2001-04-01

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Original Publication Citation

R.G. Crawford, B.A. Slade. "Appraising Industrial Special-Purpose Property", The Appraisal Journal Volume LXIX, No.2, Issue April 21, Pages 161-173, 4, 21.

features

Appraising Industrial Special-Purpose Properties

A Utilization-Based Measure for Estimating Economic Obsolescence

by Robert G. Crawford, PhD and Barrett A. Slade, MAI, PhD

abstract

This article proposes a new technique, based on utilization rates, for estimating economic obsolescence in the appraisal of industrial special-purpose properties. A utilization-based measure, which explicitly considers the operating leverage of the facility, allows for proper calculation of the obsolescence. Theoretically correct valuation principles underlie the proposed utilization methodology. The technique uses inputs that are reasonably available to an appraiser, thus providing a practical application of the proposed methodology.

Appraising industrial special-purpose property has become an important topic because specialization in assets has increased the number of special-purpose properties.[1] Most of the appraisal activity pertains to ad valorem property taxation, but appraisals for many other reasons are also required. Some have viewed appraising special purpose property as a futile task. For instance, Duvall and Black find that one court referred to the process of valuing special-use properties as "a snipe hunt carried on at midnight on a moonless landscape." Although this perspective is a bit harsh, methods have been used that have scant justification. The cynicism surrounding the valuation of special-purpose properties results from the problems encountered when attempting to apply the traditional three approaches (cost, income, and sales comparison) to valuation.

Special-purpose properties, particularly unique process facilities, generally cannot be appraised using the sales comparison approach. Either no sales of comparable properties exist or only a few sales exist in circumstances where appraisers are unable to verify sufficient facts about the sold properties to determine their comparability to the subject property. Thus, the sales comparison approach to valuation is rarely useful for estimating market value.

Similarly, the lack of critical data often makes the income approach to valuation unreliable. Special-purpose properties often are one of a number of fixed-assets in the firm; therefore, the income stream to the larger business enterprise cannot be separated into the constituent part directly attributable to the plant or the specialized asset being appraised. The income stream is earned by the business enterprise as a whole and cannot be unambiguously attributed to the real estate, the machinery and equipment, and the intangible property.

Acknowledgements: The authors would like to thank Richard Graff, Grant McQueen, and Kent Osborne for their helpful comments and suggestions. Any errors and omissions remain the responsibility of the authors.

1. "Special-purpose property. A limited-market property with a unique physical design, special construction materials, or a layout that restricts its utility to the use for which it was built." Appraisal Institute, *The Dictionary of Real Estate Appraisal,* 3rd Ed. (Chicago: Appraisal Institute, 1993): 342.

Income attribution is complicated by the forecast problem. Even if the attribution could be solved, the problem of forecasting an appropriate income stream is usually insurmountable. The intractability of the income/asset attribution problem, compounded by the forecasting problem, renders the income approach unsuitable for determining value.

In response to this obstacle, appraisers often prefer to use a proxy rental income stream from a comparable asset in the income approach. However, because of the special-use nature of the asset, a scarcity of comparables prevents this alternative method from solving the data problem. It follows that the cost approach is often the best and frequently the only feasible approach for valuing special-purpose properties (Duvall and Black).

Within the cost approach, the problem of determining economic obsolescence is often the critical problem that must be solved. Eaton claims that estimating obsolescence is very subjective and ultimately rests on the appraisers judgement. The objective of our analysis is to show that a theoretically sound, utilization-based method can be employed to eliminate the subjectivity and reliably estimate obsolescence.

Utilization measures of obsolescence that have a market-based theoretical foundation, are the least data constrained of all conventional measures, and require less guessing about future events (guesses notoriously lacking precision). Accordingly, standard economic criteria, based on objectivity and robustness imply that utilization measures are superior to other valuation methodologies currently available.

Crawford and Cornia first proposed a utilization-based method of estimating obsolescence in special-purpose properties. Their ideas have received scrutiny in cases where utilization-based measures were used by appraisers to determine obsolescence incurred by special-purpose property and whose property tax was subject to appeal. One court has accepted capacity underutilization as the method of determining obsolescence. The case is *National Sun Industries, Inc. v. Ransom County, North Dakota.*[2] This case is particularly relevant because it unambiguously accepts a capacity-based method of measuring obsolescence—stipulating only that the method be properly applied. Thus, an important aspect of this paper is to specify clearly the proper application of utilization-based measures of determining obsolescence.

This paper proceeds in five sections. The second section reviews the relevant literature and discusses the theoretical basis for using a utilization-based measure for estimating obsolescence. The third section describes the method of analysis, while the fourth section provides a practical application of the methodology. The fifth section concludes the study by summarizing the research results.

Literature and Theoretical Basis

In order to understand economic obsolescence, a general discussion of depreciation of fixed assets is warranted. Depreciation is understood on a practical basis as the loss in value from a loss in utility (Lusht). Ellsworth argues that "[a]sset depreciation is a function of the duration of the useful life of an asset as it is operated for the activity for which it was designed." Marston, Winfrey, and Hempstead captured this view of depreciation in the following formula:

$$ELF = \left[\frac{(1 + r)^n - (1 + r)^x}{(1 + r)^n - 1}\right] \qquad (1)$$

where:

ELF = Expectancy Life Factor,
r = rate of return,
n = expected life service, and
x = actual asset age.

This formula assumes a uniform or constant utility of the asset over its useful life. In practical circumstances, assets rarely exhibit constant utility for a variety of reasons. However, a service decline from the full capacity utilization of an asset can be captured by a "service factor" *(SF)* that is needed "to compensate for the fact that operational returns may not be uniform during the entire service life" (Marston et al.). The product $ELF \times SF$ defines the percent good factor *(PGF),* which reflects the reduced utility of an asset relative to its capabilities if it were new. The *PGF* is conceptual recognition of an often overlooked form of depreciation (i.e., economic obsolescence) from underutilization. An adjustment to replacement cost due to this obsolescence factor is necessary in order to estimate reliably the value of the asset via the cost approach.[3]

Most often, something analogous to the *PGF* is determined from depreciation tables in the *Marshall Valuation Service Cost Manual* for general-purpose properties. Because of the lack of data, *Marshall Valuation* does not provide depreciation estimates for special-purpose properties. Ellsworth presents an alternative to determining the *PGF* based on survivor

2. 474 N. W.2d 502 (1991).

3. This factor does not capture other sources of obsolescence such as operating cost in excess of the corresponding operating cost for a new facility.

analysis from engineering economics. Ellsworth's study derives a "survivor curve," using a large sample of coal-fired electric generating plants. This curve exhibits a concave shape, implying that depreciation occurs slowly during initial asset years, but progresses at an accelerating rate. Interestingly, this empirically determined concave shape captures the path of depreciation that is expected from economic theory. The present study finds that the path of value over time, whether determined as the present value of future cash flows from use or from the *ELF* formula, displays a similar qualitative depreciation schedule.

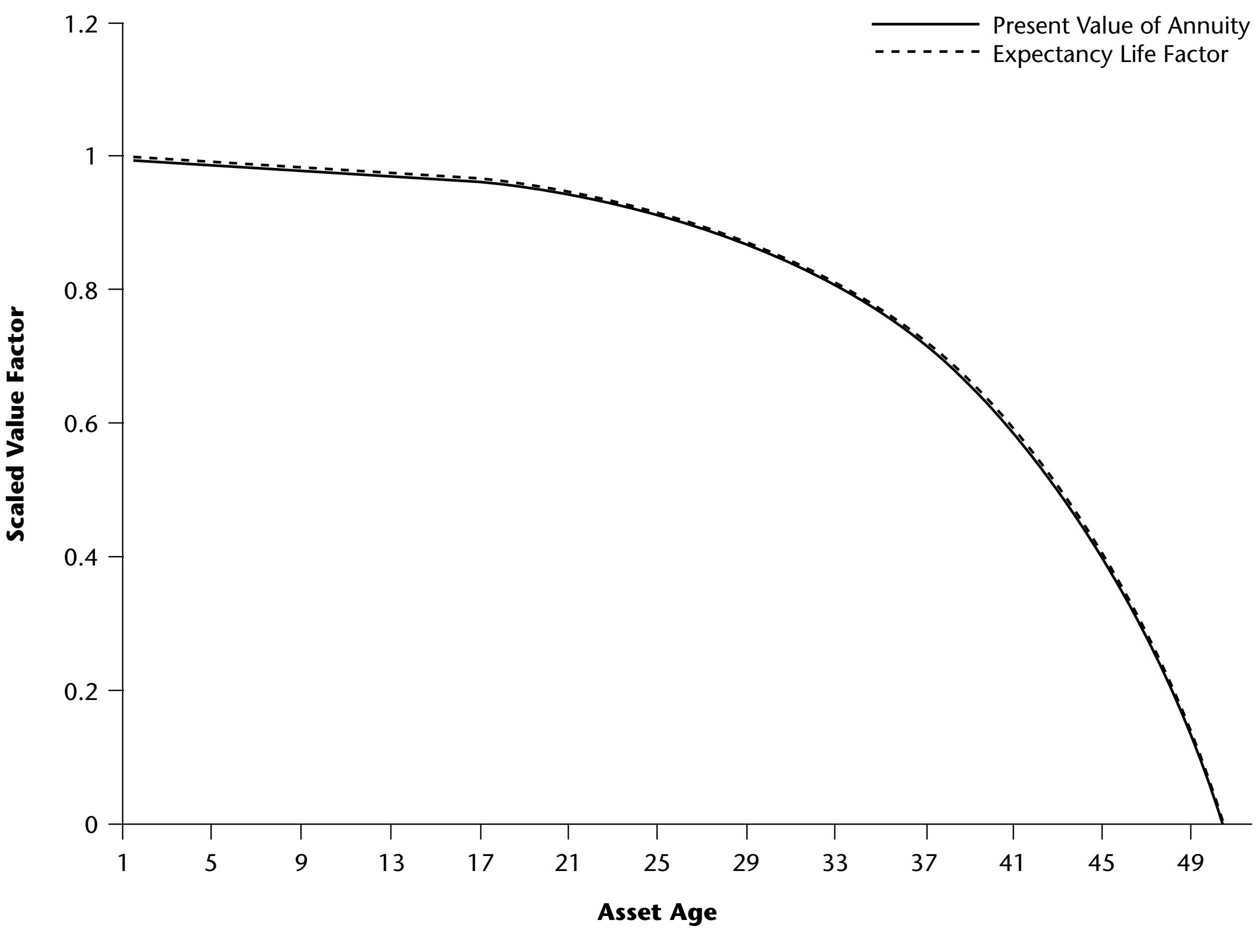
Figure 1 illustrates the *ELF* for 50 years of useful life and a rate of return of 10% compared with the present value of a constant $1 cash flow to be received for 50 years at a discount rate of 10%. Note that the two curves coincide. This shape for depreciation has been observed in studies of residential housing and office buildings. However, the problem of estimating reduction in utilization—service factor—from either *Marshall Valuation Service* or survival analysis is not satisfactorily resolved in the case of special-purpose industrial properties because comparables are rarely available to provide reliable data.

Utilization-Based Measure of Depreciation

The proceeding discussion suggests theoretical agreement on the problems that must be overcome in order to arrive at a reliable appraisal for unique properties. It also reveals that there remains a significant data problem in implementing the conceptual methods.

A solution to the data problem is suggested by analysis of the process that led to the initial asset acquisition. Theoretically, the best market-based valuation for each business asset is the present value of the income stream generated by the asset. In this methodology, the relation between asset capacity and income must be evaluated at the time the asset is

Figure 1 Comparison of Present Value Annuity Factor and Expectancy Life Factor



Note: The present value of the annuity is the present value of a constant one-dollar to be received over 50 years at a discount rate of 10%. The expectancy life factor is based on a 50-year useful life and a rate of 10%. For illustration purposes, the present value annuity factor is scaled by 10.

placed in service.[4] Clearly, the future income stream for any asset can only be an expectation, i.e., a best estimate. The asset owner must develop a complete profile of productive characteristics of the asset at the time of its construction, or the prospective owner must assess the functionality of existing asset characteristics. In either case, the specified characteristics will be those most relevant to determination of the expected income stream that justify the asset's creation or purchase price. In particular, the prospective owner must assess the correlation of the expected net income stream with the use of the asset as designed.[5]

Whether the income forecast consists of a series of specific numerical values or just a hunch is of little significance. The potential owner's conclusion of the connection between asset characteristics and income potential must be accepted because it is the owner's wealth that is at risk. This is not to say that such investors are omniscient or infallible—on the contrary, they are always wrong to some extent. Therefore, the potential for underutilization and, therefore, economic obsolescence is ever present, although it may be minor in many instances. Nonetheless, the existence of the asset implies that its initial owner was sufficiently convinced that its use would generate a return adequate to justify the initial cost. This is a fundamental logic of capital markets and the foundation of the arguments advanced in this paper.[6] This logic implies that at the time of placing the asset in service, the market value of the asset is determined by market expectations concerning the operation of the asset in its full or normal utilization, that is, the manner in which it was intended to operate.

The usual or commonplace assumption is that every asset has a designated or rated utilization capacity that, if met, will generate the expected income and required return. Under the circumstances in which actual-equal-to-intended operation persists over the life of the asset, the world is deemed to play out as expected over the economic life of the asset. In such cases, the investor earns what was expected at the outset. If so, the owner is fortunate indeed. Actual experience is sufficient to indicate that this rarely occurs. If events play out differently or worse than expected, the asset will be underutilized. Excess asset capacity means that realized income will be less than anticipated income. If the income shortfall could be determined accurately, then its present value would be the theoretically correct method of determining the obsolescence suffered by the asset. However, the lack of data restricts the direct identification of the income shortfall.

In general, the measurability problem remains. However, in instances where capacity and utilization data exist, they can be used directly to determine obsolescence because of a high degree of correlation between income and asset utilization. The correlation between asset underutilization and net income shortfall is not a linear relationship because some costs are unavoidable (fixed costs) and do not decrease proportionally with the decrease in asset utilization. The obsolescence imposed by underutilization depends on the operating leverage of the asset.

Most popular corporate finance texts show how the degree of operating leverage can be calculated from standard financial data.[7] Crawford and Cornia show that the true percentage of obsolescence imposed by underutilization is given by the following equation:

4. The present value calculation would also be performed at the time an existing asset is purchased. This specifically includes the case wherein an existing asset is purchased in an arms-length transaction.

5. This conclusion follows from Marston, Winfrey, and Hempstead (1955).

6. Strictly speaking, this assertion should be restricted to cases in which individual investors commit their own capital. In general, this analysis ignores potential agency costs.

7. Operating leverage occurs when there are fixed costs in the firm's cost structure. The degree of operating leverage is defined as:

$$DOL = \frac{Q(P - VC)}{Q(P - VC) - FC}$$

where:

Q = quantity of units produced,
P = price per unit,
VC = variable cost per unit, and
FC = fixed costs.

DOL is not a constant but varies in a range $1 < DOL < \infty$ as revenue, and variable costs change with underutilization. The degree of operating leverage can also be defined as:

$$DOL = \frac{\text{Percent Change in Operating Income } (EBIT)}{\text{Percent Change in Sales}} = \frac{\%\Delta EBIT}{\%\Delta Sales}$$

This later specification allows for a more practical calculation of the *DOL* by comparing the income statements of the facility or firm in the two most recent contiguous periods nearest the date of valuation. For more information on operating leverage see S. Block and G. Hirt, *Foundations of Financial Management*, 9th Ed. (New York: Irwin McGraw-Hill, 2000) or W. Lasher, *Practical Financial Management*, 2nd Ed. (Cincinnati: South-Western College Publishing, 2000).

$$\%OBS = \frac{DNR - ANR}{DNR} \quad (2)$$

where:

$\%OBS$ = percentage of obsolescence due to underutilization,
DNR = designed net revenue, and
ANR = actual net revenue.

It is easily shown that Equation 2 is equal to:

$$\%OBS = U \times DOL \quad (3)$$

where:

U = percentage of underutilization, and
DOL = degree of operating leverage.[8]

Since Equation 3 can be calculated when the revenue data specific to the asset is not available, it is a more precise method of determining the percentage of obsolescence *(%OBS)* due to underutilization.

Once the correct percentage of obsolescence due to underutilization is determined, total obsolescence in absolute dollar terms is given by multiplying *%OBS* by the replacement cost new less straight-line depreciation *(RCNSLD)*.[9] In summary, three facts are required for an appraiser to estimate obsolescence using the $U \times DOL$ formula:

1. The straight-line depreciated asset value assuming full utilization *(RCNSLD)*,[10]
2. *U*, the percentage of underutilization, and
3. *DOL*, the asset's degree of operating leverage.

These items are not future projections over which appraisers would differ.[11] Commonly accepted information exists that enables any appraiser to ascertain with acceptable precision the obsolescence imposed upon underutilized assets.

Method of Analysis

This section describes the analytical method used to determine the effectiveness of utilization-based obsolescence measures. Effectiveness assessment is accomplished in two steps. First, the comparison is established assuming a benchmark for a hypothetical asset. The present value of income shortfall establishes a "true" (albeit unobservable) obsolescence measure. It is the method that would be used if all information on present and future income were available. The second step estimates the obsolescence using only information that could reasonably be known by an appraiser. The third step determines the effectiveness of the "appraiser" estimate by comparing the estimate with the "true" obsolescence, wherein accuracy is measured by the percentage error of the estimate from the benchmark. For purposes of this discussion, we provide two methodologies of obtaining the appraiser estimate. The two appraiser estimate methodologies are:

1. "naïve obsolescence measure": the simple percentage underutilization times the replacement cost new or *RCN*. It is used only if sufficient information to use a more accurate measure is unavailable.
2. "levered obsolescence measure": the simple percentage underutilization multiplied by the degree of operating leverage *(DOL)* times the replacement cost new less straight line depreciation or *RCNSLD.*

Table 1 is a sample spreadsheet that calculates the obsolescence measures under the various assumptions that determine the true benchmark and the appraiser estimates.

As summarized above, we begin with essentially an omniscient assumption: by construction, we know the "true" value of the asset and the "true" obsolescence imposed on the asset by the decline in utilization because we have assumed perfect information. This "true" depreciation is the benchmark by which we measure the performance of two appraiser estimates of depreciation that presume no more information than any appraiser could generally know after appropriate investigation. We then compare these appraiser depreciation estimates with the true depreciation. For illustrative purposes, we present the spreadsheet analysis for an asset with an economic life of 10 years (Table 1). However, the analysis can easily be generated for longer periods of economic life.

The value of the asset and the true obsolescence are determined by a present value calculation. This

8. Let *R* designate full use revenue, *U*—the degree of under utilization, *VC*—variable or avoidable costs, *FC*—fixed or unavoidable costs, and *DOL*—degree of operating leverage. Then, %Obsolescence = $(DNR - ANR)/DNR = \{[R - VC - FC] - [(1 - U)R - (1 - U)VC - FC]\}/[R - VC - FC]$. After algebraic manipulation, the above expression reduces to $U[(R - VC)/(R - VC - FC)]$. Since $[(R - VC)/(R - VC - FC)]$ defines *DOL*, the expression reduces to $U \times DOL$.

9. This value is often called replacement cost new less accrued depreciation *(RCNLD)* in the appraisal literature. This term is not used here because it has a specific meaning to appraisers who include depreciation from all sources in the *D* component. Since we do not use the common methodology, we refrain from using the common terminology to prevent confusion. We use the term replacement cost new less straight-line depreciation *(RCNSLD).*

10. This assumes that the appraiser can obtain an estimate of the expected economic life at the time of construction.

11. *DOL* is a historical fact that does not involve estimates of the future. The percent of underutilization does not involve estimates of the future if it is limited to current or past utilization, and the total economic life of the asset can be estimated with reasonable precision.

Table 1 Obsolescence Model (10-Year Life, 20% Unused Capacity)

Row #	Assumptions											
1	Required Rate of Return	15%										
2	Unused Capacity	20%										
3	End of Period	0	1	2	3	4	5	6	7	8	9	10
4	Remaining Economic Life	10	9	8	7	6	5	4	3	2	1	0
5	Expected Units Produced		1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
6	Actual Units Produced		800,000	800,000	800,000	800,000	800,000	800,000	800,000	800,000	800,000	800,000
7	Price Per Unit		$3	$3	$3	$3	$3	$3	$3	$3	$3	$3
8	Expected Revenue		$3,000,000	$3,000,000	$3,000,000	$3,000,000	$3,000,000	$3,000,000	$3,000,000	$3,000,000	$3,000,000	$3,000,000
9	Actual Revenue		$2,400,000	$2,400,000	$2,400,000	$2,400,000	$2,400,000	$2,400,000	$2,400,000	$2,400,000	$2,400,000	$2,400,000
10	Revenue Difference		($600,000)	($600,000)	($600,000)	($600,000)	($600,000)	($600,000)	($600,000)	($600,000)	($600,000)	($600,000)
11	Fixed Costs		$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000
12	Expected Variable Costs		$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000
13	Actual Variable Costs		$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000
14	Expected EBIT		$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000
15	Actual EBIT		$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000
16	EBIT Difference		($400,000)	($400,000)	($400,000)	($400,000)	($400,000)	($400,000)	($400,000)	($400,000)	($400,000)	($400,000)

Explanatory Notes for Table 1
Row 1) Required Rate of Return: Cost of capital for the relevant industry.
Row 2) Unused Capacity: Underutilization resulting from economic obsolescence.
Row 3) End of Period: All cash flows are assumed to occur at the end of period.
Row 4) Remaining Economic Life: The remaining economic life of the facility.
Row 5) Expected Units Produced: The estimated annual units that the facility was expected to produce.
Row 6) Actual Units Produced: The actual annual units produced as a result of economic obsolescence.
Row 7) Price Per Unit: The price per unit as observed in the market place. The price is assumed to remain constant.
Row 8) Expected Revenue: Expected units produced multiplied by the price per unit.
Row 9) Actual Revenue: Actual units produced multiplied by the price per unit.
Row 10) Revenue Difference: The difference between the expected revenue and the actual revenue.
Row 11) Fixed Costs: Estimated fixed costs required to maintain and operate the facility regardless of output.
Row 12) Expected Variable Costs: Costs in addition to fixed costs that are required to produce the expected output.
Row 13) Actual Variable Costs: Costs in addition to fixed costs that were actually required to produce the lower actual output.
Row 14) Expected EBIT: The expected earnings before interest and taxes that result from deducting the fixed and expected variable costs from the expected revenue.
Row 15) Actual EBIT: The actual earnings before interest and taxes that result from deducting the fixed and actual variable costs from actual revenue.
Row 16) EBIT Difference: The difference between expected EBIT and actual EBIT.

Table 1 Obsolescence Model (10-Year Life, 20% Unused Capacity) *(continued)*

Row #	Assumptions											
17	Expected Value	$5,018,769	$4,771,584	$4,487,322	$4,160,420	$3,784,483	$3,352,155	$2,854,978	$2,283,225	$1,625,709	$869,565	$0
18	Expected Measure of Depreciation		($247,185)	($284,262)	($326,902)	($375,937)	($432,328)	($497,177)	($571,753)	($657,516)	($756,144)	($869,565)
19	Straight-line Depreciation		($501,877)	($501,877)	($501,877)	($501,877)	($501,877)	($501,877)	($501,877)	($501,877)	($501,877)	($501,877)
20	RCNSLD	$5,018,769	$4,516,892	$4,015,015	$3,513,138	$3,011,261	$2,509,384	$2,007,507	$1,505,631	$1,003,754	$501,877	$0
21	Actual Value	$3,011,261	$2,862,950	$2,692,393	$2,496,252	$2,270,690	$2,011,293	$1,712,987	$1,369,935	$975,425	$521,739	$0
22	Actual Economic Depreciation		($1,908,634)	($1,794,929)	($1,664,168)	($1,513,793)	($1,340,862)	($1,141,991)	($913,290)	($650,284)	($347,826)	$0
23	Estimated DOL		2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
24	% Capacity Unused		20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
25	% True Obs.		40%	40%	40%	40%	40%	40%	40%	40%	40%	40%
26	$Value of True Obs.	$1,908,634	$1,794,929	$1,664,168	$1,513,793	$1,340,862	$1,141,991	$913,290	$650,284	$347,826	$0	
27	Naive Obs.: *U* × *RCN*		$1,003,754	$1,003,754	$1,003,754	$1,003,754	$1,003,754	$1,003,754	$1,003,754	$1,003,754	$1,003,754	N/A
28	% Error from True Obs.		-47%	-44%	-40%	-34%	-25%	-12%	10%	54%	189%	N/A
29	Levered Obs. Measure		$1,806,757	$1,606,006	$1,405,255	$1,204,504	$1,003,754	$803,003	$602,252	$401,501	$200,751	N/A
30	% Error from True Obs.		-5%	-11%	-16%	-20%	-25%	-30%	-34%	-38%	-42%	N/A
31	Adjustment Factor		1.056	1.118	1.184	1.256	1.334	1.419	1.511	1.611	1.720	N/A
32	Adj F × Levered Obs. Measure		$1,908,678	$1,794,735	$1,663,502	$1,512,476	$1,338,793	$1,139,187	$909,949	$646,887	$345,307	N/A
33	% Error from True Obs.		0.00%	-0.01%	-0.04%	-0.09%	-0.15%	-0.25%	-0.37%	-0.52%	-0.72%	

Explanatory Notes for Table 1 *(continued)*

Row 17) Expected Value: The present value of the remaining expected EBIT discounted at the cost of capital. The expected value in time period zero is the value of the facility at the time of construction assuming expected utilization and market prices.
Row 18) Expected Measure of Depreciation: The estimated loss in value from the previous period due to the shorter remaining economic life (the difference between the expected value in the period under observation and the expected value in the previous period).
Row 19) Straight-line Depreciation: Expected value of the facility at time period zero divided by the total economic life of 10 years.
Row 20) RCNSLD: Replacement cost new less straight-line depreciation (accumulated).
Row 21) Actual Value: The present value of the remaining actual EBIT discounted at the cost of capital. The actual value reflects the decline in revenue from lower output because of underutilization of the facility.
Row 22) Actual Economic Depreciation: The difference between the expected value and the actual value.
Row 23) Estimated DOL: Estimated degree of operating leverage is calculated as (Expected Revenue – Expected Variable Costs)/(Expected Revenue –Expected Variable Costs – Fixed Costs).
Row 24) % Capacity Unused: The proportion of the capacity that is not being utilized as a result of economic obsolescence. This measure is calculated as 1 – (Actual Units Produced / Expected Units Produced).
Row 25) % Obsolescence: The percent of true obsolescence calculated by dividing the actual economic depreciation by the expected value.
Row 26) $ Value of True Obs.: The Dollar value of true obsolescence equals the actual economic depreciation.
Row 27) Naïve Obs. Measure: The simple percentage of underutilization times the replacement cost new or U × RCN.
Row 28) % Error from True Obs.: The percent error of the Naïve obsolescence measure from the true obsolescence calculated as the naïve obsolescence minus the true obsolescence all divided by the true obsolescence.
Row 29) Levered Obs. Measure: The levered obsolescence measure is calculated by multiplying the percent underutilization by the degree of operating leverage times the replacement cost new less straight-line depreciation.
Row 30) % Error from True Obs.: The percent error of the levered obsolescence measure from the true obsolescence calculated as the levered obsolescence minus the true obsolescence all divided by the true obsolescence.
Row 31) Adjustment Factor: The adjustment factors corrects for the estimation error in the levered obsolescence measure. They are calculated using the parameters of a 3rd degree polynomial fit of the errors (line 29 – line 26) and time in years.
Row 32) Adj F. Levered Obs. Measure: The adjustment factor times the levered obsolescence measure.
Row 33) % Error from True Obs.: The percent error of the adjusted levered obsolescence measure from the true obsolescence calculated as the adjusted levered obsolescence minus the true obsolescence all divided by the true obsolescence.

is done by calculating the impact on earnings before interest and taxes *(EBIT)* for an unanticipated inutility occurring successively in each year after the first year of asset operation. For each year, we compare the present value of actual *EBIT* for the remaining years with the present value of the expected *EBIT* for the remaining years. The difference between these two values is the "true" obsolescence (this is line 26 in Table 1). We then calculate the measures of depreciation under the limited information conditions that usually prevail using the naïve obsolescence and levered obsolescence measures.

Naïve Obsolescence Measure

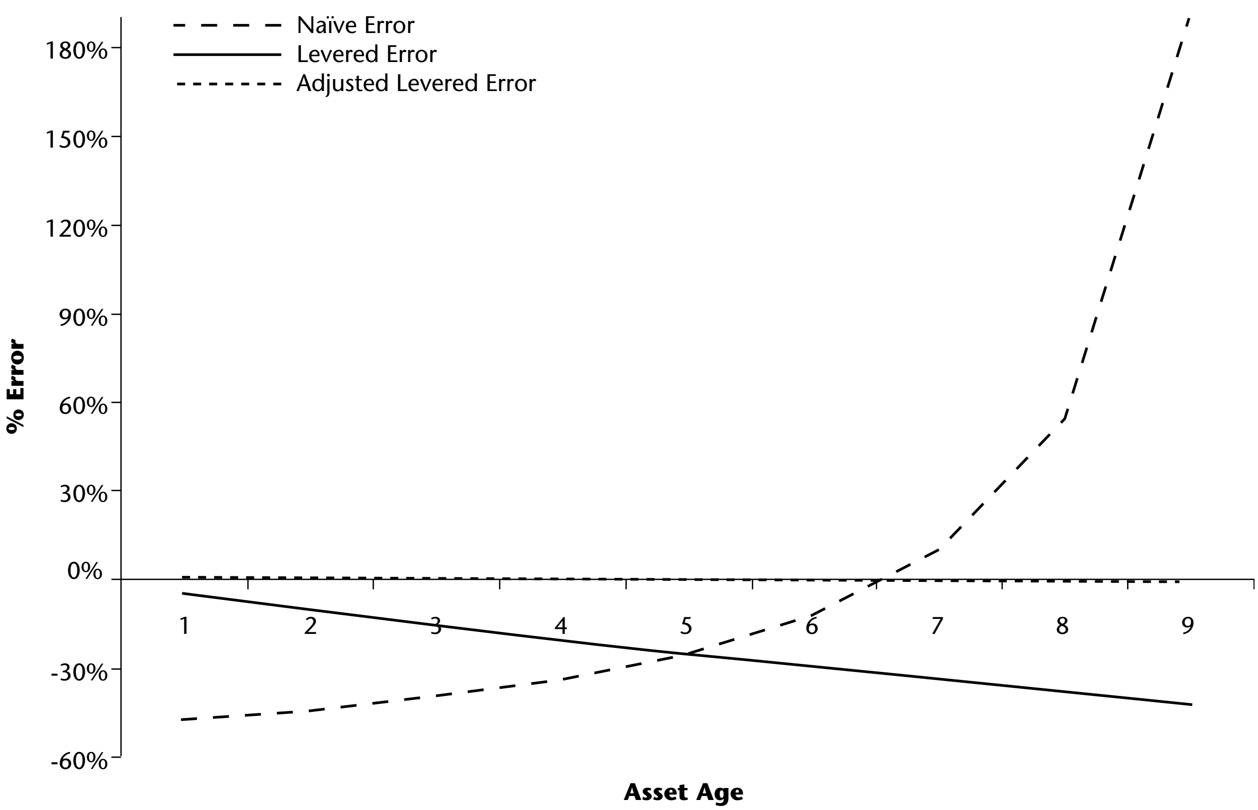
The naïve obsolescence measure determines obsolescence as the simple percentage of underutilization *(U)* times the replacement cost new value *(RCN)*, or $U \times RCN$ (line 27 in Table 1). This measure initially underestimates the true obsolescence, but towards the end of economic useful life, it overestimates obsolescence as shown in line 28 of Table 1. The pattern of the estimation error of the naïve obsolescence measure for a ten-year asset is shown in Figure 2.

Figure 2 shows that if the only information an appraiser has is the percentage of underutilization, the naive depreciation measure underestimates the extent of obsolescence for approximately 75% of the useful life of the asset. For the last 25% of the useful life, the "tail" of the useful life span, the naïve estimate overstates depreciation. For the first half of an asset's useful life, the naïve estimate is approximately 50% below the true obsolescence regardless of the degree of inutility suffered by the asset.

Levered Obsolescence Measure

The levered obsolescence measure takes into account operating leverage and is the percent underutilization multiplied by the degree of operating leverage times depreciated (straight-line) replacement cost new or $U \times DOL \times RCNSLD$. As Figure 2 shows, the levered measure underestimates the true obsolescence over the full life of the asset—but by less than the naïve estimate over the first half of the asset's useful life.

Figure 2 Comparison of Different Obsolescence Measures With True Obsolescence



Note: This figure illustrates the error difference between the three possible obsolescence measures (naïve, levered, and adjusted levered) and the true obsolescence. Observe that the naïve measure initially under estimates the obsolescence, but then significantly over estimates the obsolescence in the later periods. The levered obsolescence measure under estimates the true obsolescence over all periods, however the under estimate becomes more pronounced in the later periods. The adjusted levered obsolescence measure has been adjusted for the systematic difference between the true obsolescence and the levered obsolescence providing for a precise measure of true obsolescence caused by under utilization of the asset.

The levered obsolescence measure is contingent on a straight-line method of calculating depreciation; therefore, the path of value is a linear function of time. However, as discussed above, the true or economic value of the subject via the present value of its decreasing utility has a path of value that is a concave or nonlinear function of time. Therefore, levered obsolescence (as a percentage of the *RCNSLD*) has a systematic error that increases nonlinearly as the remaining life of the asset decreases.

The obsolescence error of the levered appraiser estimate is invariant with respect to changes in the degree of operating leverage or the percent of underutilization. Since this estimation error is simply an artifact of the computational mathematics of straight-line depreciation compared to the mathematics of nonlinear depreciation implicit in the present value calculation, it can be specified as purely a function of time independent of the characteristics of the property being appraised.

The error method of levered obsolescence compared with the true obsolescence as a function of time suggests an adjustment factor. Once the adjustment factor is calculated, a second step corrects for the error of the levered obsolescence measure, by applying an adjustment factor. This adjustment allows for a third and more precise methodology, "adjusted levered obsolescence." Adjusted levered obsolescence is defined as:

> the levered obsolescence measure adjusted for the error that arises because insufficient information forces the appraiser to use linear (straight line) depreciation instead of nonlinear depreciation.

Tables 2 through 4 present appropriate adjustment factors to correct for estimation errors.[12] The

Table 2 Adjustment Factors for Thirty-Year Asset

	Discount Rate							
Actual Age	**22.5%**	**20%**	**17.5%**	**15%**	**12.5%**	**10%**	**7.5%**	**5%**
1	1.03	1.03	1.03	1.03	1.03	1.03	1.02	1.02
2	1.07	1.07	1.07	1.07	1.06	1.06	1.05	1.04
3	1.11	1.11	1.11	1.10	1.10	1.09	1.08	1.06
4	1.15	1.15	1.15	1.14	1.13	1.12	1.10	1.08
5	1.19	1.19	1.19	1.18	1.17	1.16	1.13	1.10
6	1.24	1.24	1.23	1.22	1.21	1.19	1.16	1.12
7	1.29	1.29	1.28	1.27	1.25	1.23	1.20	1.14
8	1.35	1.34	1.33	1.32	1.30	1.27	1.23	1.17
9	1.41	1.40	1.39	1.37	1.35	1.31	1.26	1.19
10	1.48	1.47	1.45	1.43	1.40	1.36	1.30	1.22
11	1.55	1.54	1.52	1.49	1.45	1.41	1.34	1.24
12	1.63	1.61	1.59	1.56	1.51	1.46	1.38	1.27
13	1.71	1.69	1.66	1.63	1.57	1.51	1.42	1.29
14	1.81	1.78	1.75	1.70	1.64	1.57	1.46	1.32
15	1.91	1.88	1.83	1.78	1.71	1.62	1.51	1.35
16	2.02	1.98	1.93	1.87	1.78	1.69	1.55	1.38
17	2.14	2.10	2.04	1.97	1.86	1.76	1.60	1.41
18	2.28	2.23	2.15	2.07	1.95	1.83	1.66	1.44
19	2.43	2.37	2.28	2.18	2.04	1.90	1.71	1.47
20	2.60	2.53	2.42	2.30	2.14	1.98	1.77	1.51
21	2.79	2.70	2.57	2.44	2.24	2.07	1.83	1.54
22	3.01	2.89	2.73	2.58	2.35	2.16	1.90	1.58
23	3.24	3.11	2.92	2.74	2.47	2.26	1.97	1.61
24	3.51	3.35	3.12	2.91	2.60	2.36	2.04	1.65
25	3.82	3.62	3.34	3.10	2.74	2.48	2.12	1.69
26	4.17	3.93	3.59	3.31	2.89	2.60	2.20	1.73
27	4.56	4.27	3.86	3.54	3.05	2.72	2.28	1.77
28	5.01	4.66	4.17	3.79	3.23	2.86	2.37	1.81
29	5.54	5.11	4.50	4.06	3.41	3.01	2.47	1.86

Note: These adjustment factors were calculated in a three-step process. First, the percentage error of the levered obsolescence estimate from the true estimate was calculated for each discount rate. Second, using regression analysis, the percentage error was found to have a third degree polynomial relationship with the age of the asset (in each regression, the $R^2 = 1$). Third, the parameters from each regression were used to construct the adjustment factors for each asset age. This process also applies to Tables 3 and 4.

12. Since special-purpose properties are more likely to have longer economic lives, we present adjustment factors for 30, 40, and 50 years.

Table 3 Adjustment Factors for Forty-Year Asset

	Discount Rate							
Actual Age	**22.5%**	**20%**	**17.5%**	**15%**	**12.5%**	**10%**	**7.5%**	**5%**
1	1.02	1.03	1.02	1.03	1.02	1.02	1.02	1.02
2	1.05	1.05	1.05	1.05	1.05	1.05	1.04	1.03
3	1.08	1.08	1.08	1.08	1.08	1.07	1.07	1.05
4	1.11	1.11	1.11	1.11	1.11	1.10	1.09	1.07
5	1.14	1.14	1.14	1.14	1.13	1.13	1.11	1.09
6	1.17	1.17	1.17	1.17	1.17	1.16	1.14	1.11
7	1.21	1.21	1.21	1.20	1.20	1.19	1.17	1.13
8	1.25	1.25	1.24	1.24	1.23	1.22	1.19	1.15
9	1.29	1.28	1.28	1.28	1.27	1.25	1.22	1.17
10	1.33	1.33	1.32	1.32	1.31	1.29	1.25	1.20
11	1.38	1.37	1.37	1.36	1.35	1.32	1.28	1.22
12	1.42	1.42	1.41	1.40	1.39	1.36	1.31	1.24
13	1.48	1.47	1.46	1.45	1.44	1.40	1.35	1.27
14	1.53	1.52	1.51	1.50	1.48	1.45	1.38	1.29
15	1.59	1.58	1.57	1.56	1.53	1.49	1.42	1.32
16	1.66	1.65	1.63	1.61	1.59	1.54	1.45	1.34
17	1.73	1.71	1.69	1.67	1.65	1.59	1.49	1.37
18	1.80	1.79	1.76	1.74	1.71	1.64	1.53	1.40
19	1.88	1.86	1.84	1.81	1.77	1.70	1.57	1.43
20	1.97	1.95	1.92	1.88	1.84	1.75	1.62	1.46
21	2.06	2.04	2.00	1.96	1.91	1.82	1.66	1.49
22	2.17	2.14	2.09	2.05	1.99	1.88	1.71	1.52
23	2.28	2.24	2.19	2.14	2.08	1.95	1.76	1.55
24	2.40	2.36	2.30	2.24	2.16	2.03	1.81	1.59
25	2.53	2.48	2.41	2.34	2.26	2.11	1.87	1.62
26	2.68	2.62	2.54	2.45	2.37	2.19	1.93	1.66
27	2.84	2.77	2.68	2.58	2.48	2.28	1.99	1.70
28	3.01	2.94	2.82	2.71	2.60	2.38	2.05	1.74
29	3.21	3.12	2.99	2.85	2.73	2.49	2.11	1.78
30	3.42	3.32	3.16	3.00	2.87	2.60	2.18	1.82
31	3.66	3.54	3.36	3.17	3.02	2.72	2.25	1.86
32	3.93	3.78	3.57	3.35	3.19	2.85	2.33	1.91
33	4.23	4.05	3.81	3.54	3.37	2.99	2.41	1.95
34	4.57	4.35	4.07	3.75	3.56	3.14	2.49	2.00
35	4.95	4.68	4.36	3.98	3.78	3.30	2.58	2.05
36	5.38	5.05	4.69	4.23	4.01	3.48	2.67	2.10
37	5.87	5.47	5.05	4.50	4.27	3.68	2.76	2.16
38	6.43	5.94	5.45	4.80	4.56	3.89	2.86	2.21
39	7.07	6.47	5.90	5.12	4.87	4.13	2.97	2.27

adjustment factor removes the systematic underestimate of the levered depreciation measure.[13]

Adjusted-Levered Obsolescence Measure

The error of the adjusted obsolescence measure compared with true obsolescence is shown in Figure 2. By inspection, the chart shows the error is negligible. Since the adjustment factor appropriate for adjusting the levered obsolescence varies with the discount rate and the original useful economic life of the subject asset, tables of adjustment factors for discount rates ranging from 5% to 22.5% and economic lives of 30, 40, and 50 years have been generated (Tables 2–4).[14] These adjustment factors allow the appraiser to determine the proper percentage of the *RCNSLD* to deduct for obsolescence due to underutilized capacity. These adjustment factors theoretically apply to *RCNSLD* where the annual depreciation, not including obsolescence, is determined by 1/economic life or by a straight-line method of calculating deprecia-

13. A third-degree polynomial regression analysis with only time in years as the independent variable provides the parameter estimates needed to construct the adjustment factors.

14. The appraiser can use the firm or industry cost of capital, whichever is the best data. The adjustment factor is not sensitive to this choice.

Table 4 Adjustment Factors for Fifty-Year Asset

	Discount Rate							
Actual Age	**22.5%**	**20%**	**17.5%**	**15%**	**12.5%**	**10%**	**7.5%**	**5%**
1	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
2	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.03
3	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.05
4	1.08	1.08	1.09	1.09	1.08	1.08	1.08	1.06
5	1.11	1.11	1.11	1.11	1.11	1.10	1.10	1.08
6	1.13	1.13	1.13	1.13	1.13	1.13	1.12	1.10
7	1.16	1.16	1.16	1.16	1.16	1.15	1.14	1.12
8	1.19	1.19	1.19	1.19	1.19	1.18	1.16	1.14
9	1.22	1.22	1.22	1.22	1.21	1.20	1.19	1.16
10	1.25	1.25	1.25	1.25	1.24	1.23	1.21	1.17
11	1.28	1.28	1.28	1.28	1.27	1.26	1.24	1.19
12	1.31	1.31	1.31	1.31	1.31	1.29	1.26	1.22
13	1.35	1.35	1.35	1.34	1.34	1.32	1.29	1.24
14	1.39	1.39	1.38	1.38	1.38	1.36	1.32	1.26
15	1.43	1.43	1.42	1.42	1.41	1.39	1.35	1.28
16	1.47	1.47	1.47	1.46	1.45	1.43	1.38	1.30
17	1.51	1.51	1.51	1.50	1.50	1.46	1.41	1.33
18	1.56	1.56	1.56	1.55	1.54	1.50	1.44	1.35
19	1.61	1.61	1.60	1.59	1.59	1.54	1.48	1.38
20	1.67	1.66	1.66	1.64	1.63	1.59	1.51	1.40
21	1.72	1.72	1.71	1.70	1.68	1.63	1.55	1.43
22	1.79	1.78	1.77	1.75	1.74	1.68	1.59	1.45
23	1.85	1.84	1.83	1.81	1.80	1.73	1.63	1.48
24	1.92	1.91	1.90	1.88	1.86	1.78	1.67	1.51
25	2.00	1.98	1.97	1.94	1.92	1.84	1.71	1.54
26	2.08	2.06	2.04	2.02	1.99	1.89	1.76	1.57
27	2.16	2.14	2.12	2.09	2.06	1.96	1.80	1.60
28	2.25	2.23	2.20	2.17	2.13	2.02	1.85	1.63
29	2.35	2.32	2.30	2.26	2.21	2.09	1.90	1.67
30	2.46	2.43	2.39	2.35	2.29	2.16	1.95	1.70
31	2.58	2.54	2.50	2.45	2.38	2.24	2.01	1.73
32	2.71	2.66	2.61	2.56	2.48	2.32	2.06	1.77
33	2.85	2.79	2.73	2.67	2.58	2.40	2.12	1.81
34	3.00	2.93	2.86	2.79	2.68	2.49	2.18	1.84
35	3.17	3.08	3.00	2.93	2.80	2.59	2.25	1.88
36	3.35	3.25	3.15	3.07	2.91	2.69	2.32	1.92
37	3.55	3.43	3.32	3.22	3.04	2.80	2.39	1.97
38	3.78	3.63	3.50	3.39	3.18	2.92	2.46	2.01
39	4.03	3.85	3.69	3.57	3.32	3.04	2.53	2.05
40	4.31	4.10	3.91	3.76	3.47	3.18	2.61	2.10
41	4.63	4.37	4.14	3.97	3.63	3.32	2.70	2.14
42	4.98	4.67	4.39	4.20	3.80	3.47	2.78	2.19
43	5.39	5.01	4.68	4.45	3.99	3.63	2.88	2.24
44	5.86	5.39	4.98	4.72	4.18	3.81	2.97	2.29
45	6.40	5.81	5.33	5.02	4.38	4.00	3.07	2.34
46	7.03	6.30	5.70	5.34	4.59	4.20	3.17	2.40
47	7.78	6.85	6.12	5.70	4.82	4.43	3.28	2.45
48	8.68	7.49	6.59	6.09	5.05	4.66	3.39	2.51
49	9.76	8.23	7.11	6.52	5.30	4.92	3.51	2.57

tion. This method of calculating depreciation is similar to a conventional age/life method.

Practical Application

Implementing the utilization-based method requires that the appraiser to first estimate the amount of straight-line depreciation that has occurred and deduct this from the replacement cost new *(RCN)* to derive *RCNSLD.* Second, the appraiser determines both the degree of operating leverage *(DOL)* and the percentage of underutilization *(U)* affecting the subject as of the date of the appraisal. The product of these two numbers is the percent obsolescence *[%OBS]* suffered by the subject *(%OBS = U × DOL).*

As demonstrated previously, this estimate will understate the true obsolescence by an amount proportional to the age of the asset. This error is corrected by adjusting the *%OBS* by the appropriate error adjustment factors given in Tables 2 through 4. The discount rate and original economic life determine the table and column from which to select the adjustment factor. Since the adjustment factor is dependent on the actual age of the asset, this age determines the row in the table corresponding to the actual age. The selected adjustment factor is used to scale the *%OBS* by eliminating the error of the estimate. Applying the adjustment factor to the *%OBS* (*%OBS* × Adj. Factor) provides the corrected percent obsolescence *(%AdjOBS).*

The appropriate measure of obsolescence results from multiplying the replacement cost new by the corrected percent obsolescence *(RCN × %AdjOBS).* Deduction of the obsolescence estimate from replacement cost new results in current asset value. The practical application of this technique is summarized as follows:

Step 1: $RCN \times \left(1 - \frac{H}{Life}\right) = RCNSLD$

Step 2: $U \times DOL \times \text{Adj. Factor} = \%AdjOBS$

Step 3: $\%AdjOBS \times RCNSLD = \text{Obsolescence}$

Step 4: $RCN - \text{Obsolescence} = \text{Current Asset Value}$

Summary and Conclusion

Accurate estimates of economic obsolescence in industrial special-purpose properties are possible if the appraiser has access to information on underutilization, operating leverage, the replacement cost new, the current age, and the total estimated economic life of the facility. This article presents sound justification for using utilization data to measure economic obsolescence. The correlation of income with asset use is widely recognized. Utilization data is often well understood, are readily available, and serves as a reliable proxy for scarce income data. When applied using the techniques presented in this paper, utilization-based measures are effective for estimating economic obsolescence in special-purchase industrial properties.

Although the theoretical basis and techniques in this article enhance the options available to the appraisal professional, we recognize that the proposed methodology incorporates important assumptions and exhibits some limitations.

Stating a value conclusion as in Step 4, presumes that the only source of depreciation other than aging is due to underutilization. In other words, there is no depreciation from excess operating costs or other forms of asset inadequacy. In many instances, this assumption is reasonable, however, if additional sources of obsolescence are present, they must be recognized. For example, given appropriate data, obsolescence due to excess operating expenses can be accounted for by capitalizing the excess operating expenses and subtracting their present value from the appropriate *RCN* prior to subtracting obsolescence.

Any reduction in utilization that indicates economic obsolescence is presumed to be a permanent shortfall. Whether this underutilization at a given date is or is not permanent is not certain. However, since value conclusions are dated, any information on the temporary nature of underutilization will manifest itself in utilization data at a subsequent date. The obsolescence measure presented here will therefore automatically be adjusted as the data changes, whether or not it is greater or less than the measure manifested in data from the current period.

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Lastly, the methodology presented in this article presumes that the price at which units are sold remains constant over the life of the asset. Realistically, the firm may face price weakness as the utilization or output declines. Price changes add additional complexity because they alter the degree of operating leverage and require a more generalized measure of underutilization. Nevertheless, the methodology presented is still valid and is considered superior to other techniques that ignore utilization. Work on the price variability problem is currently underway, and we welcome and invite other researchers to assist in tackling this important and difficult valuation problem.

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