is the foundation used in the work reported in this paper. It assumes a finite time span that starts at $t = 0$ (D_0) and ends at $t = L$ (D_e). The planning horizon or product lifecycle is L, in years. The start date denotes the beginning of the analysis and the end date represents the end of system support for lifetime buys or planned design refreshes for bridge buys. The analysis is divided into user defined time step lengths T. For each part in the system, at each time step, the model records the part inventory level, procurement cost, holding (inventory) cost, and accumulated penalty cost. When a part goes obsolete and a lifetime buy needs to be made, at the first time step for each part, procurement costs are incurred along with holding cost for storage of all procured parts. At each subsequent time step, the holding cost decreases as the quantity decreases with part usage. If the inventory of lifetime buy parts runs out, penalties are incurred. These costs are summed together for all time steps in order to obtain a single lifecycle cost for the entire system. Any remaining parts in stock at the end of the system life that are not required to meet demands are disposed of. They may be salvaged, resold, or removed at a fee that is also summed into the lifecycle cost at the final time step.

This model operates under a set of assumptions. The planning horizon is divided into T intervals of length L/m where m is a user specified length (e.g., years, months, weeks, quarters, etc.). The analysis time intervals are represented by j and span $[j - 1, j)$, $j = 1, 2, \ldots, T$. The demand and supply are allotted at the end of the interval, and the supply can fill the demand in the same interval. Penalty costs are allocated at the end of the interval, and holding costs are allocated at the beginning of the interval. For all intervals, the demand and supply distributions are known and are assumed to be independent.

The mathematical model for a single part (i) is represented in (2). The objective is to minimize the value of the following expression over all $n_i \geq 0$, [3]

$$a^{j_i-1} c_i n_i + \underset{s_j, D_j}{E}\left[\left(\sum_{j=j_i}^{T} a^{j-1}\left(\frac{h_i}{12} S_{j(i)} + a p_i \left(S_{j(i)} + \left(s_j - d_j\right) q_i\right)^-\right)\right) + a^T r_i \left(S_{T(i)} + \left(s_T - d_T\right) q_i\right)^+\right] \tag{2}$$

where,

a	Function of the discount factor ($e^{-R/12}$), R = time in years from start date
c_i	Initial purchase cost of the part i (present when $t = t_i$)
n_i	Final order purchase quantity for part i at the beginning of time step 1
s_j	Supply of system parts (quantity distribution), in jth time step
$E[]$	Expected value
d_j	Demand of system parts (quantity distribution), in jth time step
D_j	Date corresponding to the current time step j
h_i	Holding cost for part i (present when $t > t_i$)
$S_{j(i)}$	Stock at the beginning of interval j for part i; $S_1 = n_i$
p_i	Penalty cost of part i if it is obsolete but available from alternative sources
p_{su}	Penalty cost of system if any of its parts is unavailable from all possible sources
r_i	Remove/residual cost of part i (parts removed at the end of life)
J	Index of the current time step
T	Time
t_s	Time step (in years)
O_i	Date of obsolescence for part i
G	Total expected discounted cost for a given stock quantity (n_i)
q_i	Instance of part i in a single system.

The Life of Type Evaluation tool (LOTE) is an extended version of the Teunter and Fortuin model. LOTE is a practical transformation of the Teunter and Fortuin model with additional features that allow it to be applied to electronic part lifetime buy management problems. LOTE takes into account all cost factors that contribute to procurement lifecycle cost (procurement, inventory, disposal, penalties) and weighs the positives and negatives to solve for a lifetime buy quantity that will result in the lowest lifecycle cost. Rather than categorizing all penalties as the same, the extended model breaks penalties into two distinct types, availability and unavailability. Availability penalties assume that the part is available if the lifetime or bridge buy runs out, but at a cost penalty (from the original supplier or a third party source). Unavailability penalties assume that the part is not available if the lifetime or bridge buy runs out, and that the penalty incurred is at the system level, i.e., loss of ability to support a customer, loss of ability to sell additional products, loss of future sales, etc. If a part is unavailable, the entire system will not be produced as all parts are assumed to be critical and the remaining parts experience equal run-out, i.e., the unavailable parts cause the remaining parts to be useless as well.

LOTE can handle more complex problems than the original Teunter and Fortuin model. LOTE solves for lifecycle cost for an entire multi-part system concurrently rather than one part at a time and accounts for equal run-out. LOTE also accounts for uncertainties in the demand and penalty inputs through a variety of distributions (normal, uniform, Poisson, triangular) and variations in demand. LOTE also allows users to define re-design dates and look-ahead times for bridge buys in addition to lifetime buys. Additionally, it can allow for life extensions using its distribution options.

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