# Obsolescence Risk and the Systematic Destruction of Wealth

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## Abstract

Obsolescence of physical assets and processes is a major component of operational risk for some companies. A simulation experiment shows that managers, who consider the retirement and replacement of individual assets in isolation, have rational incentives, due to risk aversion and uncertainty, to defer the replacement of assets past a time optimal from the perspective of the shareholder who owns the entire portfolio of such assets. This results in measurable wealth destruction—and a demonstrable opportunity to significantly enhance a company's value.

# 1  Introduction

Obsolescence is the state of a fixed asset, service or process when it becomes unwanted or should no longer be used. However, the asset may still be (and usually is) in good working order. In industry, obsolescence is thought to occur because a like replacement is available that is economically superior in some way. A replacement asset may have comparative advantages to the existing asset, such as time savings, or reduced energy usage, potential loss costs or consumption of scarce resources. This last point suggests a relationship between obsolescence and sustainability. Obsolescence may be due to the availability of new technology or the aging condition of the asset itself.

Obsolescence risk can be perceived from two different views:

- When deciding whether or not to replace an asset, from the user's perspective
- When making decisions to invest in the upfront costs associated with the production infrastructure of a new asset (i.e., a manufacturing line)
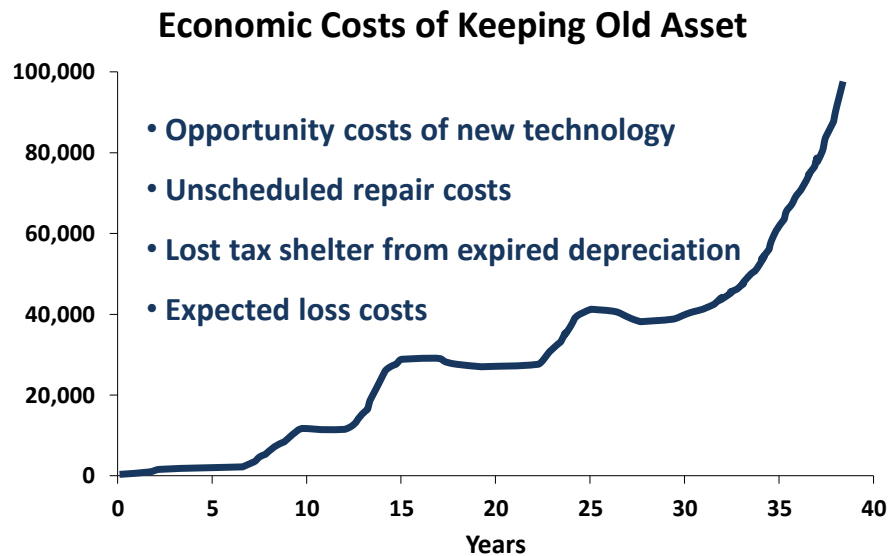
In this paper, we are mostly concerned with the first perspective, although the approach addressing asset mortality discussed in this paper can be used to evaluate the risk from either outlook.

We will specifically define obsolescence using the notion of calendar year economic costs associated with keeping an old asset (not having the newer version of the like asset). Such costs may include:

- Opportunity costs associated with not having new technology (energy savings, lower staffing, etc.)
- Unexpected maintenance costs associated with older assets
- Opportunity cost of lost tax shelter due to expired depreciation
- Expected loss costs associated with declining reliability of an old asset (i.e., lost revenues)
- All other quantifiable calendar year costs of time, energy and materials needed above and beyond owning the newest and latest like asset

Such costs, by definition, begin at zero when the asset is new. These costs generally increase as the asset ages. These costs are an abstract construct (a model), but they can be measured in real time and tracked over time using a database. These costs are represented by the blue line in Figure 1.

**Figure 1**

## Economic Costs of Keeping Old Asset

- Opportunity costs of new technology
- Unscheduled repair costs
- Lost tax shelter from expired depreciation
- Expected loss costs

(y-axis: 0, 20,000, 40,000, 60,000, 80,000, 100,000)

(x-axis: 0, 5, 10, 15, 20, 25, 30, 35, 40 — Years)

At some **threshold** of these costs, it is natural to ask how high they can continue to go before a manager must consider replacement of the asset with the newest and latest version. We can arbitrarily choose such a threshold. When the economic costs cross this threshold, the asset is said to be obsolete. The asset is replaced at this obsolescence threshold, and the evolution of economic costs associated with having an old asset begins again at zero. This cycle repeats itself indefinitely into the future. The obsolescence threshold is depicted in Figure 2.

**Figure 2**

### Economic Costs of Keeping Old Asset
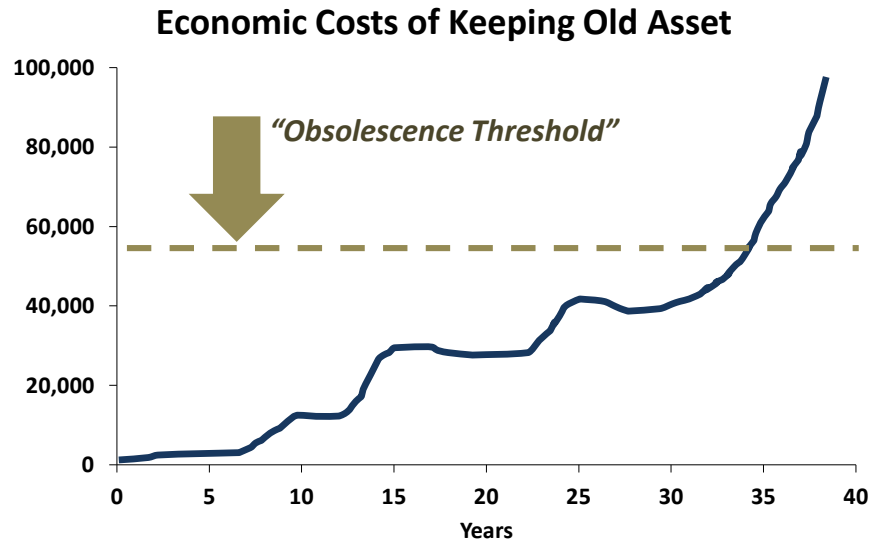


The evolution of these costs cannot be known in advance. They have never been recorded historically. They follow a stochastic process $f(A,B,t)$ where A and B are parameters that define the rate at which the economic costs increase; t is time. The stochastic process, as well as some arbitrary paths of these costs, is depicted in Figure 3.
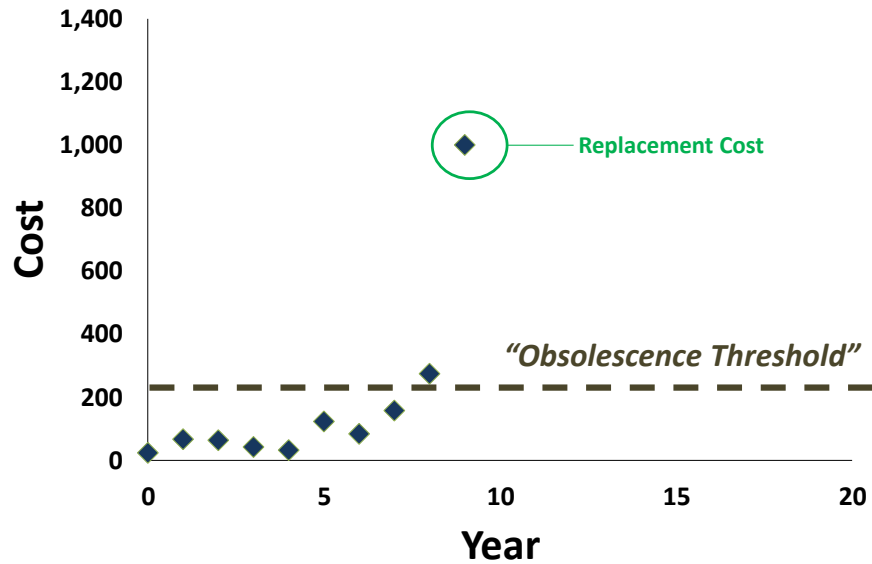
**Figure 3**

**Economic Costs of Keeping Old Asset**



*f*(A,B,t)

Years
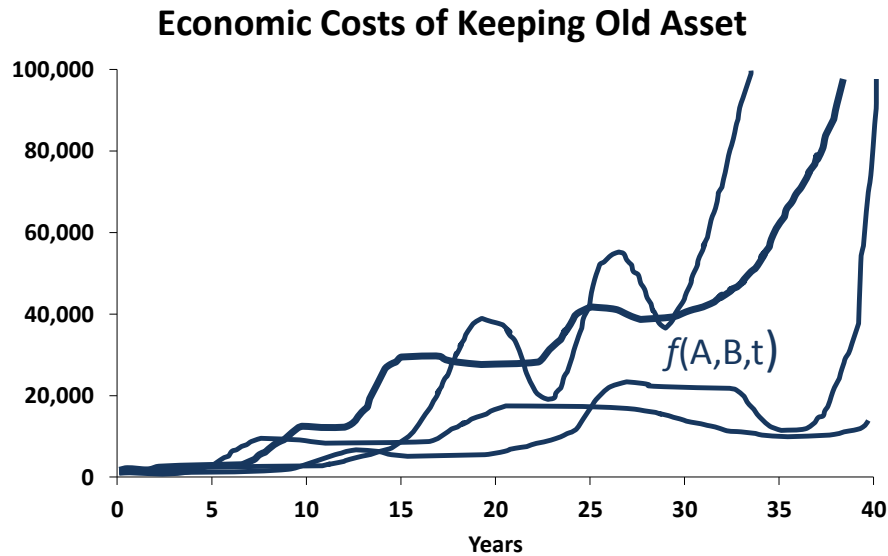
In Figure 4, a series of such annual economic cost points is shown and ends with the highest point being the asset replacement cost. These costs have a lot in common with a 10-year bond obligation, in that they closely resemble a series of interest payments ended by a payment of principle. The future costs of Figure 4 are just as real as those of a bond obligation or a casualty reserve except that they are not contractual obligations. Nevertheless, they are 100 percent likely to occur in the future. As such, they constitute an invisible liability to the firm. This is relevant because

1. The value of these invisible liabilities is large compared to the corresponding depreciated value of fixed assets on the balance sheet and small proportional changes in their aggregate value can have a significant impact on shareholder net equity.
2. We hypothesize prior to this experiment that it is possible to control and minimize the aggregate value of these liabilities by carefully defining obsolescence, or asset death, in terms of the obsolescence threshold.

**Figure 4**



In Figure 5, we show the indefinitely repeating cycle of these costs. This is the cost structure over time of the invisible liability created by a fixed asset. It is a stochastic process similar to an industrial queuing problem. The time between replacements is a random number. We wish to observe changes in the present value of the time series of these costs as the obsolescence threshold is varied.

**Figure 5**
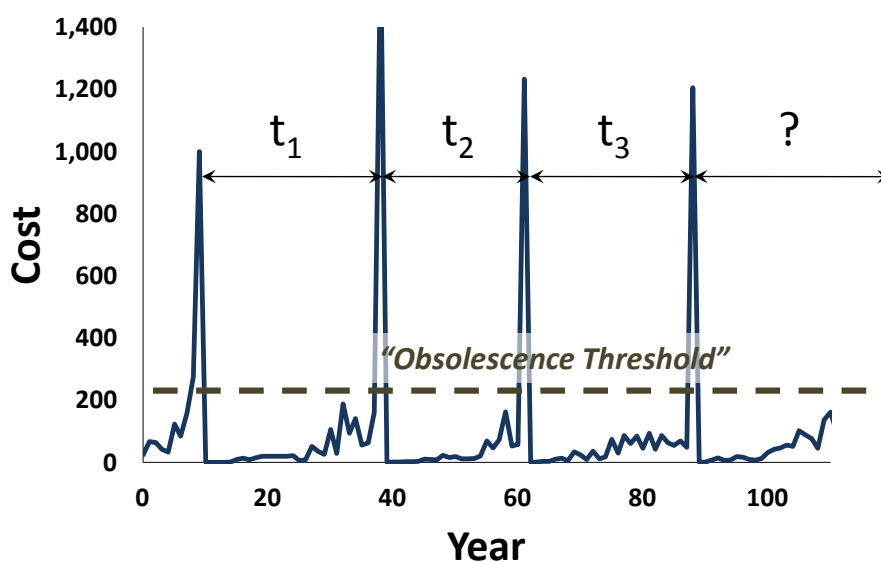


These future costs are as real as the future cash flow obligations associated with a bond issue or an insurance company reserve. However, unlike bonds and reserves, they are not recorded as a liability on the balance sheet. The value of this invisible liability may be worth many times the depreciated value of the corresponding asset, which *is* on the balance sheet. Small proportional changes in the value of this invisible liability, in the aggregate, may be large compared to shareholder equity. The thesis of this paper is that the value of this liability can be optimized (minimized) through proper selection of obsolescence thresholds for each asset in the portfolio of assets and that managers may have rational incentives to make suboptimal selections, thereby systematically destroying wealth.

In Figure 6, we show how the intersection of the stochastic economic costs with a selected threshold can create a kind of life distribution. It is possible to collect small amounts of empirical seed longevity data for different classes of assets in order to calibrate the parameters of the stochastic process. However, this will not be done in this experimen

**Figure 6**

## Economic Costs of Keeping Old Asset
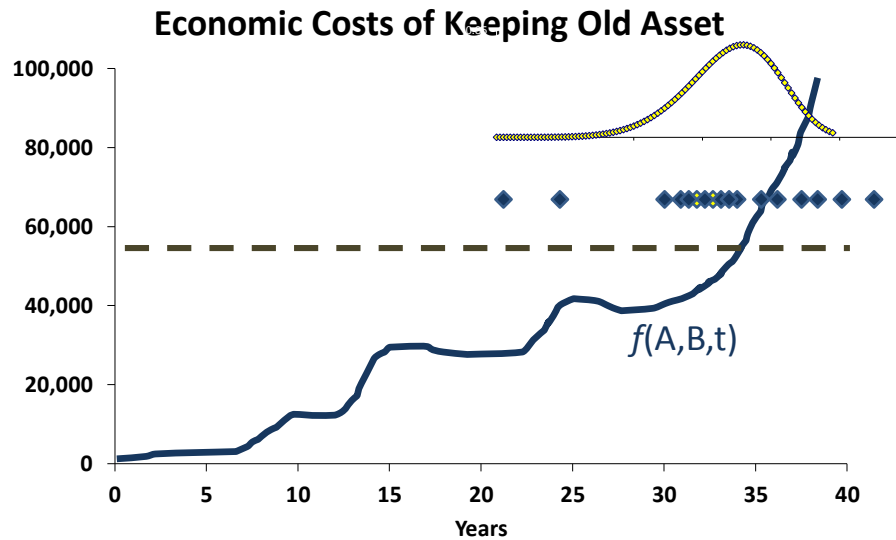


**2  Procedures and Observations**

**Procedure A**

Procedure A of the simulation experiment was intended to investigate simply whether or not this arbitrary choice of obsolescence threshold matters. We set up the simulation using the code in the Appendix to create these randomly increasing economic costs as a series of calendar year values. When the arbitrarily selected threshold was exceeded for the first time, the simulation replaced the asset in that year, and the random process of increasing economic costs started over again, and this cycle continued indefinitely. Each time series (consisting of both economic and replacement costs of Figure 5) represented a single trial of the simulation. We ran many trials.

The present value of each time series resulting from each trial was calculated, expressed as a fraction of the asset replacement (not depreciated) value and compiled in a histogram. We wished to observe the effects on this histogram due to the selection of varying values of the obsolescence threshold.

Another variable in the experiment was the number of assets in the portfolio. We wished to see if diversification influenced the histogram.

The following is a summary of the variables of this experiment:

Independent variables (what we changed):

- Obsolescence threshold at which replacement is simulated
- Number of assets in the portfolio

Dependent variables (what we measured):

- The present value of each simulated time series expressed as a fraction of total portfolio replacement cost
- The expected value and variance of the present values of the trials of this histogram

Controlled variables (what stayed the same):

- The parameters A and B of the simulation that define the stochastic process with which the economic costs increase
- The discount rate (4 percent)
- The value of each asset ($1 million)

With four different portfolios with different numbers of assets, we plotted the four resulting histograms showing the differences in present values resulting from a switch in replacement threshold from $200,000 to $100,000 (20 percent to 10 percent of the individual asset replacement value). The number of trials used to create this histogram is marked on Figure 7.

## Figure 7
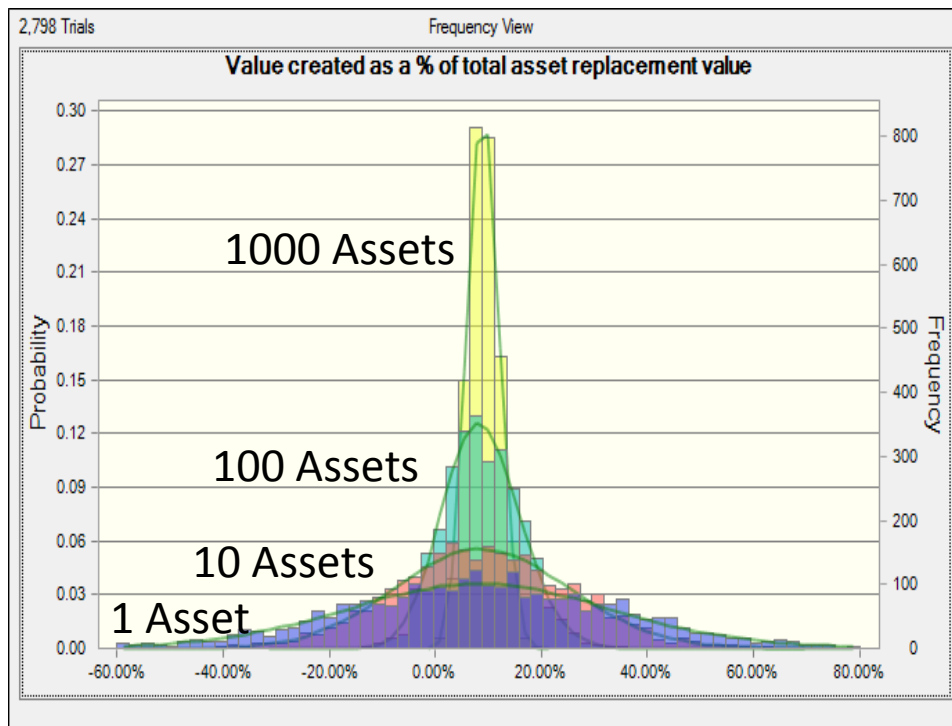


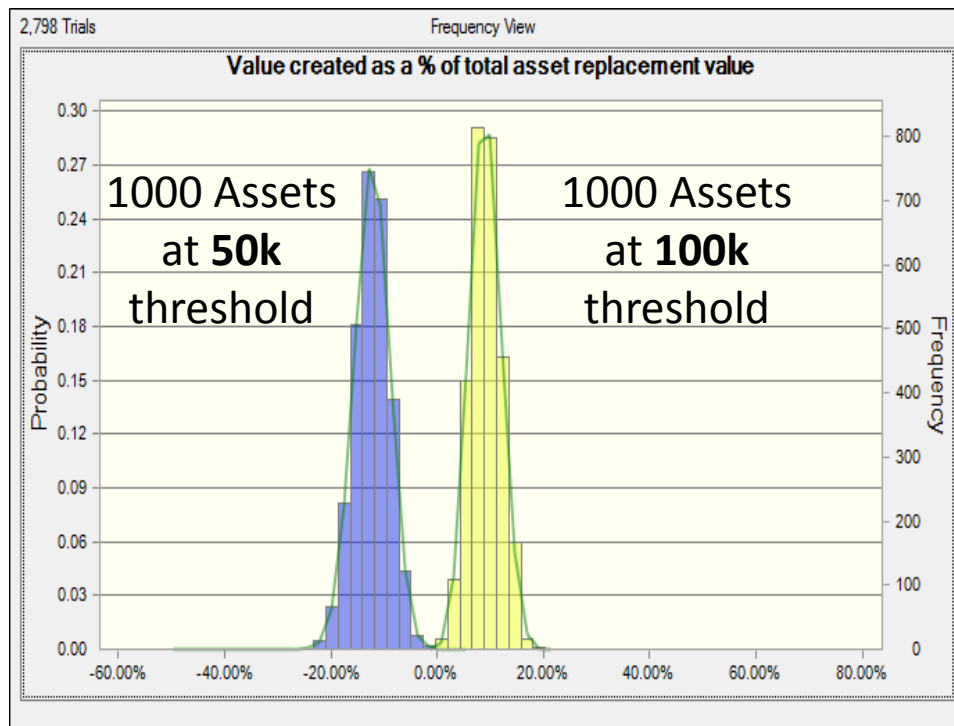### Observations A

Although this was only a single experiment with arbitrarily selected values, it demonstrated a positive value creation centered at about 10 percent as a fraction of total portfolio replacement value, due to the switch from a 20 percent replacement threshold to 10 percent obsolescence threshold. The statistical significance (inversely proportional to the variance of possible outcomes) of this value creation increased as the number of assets in the portfolio increased. This value creation become more statistically significant as the size of the portfolio increased from 1 to 10 to 100 to 1,000 assets.

### Procedure B

Next, using a 1,000-asset portfolio, we generated a histogram for a switch from $200,000 to $100,000 obsolescence thresholds (yellow histogram) and another histogram for a switch from $200,000 to $50,000 obsolescence thresholds (blue histogram). The resulting 2 histograms are plotted below.

**Figure 8**



Value created as a % of total asset replacement value

1000 Assets at **50k** threshold

1000 Assets at **100k** threshold

2,798 Trials — Frequency View

## Observations B

We noted that the switch from the 20 percent to the 5 percent threshold resulted in destruction of value centered at about negative 13 percent (the blue histogram to the left in Figure 8).

## Procedure C

Next, we calculated the present values (again, as a fraction of replacement cost of the entire portfolio) of the time series for an entire range of obsolescence thresholds.

This data was analyzed in figures 9 through 13; however, we superimposed a new kind of uncertainty into the results. First of all, some definitions.

- Aleatory uncertainty: the inherent randomness of the process that cannot be reduced through the collection of more information; for example, the unknown time to future obsolescence of the replacement asset.
- Epistemic uncertainty: the randomness in outcomes due to lack of knowledge of the process itself. This uncertainty can be reduced through the collection and analysis of more information; for example, the unknown parameters of obsolescence process of Figure 6.

The epistemic uncertainty is simply the manager's uncertainty about the exact threshold at which to replace the asset due to lack of knowledge about the obsolescence process of Figure 6. Without knowing more about the stochastic process of Figure 6, the manager will not know exactly the best threshold to minimize the present value. This uncertainty was created outside of the code shown in the Appendix. In the spreadsheet, we created the present value of a perpetuity that varied + or – 50 percent from the true optimum. We then varied the obsolescence threshold over a range of 1 percent to 30 percent and generated the 300 trials in Figure 9.

Those trials for which the present value of the manager's guess of optimum threshold costs in perpetuity exceeded the present value of the simulated time series (of Figure 5) were marked in black as "money making" outcomes. Those in which the relationship was reversed were marked in red as "money losing" outcomes.

## Observations C

The results of Procedure C are graphed in figures 9 through 13.

In Figure 9, for only one asset, the points seem to gravitate downward toward a minimum somewhere at the center of graph, but there is too much noise in the data to be sure. The money-losing outcomes are more frequent for lower thresholds of obsolescence, but both money-losing and money-making outcomes are mixed over a wide range of obsolescence thresholds.

**Figure 9**



PV of All Future Costs (as % of Replacement Cost), for 1 Asset
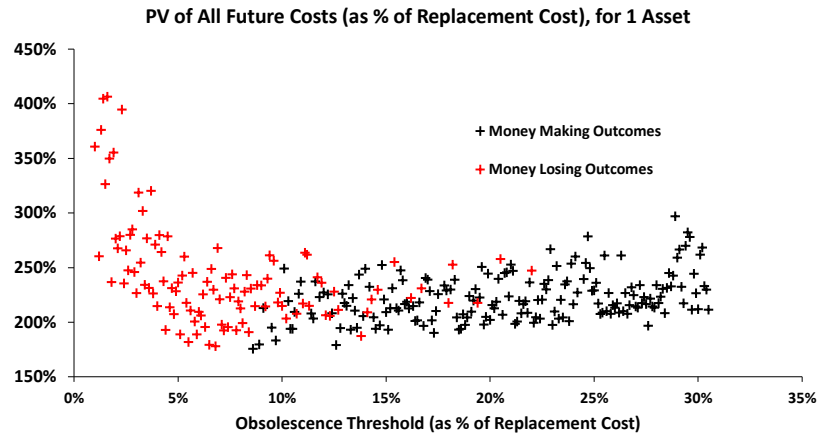
In Figure 10, the number of assets in the simulation has increased to 10 (from 1). Much of the noise resulting from the aleatory uncertainty of the simulation has been diversified away, and the minimum is more clearly discernible at about 11 percent.

## Figure 10
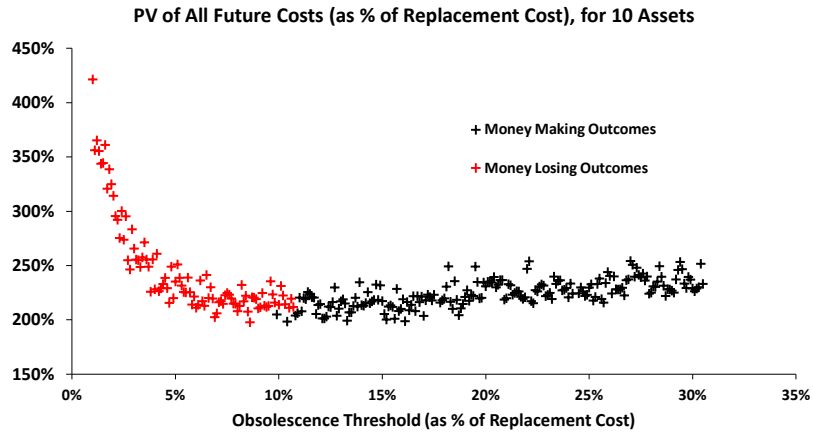


In Figure 11, we now have 100 assets, and more diversification of uncertainty has taken place.

# Figure 11

**PV of All Future Costs (as % of Replacement Cost) , for 100 Assets**
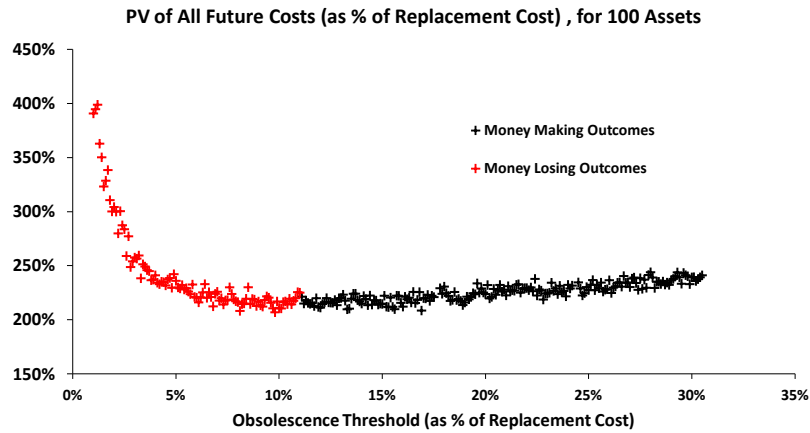


In Figure 12, we now have 1,000 assets in our simulated portfolio, and the optimum obsolescence threshold is clearly visible. Comparing the present value at this threshold with the present value at a commonly chosen 20 percent threshold (i.e., the commonly used five-year payback period rule for replacements), shows a difference of about 10 percent of the replacement value of the asset.

## Figure 12

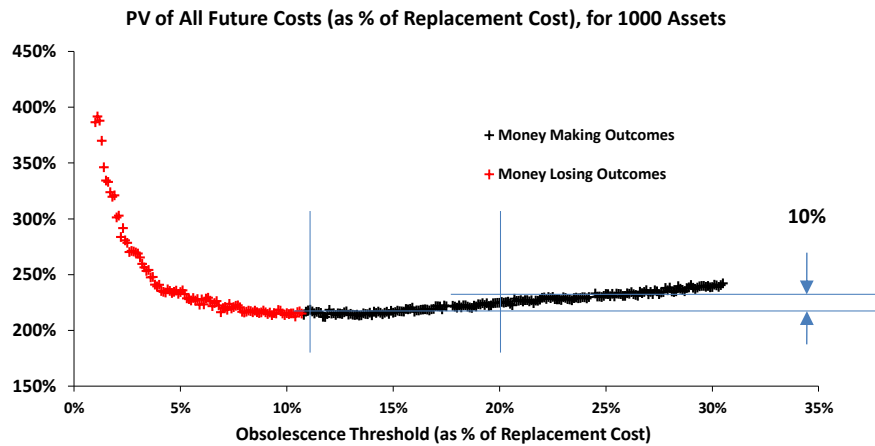

**PV of All Future Costs (as % of Replacement Cost), for 1000 Assets**

+ Money Making Outcomes

+ Money Losing Outcomes

10%

Obsolescence Threshold (as % of Replacement Cost)

In Figure 13, we returned to a portfolio of only one asset but left the markers showing the 11 percent obsolescence threshold that creates the minimum expected value of present value of future costs. At this point, you can see that the money-making and money-losing outcomes are about evenly mixed, and the money-losing outcomes become rarer with a higher obsolescence threshold. The longer the manager waits to replace the asset, the more likely that the manager's decision will be a money-making one.

**Figure 13**
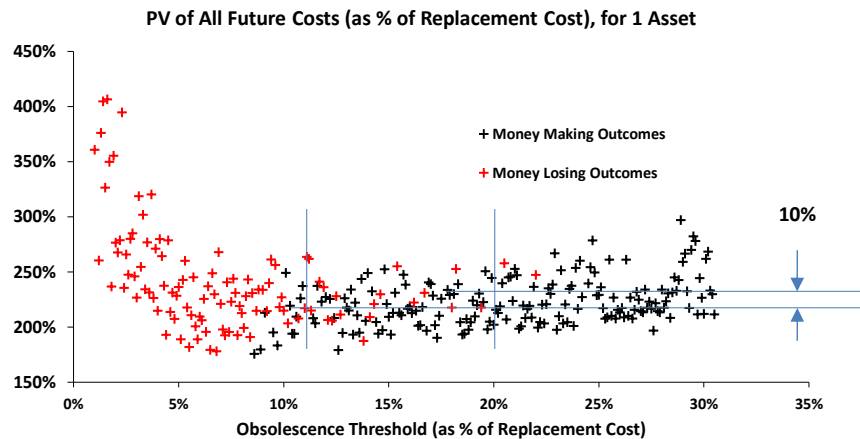


**3 Experiment Conclusions**

Part A: The choice of threshold used to determine when an asset was obsolete had a significant effect on the present value of future cash flows of Figure 5. The 10 percent value created in Figure 8 can be large when compared to shareholder equity, particularly for companies whose balance sheets are mostly comprised of assets susceptible to obsolescence. The value creation becomes statistically significant as the size of the portfolio increases.

Part B: Again, the choice of threshold-defining obsolescence is important, and a suboptimal choice can lead to destruction of value that may be large compared to shareholder equity.

Part C: There is an optimum policy threshold for an asset that minimizes the expected value of the present value cost impact to shareholder equity. Also, a manager viewing an asset replacement decision for a single asset in isolation may have incentives, due to uncertainty and risk aversion, to defer replacement of the asset past the optimum threshold of 11 percent. At a 20 percent threshold, the manager may feel more confident that the decision will not be a money-losing one. However, when many of these assets are aggregated together, the risk of a money-losing outcome is diversified away, and there is a clearer optimum threshold.

# 4 Overall Conclusion

The determination of when assets are obsolete (using a threshold of economic costs associated with not owning a new asset) can have an important impact on shareholder wealth. Managers who make determinations of obsolescence on individual assets or small portfolios of assets in isolation may have rational incentives, due to risk aversion and uncertainty – both epistemic (an unknown obsolescence process) and aleatory (unknown time to future obsolescence of the replacement asset), to defer this determination past the optimum threshold. This results in the systematic destruction of wealth.

This wealth destruction can, in theory, be quantified for a firm by reducing the epistemic uncertainty about the nature of the obsolescence process through industry surveys (described in Wendling 2011), application of actuarial science to characterize the longevity of different classes of assets and the continuous monitoring of the economic costs described in this paper. The aleatory uncertainty in the determination of the optimum obsolescence threshold can be managed simply through diversification by increasing portfolio size, such as in all insurance applications.

# Appendix

The simulation used in the experiment was created using the following code written in VBA for Excel. This creates a user-defined function called "MARKOV1" that must be inserted as an array on the worksheet.

```
Function MARKOV1(Periods As Integer, Trials As Double, Crenew As Double, Prenew As Double, MTBF, Shape, Age, Cost,
Modules, MDT)


'************************************************************************
'***********  Asset Mortality Simulation  *********************************
'************************************************************************


MARKOV1 = 0


'This next block of code creates VBA arrays of the array arguments,
'for easier manipulation within this function code
'************************************************************************************

Dim ltyp(500) As Double
p = 0
For Each Item In MTBF
    p = p + 1
    ltyp(p) = Item
Next Item

Dim styp(500) As Double
p = 0
For Each Item In Shape
    p = p + 1
    styp(p) = Item
Next Item

Dim Agee(500) As Double
p = 0
For Each Item In Age
    p = p + 1
    Agee(p) = Item
Next Item

Dim Coste(500) As Double
p = 0
For Each Item In Cost
    p = p + 1
    Coste(p) = Item
Next Item

Dim Units(500) As Integer
p = 0
For Each Item In Modules
    p = p + 1
    Units(p) = Item
Next Item

' note that p here is equal to whatever number of item components there are,
'into the model.

'*********************************************

'This For-Next Loop runs the number of trials required for the running
'average calculation


For z = 1 To Trials



'This For-Next loop runs through p different Items, with p being a
'convenient count of items left over from the previous code, and constant for
'the remainder of the model.

    For List = 1 To p


        'setting volatile to true allows it to regenerate in Crystal Ball,
        'this command was put in to a command button on the worksheet
        Application.Volatile True


        'This array will keep a running total of failures per period

        Dim OutComes(1000) As Variant
```

```
DESCRIPTION OF VARIABLES
Periods: number of years of forecast
Trials: number of simulation trials
Crenew: (not used)
Prenew: (not used)
MTBF: replacement threshold before t = 100
Shape: replacement threshold after t = 100
Age: initial age of units = 0
Cost: replacement cost of each unit = 1,000,000
Modules: number of units = 1
MBT: (not used)
```

```vba
'The next For-Next loop generates the Modules, and creates discrete time
'        series of economic costs and replacement costs
'        for each module over the life of the contract.

        For M = 1 To Units(List)

'resets several variables from one module to the next. dblTime is the absolute time in years from present
        Dim dblTime As Double
        Dim serTime As Double
        Dim Aget As Double
        'dblMaint is the value of the economic costs prior to replacement.
        Dim dblMaint As Double

        Aget = Agee(List)

            Randomize

            Threshold = ltyp(List)

        'This next line sets the initial age of the asset
        dblTimeTotal = -Aget

        'this loop generates the interreplacement times while the running total <Periods
        Do While dblTimeTotal < Periods

            dblMaint = 0
            'Initializing i which is a time scale between replacements
             i = 0

             'this do loop generates the time series of costs

            Randomize
            Factor = (Rnd)

            Randomize
            Weight = (Rnd)

              Do While dblMaint < Threshold * Coste(List)

                   Threshold = ltyp(List)

                   'these next lines generate the economic costs as a function of i

                   dblMaint = Weight * (3.882 * (1.4 - Factor) * i) + (1 - Weight) * ((1.5 - Factor) *
                       (0.000000000067 * i + 0.000000001696 * i ^ 2 + 0.000000037193 * i ^ 3 + 0.000000780821 * i ^
                       4 + 0.000016087092 * i ^ 5))
                   Randomize
                   dblMaint = dblMaint * Exp(1 - 2 * Rnd)


                   'this code allows for transitions in threshold at year 100, just to see the effects of a change

                   If dblTimeTotal > 100 Then Threshold = styp(List)
                   If dblMaint > Threshold * Coste(List) Then dblMaint = dblMaint + Coste(List)
                   If dblTimeTotal >= 0 Then OutComes(dblTimeTotal) = OutComes(dblTimeTotal) + dblMaint



                   'Here we increment both time counters (years)
                   dblTimeTotal = dblTimeTotal + 1
                   i = i + 1

                  Loop
            Loop
        Next M
     Next List
Next z

'Calculates the average over the number of iterations
'the For-Next loop that does this starts at 0 and ends at Periods-1, because the
'INT function was used to index the array.

For a = 0 To (Periods - 1)
    OutComes(a) = OutComes(a) / Trials
Next a

'Delivers the array of yearly costs as a vertical column in the preselected cells.

MARKOV1 = OutComes

End Function
```

# References

Wendling, Thomas E. "A Life Contingency Approach for Physical Assets: Create Volatility to Create Value." Society of Actuaries 2011 ERM Symposium Monograph.

Grossi, Patricia, and Howard Kunreuther, eds. *Catastrophe Modeling: A New Approach to Managing Risk*, 70, New York: Springer, 2005.