Beyond the Operating Ratio:

Using Financial Statement Analysis to Assess Fixed Capital Investments

by

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Abstract

Current practice among investors, policy makers, and industry groups for identifying the condition of physical capital in water and wastewater utilities includes the use of several key financial ratios such as Operating Ratio, Age of Plant, Fixed Asset Turnover and Infrastructure Condition. However, these ratios are frequently misinterpreted by users of the data who are unaware of the impact of inflation upon the ratios. Because inflation exaggerates the value of newer investments in fixed capital relative to existing historical investments, the newer assets dominate the calculation of fixed asset related financial information (depreciation expense, accumulated depreciation, gross fixed assets and net fixed assets). As a result, the calculation of capital condition ratios leads to frequent overestimates of the condition of the fixed capital and the time until replacement, particularly for utilities with a large portion of older assets. Financial modeling indicates that this inflation driven distortion is also impacted by the timing and expected life of investments in physical assets. Sensitivity testing of inflation, investment schedule, and expected life is used to determine guidelines for correctly interpreting financially based capital condition ratios within a given utility or better identification of peer group utilities for the purposes of benchmarking.

Introduction

Review of literature from ratings agencies, industry groups, policy bodies, and financial statement analysis texts indicates that four financial metrics are commonly used to identify investment and renewal of physical assets: Operating Ratio (Bernstein, 1993), Age of Plant (Hessenthaler, Quiroga, & Masterson, 2008), Fixed Asset Turnover (Bhattacharya, 1995), and Infrastructure Condition (Garvin, 2003). However, the financial statements these metrics are built from follow a convention of recording assets at their historic or book value – the value, in nominal dollars, at which they were purchased. This convention, combined with the common approach to depreciation of assets (straight-line depreciation) leads to distortions between the economic value of the assets and the value reported on the annual financial statements (Ratcliffe & Munter, 1981). Because inflation leads to an underrepresentation of the purchasing power of dollars that were invested in the past, more recent investments inappropriately dominate the fixed asset and depreciation related figures on the annual financial reports. Thus, the characteristics of the older assets: the value of the investment, the expected life, the degree to which these older assets have depreciated, and the annual depreciation expense recorded against the older assets appear inappropriately insignificant once they are aggregated together with the newer investments. The use of capital condition ratios further complicates and hides the intuition behind these inflation driven distortions and can lead to inaccurate information regarding the state of a given utility's fixed capital. Identifying the nature of these distortions, and recognizing the degree to which each fixed asset condition ratio is distorted as a result of specific factors such as inflation, expected life, and investment schedule can allow outside parties to play a more effective role in identifying utilities that struggle to fund the renewal of their fixed assets.

The goal of this paper is to improve the ways in which financial metrics are used to examine the state of the fixed capital (the pipes, treatment facilities, and similar heavy equipment) within a water or sewer utility. The first section consists of a brief introduction to the problem. This is followed by an illustrative calculation of the accounting figures which form the basis for capital condition metrics. Section three provides a more thorough background exploring the purposes of accounting, depreciation and previous attempts to address the problems of inflation in accounting. The fourth section provides a qualitative discussion of the calculation and use of each of the four capital condition ratios. The fifth section discusses the financial model of a hypothetical utility used to explore the distortions between nominal and constant dollar based metrics. The sixth and final section highlights significant results and draws conclusions from the model.

Accounting for Fixed Assets: An Illustration

Inflation occurs when the purchasing power of a single unit of currency decreases over time. The annual rate of inflation can be calculated by comparing the purchasing power of a given monetary unit from a year ago and comparing it with the purchasing power of the given monetary unit from this year. For example, if it takes $110 dollars to buy the same basket of goods that could have been purchased with $100 last year then it can be said that the annual rate of inflation is 10%. In recent history in the United States the annual rate of inflation has remained relatively low – around 2% to 5% with a peak around 12%-15% during the mid 1970s to early 1980s. Although single year inflation has been relatively low, inflation compounds over time and so the differences in purchasing power of a unit of money going back even over just a few decades can become quite significant. For example, let's pretend that you had $100 today and you decided to put that money under your mattress for a rainy day, and that rainy day finally comes 50 years from now. If we assume a historically low annual inflation rate of 2% every year over that 50 years then the $100 you put away would buy only 37% of the goods and services that it would have bought had you used it today. The table below presents the nominal dollars, varying with inflation that you would need at each decade over the next 50 years to purchase the same goods that you could buy in the present with $100.

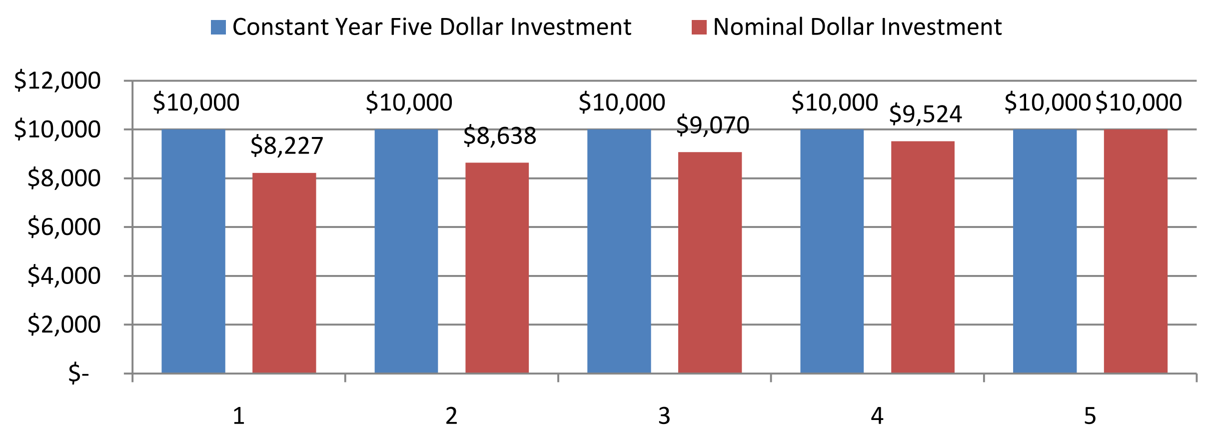
Table 1. Effects of Inflation on Purchasing Power

		Annual Inflation									
		1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
Number of Years in the Future	10	$ 110.46	$ 121.90	$ 134.39	$ 148.02	$ 162.89	$ 179.08	$ 196.72	$ 215.89	$ 236.74	$ 259.37
	20	$ 122.02	$ 148.59	$ 180.61	$ 219.11	$ 265.33	$ 320.71	$ 386.97	$ 466.10	$ 560.44	$ 672.75
	30	$ 134.78	$ 181.14	$ 242.73	$ 324.34	$ 432.19	$ 574.35	$ 761.23	$ 1,006.27	$ 1,326.77	$ 1,744.94
	40	$ 148.89	$ 220.80	$ 326.20	$ 480.10	$ 704.00	$ 1,028.57	$ 1,497.45	$ 2,172.45	$ 3,140.94	$ 4,525.93
	50	$ 164.46	$ 269.16	$ 438.39	$ 710.67	$ 1,146.74	$ 1,842.02	$ 2,945.70	$ 4,690.16	$ 7,435.75	$ 11,739.09

Real or constant dollars are one way that economists talk about this fluctuation of purchasing power. A real or constant dollar would have the same purchasing power regardless of when it is being spent. However it is still important to indicate which year is being used as the basis for the constant dollar. Constant year 1950 dollars would have much higher buying power than constant year 2000 dollars for example.

A hypothetical water distribution facility allows us the opportunity to examine the impact of inflation in the accounting for fixed assets of a water distribution facility. For the sake of simplicity let us assume that this facility consists only of pipes; treated water is purchased from another entity, our facility carries the water through a set of pipes and then sells it. Our facility is five years old and has purchased and installed 1000 yards of pipe every year for each of the past five years. Further, let's say that the price of 1000 yards of pipe in today's dollars is $10,000 and that inflation has been 5% annually for the past five years. The annual investments have been consistent in economic terms – they have been purchases of an equivalent physical asset in each year. Another way to put this is that in constant year five dollars the investments would have been $10,000 dollars in each year. However, in nominal terms, the dollars that would have been spent on each investment of pipe would have been less due to inflation. The graph below illustrates the difference between the nominal and constant dollar annual investments. Notice that the nominal and constant dollar expenses are the same in the current year, year 5, but as the time of investment moves further into the past the nominal dollar value of the investment decreases although the economic value of the purchases was the same across all of the years.

Figure 1. Nominal Versus Constant Dollar Annual Capital Investments for Hypothetical Utility



Current accounting practices deal only with the nominal dollars represented by historic prices and so the gross fixed assets entry that one would find on the annual financial statements of such a hypothetical utility would be the sum of the nominal investment, $45,460 rather than the constant year five dollar based calculation of $50,000. The details of this calculation are presented in Table 2.

Table 2. Calculation of Gross Fixed Assets in Nominal and Constant Dollars

	Nominal Dollars	Constant Dollars
Investment in Year 1	$ 8,227.02	$ 10,000.00
Investment in Year 2	$ 8,638.38	$ 10,000.00
Investment in Year 3	$ 9,070.29	$ 10,000.00
Investment in Year 4	$ 9,523.81	$ 10,000.00
Investment in Year 5	+ $ 10,000.00	+ $ 10,000.00
Gross Fixed Assets	$ 45,459.51	$ 50,000.00

The next accounting calculation that is made is the determination of the annual depreciation expense. Because most utilities use straight-line depreciation that method is adopted here. Starting in year one when the first investment was made the accountants make a determination about the expected life of the pipes. Let's assume that they determine that the pipes are expected to last 10 years. The accountants then divide the nominal, or book value of the asset, $8,227 by 10 to get a first year depreciation expense of $822.70. In year two they are interested in the depreciation of both the assets that were put into operation the year before as well as the assets purchased in year two so they would take a second depreciation expense for the year one assets at $822.70 plus a depreciation expense of $863.84 for the year two assets for a total depreciation expense of $1,686.54. This process then continues with the summation of the depreciation on each year's investments until a final year five depreciation expense figure is reached. On the other hand, if accounting were based upon year five constant dollars, then the depreciation expenses would have been $1,000 for year one and $1,000 plus $1,000 equals $2,000 for year two and so on in the same manner. These calculations for annual depreciation expense in year 5 are shown in Table 3. Figure 2 illustrates the annual depreciation expense for each of the five years for both nominal and constant year five dollars.

Table 3. Calculation of Annual Depreciation Expense for Year 5

	Nominal Depreciation Expense	Constant Dollar Depreciation Expense
Depreciation on Investments Made in Year 1	$ 822.70	$ 1,000.00
Depreciation on Investments Made in Year 2	$ 863.84	$ 1,000.00
Depreciation on Investments Made in Year 3	$ 907.03	$ 1,000.00
Depreciation on Investments Made in Year 4	$ 952.38	$ 1,000.00
Depreciation on Investments Made in Year 5	+ $ 1,000.00	+ $ 1,000.00
Annual Depreciation Expense for Year 5	$ 4,545.95	$ 5,000.00

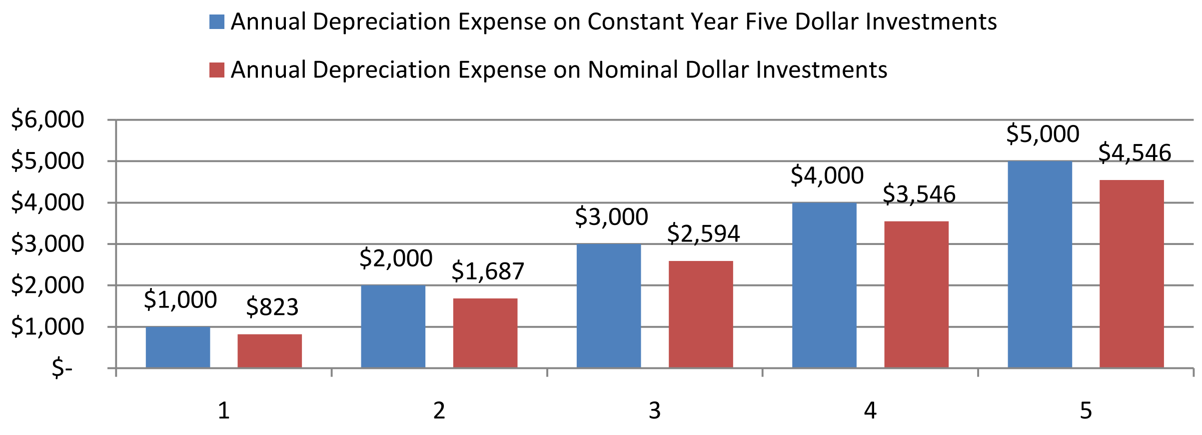


Figure 2. Nominal Versus Constant Dollar Annual Depreciation Expense for a Hypothetical Utility

The next step for accounting for capital assets is the calculation of accumulated depreciation. Accumulated depreciation is calculated by taking the sum of the annual depreciation expenses that have been recognized to date. So, for example, going back to our previous scenario where we had calculated that in year two of our hypothetical water utility the nominal depreciation expense was $1,685.54 and our year one nominal depreciation expense was $823, we can see that the year two accumulated depreciation figure would be $1,685.54 plus $823 equals $2,509 in nominal terms. This process would then continue until a year five accumulated depreciation figure is reached. On the other hand, in constant year five dollar terms the accumulated depreciation figure would be $1,000 plus $2,000 equals $3,000. Table 4 lays out the calculation for the year 5 accumulated depreciation figure in both constant dollar and nominal dollar terms and Figure 3 presents the accumulated depreciation figure in constant year five dollars and nominal dollars for each of the past five years.

Table 4. Calculation of Accumulated Depreciation

	Nominal Accumulated Depreciation	Constant Dollar Accumulated Depreciation
Depreciation Expense Recorded in Year 1	$ 822.70	$ 1,000.00
Depreciation Expense Recorded in Year 2	$ 1,686.54	$ 2,000.00
Depreciation Expense Recorded in Year 3	$ 2,593.57	$ 3,000.00
Depreciation Expense Recorded in Year 4	$ 3,545.95	$ 4,000.00
Depreciation Expense Recorded in Year 5	+ $ 4,545.95	+ $ 5,000.00
Accumulated Depreciation for Year 5	$ 13,194.71	$ 15,000.00

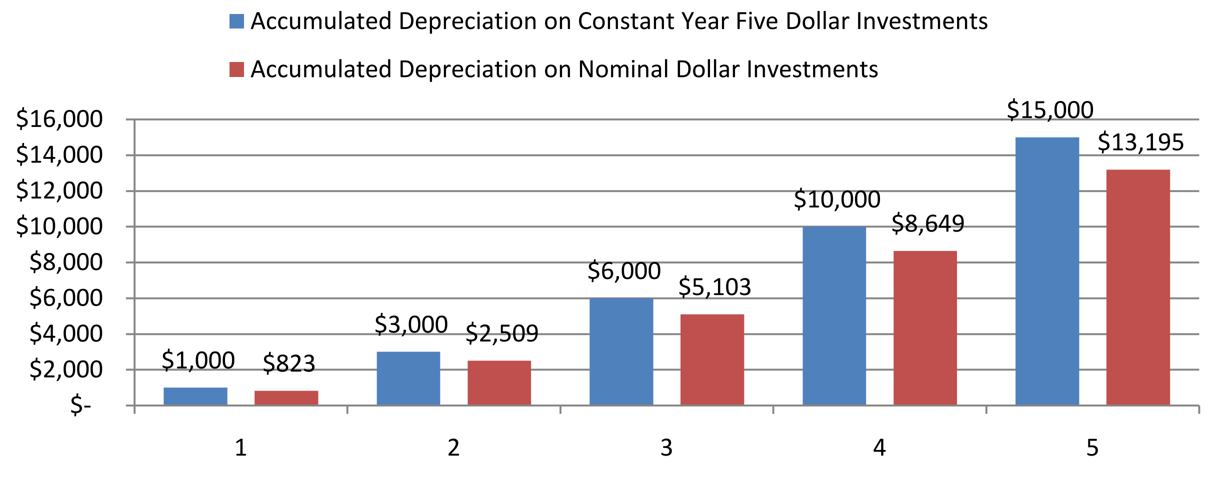
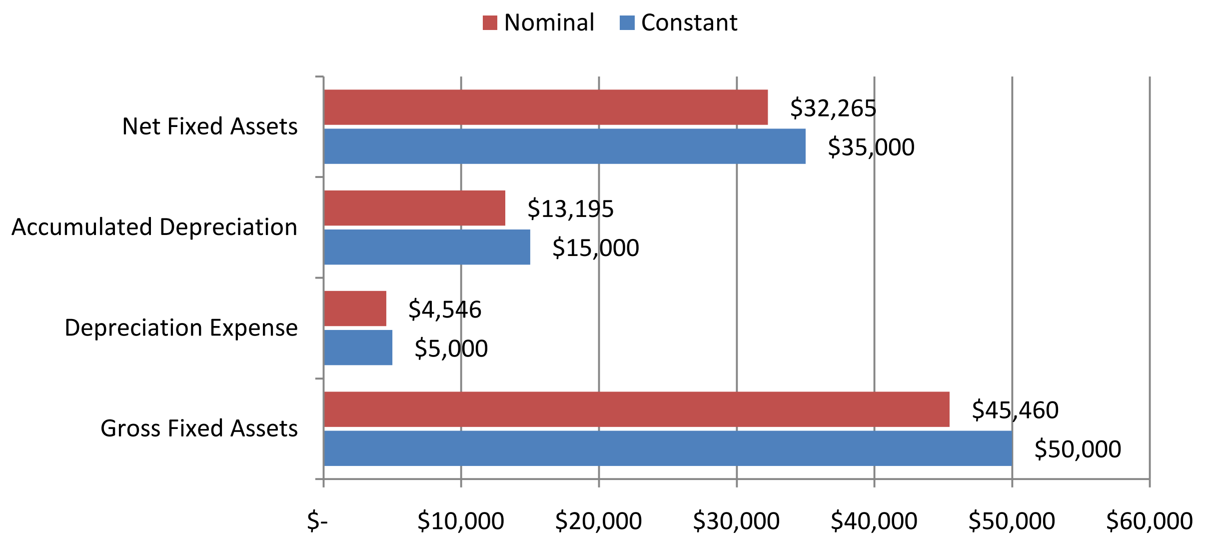


Figure 3. Nominal Versus Constant Dollar Accumulated Depreciation

The final fixed asset related accounting entry is net fixed assets which is calculated by taking the gross fixed assets for an entity and subtracting the fixed asset related accumulated depreciation. The net fixed assets figure in nominal terms would be gross fixed assets of $45,460 (as calculated in Table 2) minus accumulated depreciation of $13,195 (as calculated in Table 4) equals net fixed assets of $32,265. In year five constant dollar terms the net fixed assets figure would be gross fixed assets of $50,000 minus accumulated depreciation of $15,000 equals net fixed assets of $35,000.

We can see that even in five short years there is already a significant divergence between the nominal figures reported on the annual financial statements and the economic realities represented by constant dollar based calculations. Further, note that in each of the figures above the difference between the nominal and constant dollar value becomes proportionally larger with each year. This increasing distortion between nominal and constant dollar based calculations will continue due to the exponential nature of inflationary growth. Figure 4 below summarizes the differences between nominally based accounting figures and the real dollar calculations in year five that have been explored in detail above.

Figure 4. Nominal Versus Constant Dollar Fixed Asset Related Accounting Entries



As discussed in the background there are good reasons why accountants depend on historical figures – they are conservative estimates with proven value because they have actually been exchanged at the market at that price. Constant year dollars, on the other hand, depend upon some method of modifying the dollars with each year so that investments in different periods can be measured using a common economic reference. The financial community has refused to undertake such inflation accounting because of the complexities involved with this process and because of concerns that widespread agreement on how the figures should be inflated will be difficult to achieve and may open new opportunities for corrupt manipulation of financial statements. However, as we have demonstrated above, using nominal values for fixed assets in water and wastewater utilities leads to significant distortions between accurate values and the figures on the financial statements.

Taken in the context of the four capital condition indicators examined in this research, these inflationary distortions result in either indicators which are demonstrably incorrect, as is the case for Age of Plant and Infrastructure Condition, or else leads to flawed intuition as is the case for Fixed Asset Turnover and Operating Ratio. Age of Plant and Infrastructure Condition are used to describe how old the fixed assets of a utility are. They each use a dollar weighted average to calculate the progress of the utility as a whole towards exhaustion, but because they depend upon nominal dollars more recent investments weight more heavily in the equation. Because these heavier weighted newer investments are by definition younger, the ratios end up systematically under representing the age or nearness to replacement of the utility's assets. Fixed Asset Turnover and Operating Ratio use revenues or expenses which are in current dollars to measure the investment or efficiency of the fixed assets. However, because older utilities will have smaller nominal fixed assets, these two ratios falsely identify older utilities as providing better economic profits flowing from operations and more efficient use of their fixed assets.

Background

The field of accounting has ancient foundations, but in the United States accounting's modern era began during the late 19th century as a way for railroad managers in the United States to communicate revenues, expenses and profits to British investors (King, 2006). The rise of the industrial economy, with intensive equipment use and wear, coupled with the rise of the corporate legal framework, informed much of the development of the current accounting structure. During the late 19th and early 20th century the accounting system that had been developed for corporate bodies was adapted and standardized for use in governmental bodies as a way to combat the widespread graft and corruption which had become ingrained in the political machines that dominated American cities at the time (Moussalli, 2008) As a result, these two systems of accounting, government and financial, depend upon many of the same concepts and processes. Governmental accounting, like financial accounting, uses double entry book keeping to track assets, liabilities, equities, revenues and expenses on balance sheets and operating statements. Government and corporate annual financial statements consist of two major documents: the balance sheet and the operating (or income) statement. Reconciliations with a cash flow statement are also frequently prepared and presented. The balance sheet is meant to portray a snapshot taken at a single moment of all the assets, liabilities and equities which constitute an entity. The operating statement represents the flows which changed the levels of assets, liabilities, and equities since the last reporting period. Cash flow statements reconcile the full accrual method of recognizing revenues and expenditures with the movement of actual cash flows.

Both governmental and financial accounting systems rely on the fundamental accounting equation: that assets must equal liabilities plus equities. Assets are the resources that an entity has; liabilities are the debts that it owes; and equity is the difference between the two. Functionally, the value of assets plays an important role in limiting the amount of debt that an entity can issue. As a result, assets are recorded conservatively with an eye towards maintaining a value for the assets which could be captured through liquidation to satisfy outstanding debts, or which have been purchased with debt and which are therefore offset on the balance sheet by the outstanding liability (Harris, 1999). There is, however, some difference in the way that corporate accounting identifies assets and the way in which government accounting identifies some entities' assets.

The primary difference between governmental and corporate accounting is that governmental accounting uses many different funds to organize the information around different activities, and several of these funds have slightly different sets of rules about what and when information should be recorded. That is, in governmental accounting the processes associated with different funds vary according to their measurement focus and their basis of accounting. The two forms of measurement focus are economic or current financial. The two major forms of basis are full accrual and modified accrual. The measurement focus determines what the accounting system is attempting to record. Current financial measurement focus looks only at resources that will convert into cash during their typical lifespan. Economic focus includes all resources which are of value in the firm. The basis of accounting determines when revenues and expenses or expenditures are recorded as having occurred. Modified accrual requires revenues to be recorded when they become available. Full accrual allows revenues to be recorded as soon as the service which will be exchanged for the revenues is completed.

In the public sector, water and wastewater systems are typically treated as enterprise funds which fall under the economic measurement focus and the full accrual basis of accounting. (This approach is the same one used in the private sector for financial accounting.) The matching principle provides one of the major underlying arguments for the use of the full accrual method of accounting. It dictates that expenses should be reported in the same period as (matched with) the revenues which resulted from these expenses. Systems with an economic measurement focus use depreciation expense to divide the initial cost of a piece of equipment over the period of time that it is used to create revenues. Thus, a taxi company which buys a car for $20,000 and expects that car to last 5 years may, using the technique of straight-line depreciation, record a depreciation expense of $4,000 in each year that the car is used. This depreciation expense will then be netted from revenues in each year, along with other forms of expenses, to reflect a change in net assets figure for the reporting period.

History of Financial Benchmarking

On a set of financial statements, depreciation is the primary figure used to communicate the condition of capital assets. However, as with many of the figures and concepts presented on the financial statements, there are methods for standardizing and benchmarking this information to make it more meaningful for readers of financial statements. However, unlike earnings ratios or credit quality ratios, the methods for benchmarking capital conditions remain relatively rudimentary due to the conventions that developed during the standardization of the accounting system. The focus in practice during the standardization of accounting systems during the nineteenth century was on communicating economic details regarding the operation of the railroads to key investors in Britain. Thus, at that time, the focus of accounting and therefore the key metrics that were developed was on identifying the profitability of firms (Kester, 1918). Equity investors and stock markets were the major drivers of the development of financial metrics (Bhattacharya, 1995). However, as the financial system grew to rival the industrial and manufacturing corporations banks gained the power to demand more sophisticated financial statements, and developed new financial metrics to facilitate credit analysis. Because banks were largely involved with the provision of credit, rather than equity financing, credit ratios became a more significant focus. These metrics then gained in sophistication following World War II as statistical analysis of the effectiveness of key ratios in predicting bankruptcy became widespread. This ultimately led to the development of Altman's Z Score in 1968. Altman's Z was able to predict bankruptcy of publicly held manufacturing companies with greater than 70% reliability through a combination of five different ratios (Calandro, 2007). Ratios have since been developed to serve a wide range of purposes, including ratios based on internal measures that are used to assess and reward managerial ability.

Altman's Z-Score: Variables

- Working Capital / Total Assets. Measures liquid assets in relation to the size of the company.
- Retained Earnings / Total Assets. Measures profitability that reflects the company's age and earning power.
- Earnings Before Interest and Taxes / Total Assets. Measures operating efficiency apart from tax and leveraging factors. It recognizes operating earnings as being important to long-term viability.
- Market Value of Equity / Book Value of Total Liabilities. Adds market dimension that can show up security price fluctuation as a possible red flag.
- Sales/ Total Assets. Standard measure for turnover (varies greatly from industry to industry).

Depreciation

> Depreciation is a difficult item to deal with, more particularly as it has, unfortunately, got largely into the hands of auditors and bookkeepers, who deal with it according to their own limited knowledge and entirely as a matter of account. Depreciation is much more than this, and can only be properly adjusted by an engineer who has thorough knowledge of his profession and intimate acquaintance with the particular buildings and machinery with which he is at the moment dealing (Wolf & Fitch, 1994)

Historically, depreciation has generally referred to the appropriate technique to use in calculating annual depreciation expense (Wright, 2006). Straight-line depreciation is the most common method due to its ease of calculation. However, there are several other techniques such as sum of years, or double declining method. These different methods are argued to more accurately capture the process by which capital is consumed or devalued over the course of its useful life. The annual depreciation charges associated with different methods of accounting are illustrated below in Figure 5 for an asset with a purchase price of $10,000, a salvage value of $1,000 and a 10 year estimated useful life.

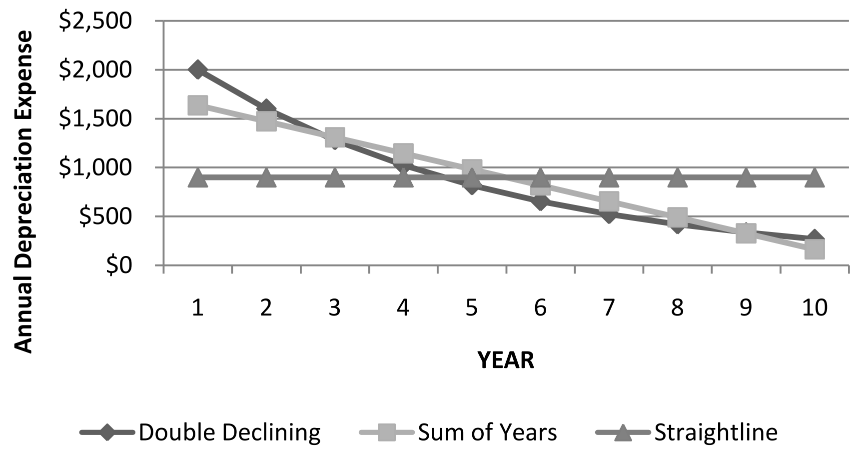


Figure 5. Common Depreciation Techniques

Depreciation has been further complicated by tax policy and utility regulation. Because depreciation is a tax deductable expense, corporations have an incentive to recognize depreciation as quickly as possible in order to reduce their tax liabilities and thus increase profits in the near term, leading to lobbying efforts in support of the more aggressive techniques for depreciating assets depicted above. As a result, depreciation techniques and approved practices can be the source of intense political debates that are divorced from the underlying economic theory which was the basis for depreciation. Regulated utilities have exacerbated this politicization of depreciation as the formula (Brigham & Pettway, 1973) which determines their allowable return explicitly references depreciation and therefore the depreciation calculation directly determines their revenues and returns to shareholders (Bickley, 1928). Customers can also be subjected to rate shock as a result of sudden increases in depreciation expense as a result of new capital outlays (Marcus, 1986). Within the public sector, however, water and sewer utilities generally use straight-line depreciation which is calculated by dividing the book value of the asset by the expected life of the asset. This number is then reported as a depreciation expense on the operating statement, and the accumulation of these numbers is netted against the gross book value which is reported under the assets section of the balance sheet.

Inflation Accounting

Depreciation as it is currently calculated depends upon four major assumptions about the economic unit which is being appraised: the entity, the time period, the going concern, and the stable monetary unit (Wolf & Fitch, 1994). The entity assumption relates the lines which have been drawn around a particular operation. For example, in a city which manages a water system, some decision may need to be made about how to divide the depreciation expense for the building which houses both the water system administrative employees as well as the town clerk's office. The time period assumption relates to the period which has been chosen for reporting, usually a year. Because fixed assets typically last many years, decisions about when to record depreciation expenses must be predicated on assumptions made about the economic activities in future periods. The going concern assumption presumes that the entity will continue to operate into the future such that it makes sense to spread costs against future revenues. The final assumption, stable monetary unit assumption, relates most directly to this research as it presumes that inflation does not exist and that dollars over time share constant purchasing power.

The stable monetary unit assumption inherent in the current methods for calculating depreciation creates significant flaws in the economic validity of the information being presented. During times of high inflation there have been calls to reform the historic value convention which records assets at the price that they were purchased for and keeps them at that same, nominal, price (Tweedie & Whittington, 1984). The most recent attempt to address the stable monetary unit assumption came during the early to mid 1980s in the corporate sector. In 1979 the Financial Accounting Standards Board (FASB) issued Statement 33 which required corporations with $1 billion or more in assets and at least $125 million worth of inventory to report the current costs of inventory, plant and equipment in a supplemental report to their annual financial statements (Wolf & Fitch, 1994). However, FASB relented on this requirement in 1986, making the reporting an option. According to an article in Forbes magazine at the time,

> Corporate financial types never stopped complaining about Statement 33, and as inflation lessened over the past five years, corporate lobbying efforts intensified. Instead of complaining about the negative effect of inflation accounting on earnings reports, corporate officials more shrewdly lobbied against what they pictured as the needlessly complex way the Financial Accounting Standards Board had chosen to deal with calculating "current costs." (Andresky, 1987)

Inflation since then has remained relatively low, and there have been few calls for the return of inflation accounting since. However, it is worth noting that at the time there were actually many different proposals for how to deal with inflation. These include the constant purchasing power method which translates all dollars into equivalent dollars at some specific time period, usually the present, and the current cost accounting method which looks to current prices of similar goods or equipment (Tweedie & Whittington, 1984). The current cost accounting method has a number of variants including the replacement cost method, which uses the cost that a firm would incur if it were to repurchase or rebuild the assets, the net realizable value method which uses the price that the firm could get for the goods if sold on the market, and the net present value method which discounts back the cash flows that will result from the use of the asset to provide a service or good. For the purposes of this research, constant purchasing power has been adopted as the preferred method. This has the benefit of being easier to calculate since it is based upon the use of a price index, in this case the construction cost index. Further, the major objection to this method, that different commodities experience different price fluctuations is somewhat overcome since all the assets involved here are fixed capital assets relating to construction. The Construction Cost Index published by Engineering News-Record has been adopted for price conversions for the purposes of this paper.

Capital Condition Ratios

A review of literature on capital asset ratios identified four key metrics that are used as indicators of capital condition by investors, engineers or industry bodies. The Operating Ratio, Age of Plant, Infrastructure Condition and Fixed Asset Turnover ratios each take a different approach to analyzing the information present on financial statements to assess the age or condition of a system's fixed capital. A more detailed examination of the calculation of each of these ratios follows.

Operating Ratio

$$\frac{Operating\ Income}{Operating\ Expenses}$$

The Operating Ratio would seem to be one of the most straightforward metrics to calculate. Both operating revenues and operating expenses are explicitly present on the operating statement and one would assume that these are the numbers that should be included in the ratio. Yet complications exist both on the revenue side and on the expense side. Many water and sewer utilities depend on tap and impact fees as revenue generators. This makes sense as there are costs associated with putting in a new meter that show up as operating expenses and so these should logically be offset with operating revenues. However, many utilities do not differentiate between the tap fees and the capacity or impact charges that are meant to pay for more long term capital expenses. Counting these fees as operating revenues falsely inflates the Operating Ratio. Moving to the divisor, operating expenses, some calculations of Operating Ratio exclude depreciation from the calculation. Others use a more cash-focused calculation of expenditure, substituting annual debt payments for depreciation expense. In this paper I have calculated a classic Operating Ratio which takes operating revenues and expenditures exactly as they are calculated on the income statement including depreciation.

The Operating Ratio is a widespread and commonly used metric to determine whether an entity is collecting enough regular and continuous revenues to cover regularly occurring expenses. A ratio of one just meets this obligation and ratios higher than one presumably allow reserve accounts to be funded for capital needs and unexpected costs. For example, a Classic Operating Ratio of 1.3 implies that a system is setting aside 3/13ths of its revenues towards capital reserve accounts or using those cash flows to meet its debt service payments on fixed capital that was purchased with a loan.

However, the Classic Operating Ratio is distorted because of the historical pricing convention – that is, an amount equal to the historical price of the fixed asset divided by the expected useful life of the fixed asset is taken as the depreciation expense under the straight-line depreciation technique commonly used in public water and wastewater accounting. As a result, in a plant with older assets, the Operating Ratio may in fact be underfunding the reserve account while maintaining a positive Operating Ratio. For example, a system which is 40 years into a 50 year useful life on $100 million of fixed assets – all purchased 40 years ago – would show an annual depreciation of $2 million. However, the cost to replace this system at the present time would likely be much greater than the $100 million price 40 years ago. Funding depreciation expense calculated against the present value of the asset would provide a level playing field for the comparison of different utilities regardless of the age of their assets and would encourage more homogenous rate increases rather than sudden jumps in rates at the time when new assets are purchased.

Another option is to leave the depreciation figure out of the equation and calculate a capital-free Operating Ratio which leaves the entire remainder for capital costs whether they be debt financed or set aside for future pay as go acquisition. However, using the Capital-Free Operating Ratio as a benchmark has its own set of challenges – it depends upon a somewhat homogenous or predictable relationship between labor and other operating expenses (excluding depreciation) versus the appropriate amount of fixed capital in current value terms. In general, although the Operating Ratio is used frequently due to the surface level intuition behind its calculation, it has relatively little predictive ability with regard to funding and replacement of fixed capital.

Infrastructure Condition

$$\frac{Accumulated\ Depreciation}{Gross\ Property\ Plant\ and\ Equipment}$$

Infrastructure condition is calculated by taking the accumulated depreciation, which is the aggregate of the prior years' depreciation on each piece of equipment still in active use in the utility, and dividing it by the gross, or undepreciated, book value of each piece of equipment in active use in the utility. The result is a percentage indicating, on an original purchase price weighted basis, how far through the expected life the plant and distribution equipment has passed. It is also advisable, where possible, to leave out the property figure from the calculation as land is not a depreciating asset and so would distort the ratio. According to this measure, a utility with an Infrastructure Condition metric approaching 100% would be a plant that is coming close to reaching the end of its expected life.

This metric encounters a number of complications. Expected useful life is a very rough approximation. Ideally it should be updated over time as examinations of assets reveals that they are likely to last longer or shorter periods than was originally estimated. However, in reality this sort of adjustment is seldom done. This has two effects on the Infrastructure Condition equation. On one hand changes in the depreciation schedule may make the metric less intuitive. For example, it would mean that an Infrastructure Condition ratio of 20% could not be interpreted as being one fifth of the way through its expected life because it may be that the expected life has been revised and that it will depreciate at a slower rate moving forward. This would imply that the correct ratio should be somewhat lower. On the other hand, if the utility does not update their forecasts then the ratios are likely to be incorrect because the ratio is counting down to a termination of the equipment which is not reflected in reality. This becomes particularly problematic when utilities have equipment on their books which is fully depreciated but remains in use. For example, a utility that assumes a 50 year useful life for its equipment and whose equipment is all at year 45, but is showing signs of lasting until year 60 would show an Infrastructure Condition metric of 90% when in fact the metric should be 75%. While these flaws are serious, they are really only fully addressable by a fully implemented asset management system and are outside of the scope of this paper.

However, there is another systematic bias in this metric that is explored more fully here. Under a constantly inflationary environment, newer pieces of equipment will cost more in nominal dollars than did older pieces of equipment. As a result the Infrastructure Condition calculation will always (in a historically inflationary environment) skew towards the younger (newer) equipment and will hence under report the true degree to which the assets have depreciated. This results in a predictably under reporting of the true age of the assets.

Average Life of Plant and Equipment

$$\frac{Accumulated\ Depreciation}{Current\ Year\ Depreciation\ Expense}$$

Age of plant has been adopted by Fitch's Water and Sewer ratings criteria as an indicator of capital age and it has also been included in prominent financial statement analysis guides (Hessenthaler, Quiroga, & Masterson, 2008) (Bernstein, 1993) The ratio produces an estimate of the average number of years that the plant and equipment have been in use. The numerator is the aggregate of the depreciation expenses that have been recorded over the years for fixed assets that continue to be in use. The denominator is the current year depreciation expense.

This metric is flawed in a number of ways, most linked to the historic pricing convention. Because older investments are recorded in earlier year dollars, their actual values are underrepresented. As a result, newer investments dominate the historic book value of the entity. For example, a utility which installs pipes at a cost of $10 million and builds a treatment plant at a cost of $40 million and which then 30 years later replaces that treatment plant at a cost of $50 million will appear to be a relatively new plant with a long average life, even though the pipes may be coming up for replacement very soon and at a much higher cost then their historic price. The expected age of each asset also gets weighted by its nominal dollar value, so if a new plant is built with better technology and is expected to last longer, its expected life will inappropriately dominate the calculated value. In inflationary (rather than deflationary) environments average age of life is always an underestimate of the true age of the plant because younger assets are over weighted relative to the true economic makeup of the utility.

Age of plant and infrastructure ratio approach the measurement of capital in similar ways. Both attempt to give a sense of how soon a significant investment in fixed asset renewal will need to be made. Yet their calculation makes slightly different assumptions which are important to recognize. Age of plant depends upon the interpreter of the data to bring some outside knowledge of the total expected life of the fixed assets as a benchmark against which to measure the Age of Plant calculation. Infrastructure condition, on the other hand, incorporates the accounting assumed expected life as the full measure of life. In some ways, this makes Age of Plant a preferable metric because it allows superior expertise in the lifespan of water and wastewater utilities to be brought to bear on the metric.

Fixed Asset Turnover Ratio

$$\frac{Operating\ Revenue}{Net\ Fixed\ Assets}$$

Fixed asset turnover is calculated by taking operating revenue and dividing it by the depreciated fixed assets. This ratio measures the number of dollars of annual revenue produced by each dollar of investment in fixed assets. Because the water and wastewater industry has relatively little competition and demand is relatively inelastic, long term trends can be accounted for primarily by variations in the amount of capital that has been invested in the fixed assets and by how much that capital has depreciated. Comparisons across utilities may reveal increased levels of investment by utilities which serve areas with low population densities. Trends within a firm over time or across firms with similar service demographics may reveal underinvestment in infrastructure. A low ratio indicates excessive investment or low efficiency of the fixed assets, while a high ratio may indicate under investment. Fixed asset turnover ratio, like the other ratios discussed here, is distorted by the historic value convention. Older plants will have their remaining assets undervalued since the accounts reflect earlier, uninflated dollars.

Analytical Approach

Using Microsoft's Excel software a financial model was built which replicates the relationship between investments in infrastructure over the life of a hypothetical utility first placed in operation in 1951 and the resulting figures that would be reported on the annual financial statements (using straight-line depreciation) as of fiscal year end 2000. The process of calculation of the accounting figures closely follows the illustrative example provided in section two of this paper, although on a longer timeline. Certain assumptions also had to be made in order to calculate operating ratio and fixed asset turnover since they also incorporate revenues and expenses into the metric calculation. The assumed level of operating expenses other than depreciation and the investment in land affect the calculation of percent error for Operating Ratio and Fixed Asset Turnover, respectively. For these purposes an approximate median for each value (land as a percentage of total fixed assets and non depreciation operating expenses as a function of total operating expenses) was taken from the statewide North Carolina utility financial statements. The specification of revenues in the model was similarly benchmarked, but is ultimately not relevant as it cancels out during the calculation of percent error between nominal and constant dollar Fixed Asset Turnover. Table 5 presents a sample calculation of error for the metrics derived from a hypothetical utility with level investment and expected life schedule and actual inflation from 1950 to 2000.

Table 5. Calculation of Error Between Nominal and Constant Metrics

Metric	Nominal	Constant	Calculation of Error
Operating Ratio	0.84	0.55	(0.84-0.55)/0.84=51%
Age of Plant	15.84	25.50	(15.84-25.5)/15.84=-38%
Fixed Asset Turnover	0.04	0.02	(0.04-0.02)/0.04=78%
Infrastructure Condition	0.25	0.41	(0.25-0.41)/0.25=-38%

Sensitivity Analysis

The distortion between the economically accurate constant dollar and the distorted nominal dollar based calculations is not solely driven by inflation and the length of time the utility has been in operation. For example, take two plants that both went into operation at the same time, have the exact same real dollar investment in their fixed assets, and even the exact same physical assets themselves can still have different levels of distortion between the nominal and economic ratios depending upon the timing of the purchase of these assets. A utility which put the majority of its assets into operation when it first opened fifty year ago would have much larger levels of distortion than a plant which began as a small operation fifty years ago and has only recently made large investments. This variation in timing of investment is referred to as a change in the investment schedule.

Another variable which may influence the distortion between the economically accurate constant dollar and the distorted nominal dollar based calculations is whether more recent investments have longer or shorter lives than do older assets. For example, returning to the example of our water distributing utility lets presume that the pipes are of two different types: steel and plastic. Both have the same real dollar cost per foot but plastic pipes last fifty years while steel pipes last one hundred years. If the utility installed the plastic pipes fifty years ago and the steel pipes last year then the calculation of expected life of the utility would be inappropriately lengthened because the relative value of the steel pipes would be inflated as a result of their value being larger in nominal terms. This difference in expected life would then affect the calculation of depreciation expense, accumulated depreciation, and net fixed assets. This variation in distribution of expected life throughout the investments of the utility is referred to here as expected life schedule.

The model used in this research replicates the process of calculating annual depreciation expense, accumulated depreciation, gross fixed capital and net fixed capital for a utility which was first constructed in 1950. Sensitivity tests are performed not just to examine the effects of different levels of inflation over the 50 year life of the utility but also the impact of changes in the investment schedule and expected life of the hypothetical utility. For the sake of uniformity and easily interpretable results these variables have been tested across linear variations. That is, the figures for each year’s investment schedule or expected life schedule are determined using a linear formula wherein the year is the x axis and either the dollar value of the investments or the expected life of the assets is the y axis value. The year 1975 falls at the origin along the x axis and thus the y intercept represents the value of the investment or the expected life of the investment made in 1975. Changing the slope of the investment schedule line varies to what extent the investments in fixed assets have changed over time and whether the more recent or more distant investments were larger. Changing the slope of the expected life schedule line varies to what extent more recent investments have longer or shorter expected lives than older investments. The expected life line had a midpoint of 62.5 years and the sensitivity tests varied this by a slope of between 0.5 and -0.5, which ranged the expected life of the 1950 and 2000 assets between 50.25 and 74.75 years. The investment schedule line had a mindpoint of 2.55 and the sensitivity tests varied the slope of this line between 0.1 and -.1, which ranged the investment in 1950 and 2000 between .1 and 5. As the years move closer to 1975 the range of variation grows smaller.

These tests do not examine the impact of different initial operating years. The number of years in operation will function in direct relation with the inflationary environment to create an increase in the difference between the nominal and constant dollar ratios. Thus for general purposes of error direction, utilities that have been in operation for longer periods of time will experience the same sorts of distortion as result from higher inflation levels in the model. It is also recognized that utilities are unlikely to have linear variation in investment schedule or expected life schedule, however testing the sensitivity of error to changes in these metrics provides useful intuitive guidelines to use in assessing calculated metrics for a specific utility. These sensitivity tests are meant to give an impression of the direction and shape of the distortion along with a sense of what the drivers of the distortions are. The 50-year lifespan is meant to be representative of a reasonable hypothetical utility.

Results

Table 6 presents the summary results of the sensitivity tests of variations in inflationary environment, expected life schedule and investment schedule for the capital condition ratios of a hypothetical 50 year old utility. Both Operating Ratio and Fixed Asset Turnover are found to have higher nominal dollar based indicators as a result of increasing inflation. Age of plant and Infrastructure Condition react in the opposite direction as higher inflation results in a lower nominal dollar based ratio calculation. Further, because inflation and the number of years that the plant have been in operation work together to drive the distortions, similar interpretation can be made for utilities having shorter or longer periods of operation. Thus plants which have only been in operation for a few years will have higher Age of Plant and Infrastructure Condition metrics than older utilities, and lower Operating Ratio and Fixed Asset Turnover ratios than older utilities holding all else constant. Larger more recent investments in fixed assets (in real dollar terms) are found to decrease the size of the error in Operating Ratio and Fixed Asset Turnover while larger more recent investments in fixed assets increase the size of the error for Age of Plant and Infrastructure Condition. Increasing expected life in more recent investment periods increases the difference between the nominal and constant dollar ratios for Operating Ratio and Infrastructure Condition, but decreases the absolute value of the error for Age of Plant and Fixed Asset Turnover.

Table 6. Results of Hypothetical Model and Sensitivity Tests

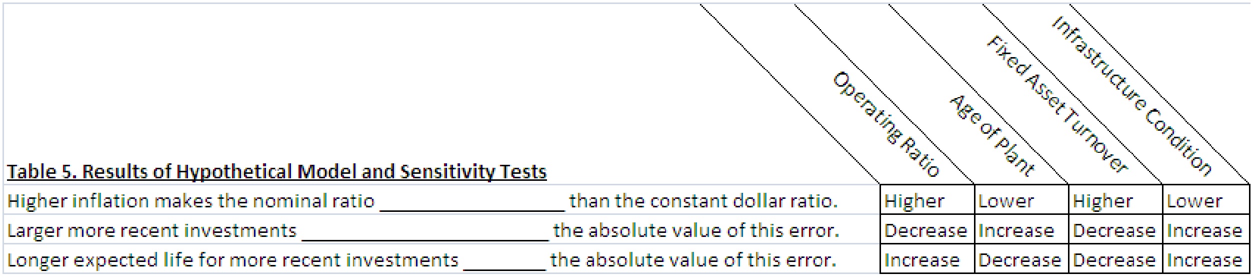
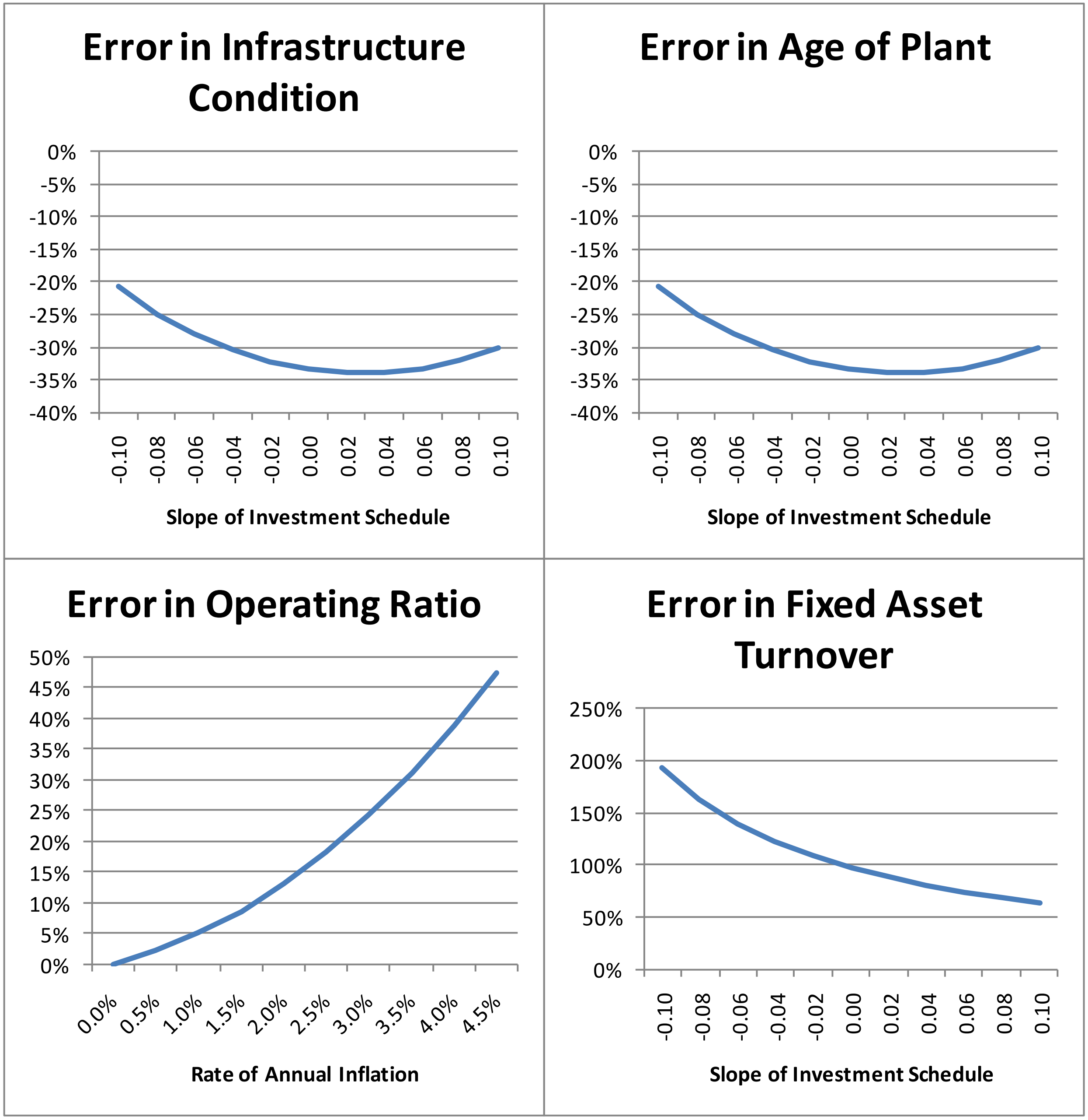


Table 5. Results of Hypothetical Model and Sensitivity Tests

	Operating Ratio	Age of Plant	Fixed Asset Turnover	Infrastructure Condition
Higher inflation makes the nominal ratio ________________ than the constant dollar ratio.	Higher	Lower	Higher	Lower
Larger more recent investments ______________________ the absolute value of this error.	Decrease	Increase	Decrease	Increase
Longer expected life for more recent investments _______ the absolute value of this error.	Increase	Decrease	Decrease	Increase

In general, the effects of changes in annual inflation, the slope of the investment schedule and the slope of the expected life schedule affect the level of distortion between the nominal and constant dollar ratios in a linear fashion over the range of sensitivities that were tested. However, in a handful of cases the results were parabolic or exponential in nature. These nonlinear results are depicted in Figure 6. As the slope of investment schedule becomes more negative the degree of distortion between the nominal and constant dollar Fixed Asset Turnover ratio increases in an exponential fashion. Similarly, the error in Operating Ratio responded to increasing rates of inflation in an exponential manner. Infrastructure Condition and Age of Plant responded to changes in investment schedule in a parabolic fashion with investment schedules with a slope of around .03 (which indicates moderately increasing real dollar value of investments over time) having the lowest degree of error between the nominal and constant dollar based ratios, and the error then increases exponential as the slope increases or decreases. Users of financial based capital condition ratios should take particular care when dealing with utilities which have extreme characteristics of these variables.

Figure 6. Nonlinear Distortions in Sensitivity Analysis



Error in Infrastructure Condition

Error in Age of Plant

Error in Operating Ratio

Error in Fixed Asset Turnover

The model used in this research has identified the sensitivity of distortion between a nominal dollar based calculation and a constant dollar based calculation of Age of Plant, Fixed Asset Turnover, Infrastructure Condition, and Age of Plant ratios. In many cases the distortive effect can be significant, with the constant and nominal metrics frequently differing by more than 50%, depending upon the severity of the inflationary environment and the investment timing and expected life characteristics of the specific utility. This finding has implications for the use of such metrics for purposes of both benchmarking utilities against each other and tracking of conditions within a single institution.

The model indicates that the use of any single capital ratio to benchmark across wide ranges of utilities is questionable. Utilities with relatively new investments in assets should not be judged against older utilities without some process to resolve the systematic distortion of the ratios. One solution for outside observations may be to group utilities according to their historic demographic trends since investments in water and wastewater infrastructure frequently mirror the historic population growth of an area. However, this corrective will only address the investment schedule aspect of the distortion, and so may be particularly inappropriate for metrics whose error is dominated by the variation in expected life. Further, while benchmarking against other similar utilities may produce an approximate ranking for how the utility is performing relative to its peers, the economic intuition behind the metric will continue to be distorted.

For utilities which are seeking to use these benchmarks to track their own practices over time and have access to detailed nominal investment schedules, it may be appropriate to use a detailed corrective function to correct these measurements. For example, if Infrastructure Condition is adopted as a key ratio it may be possible to determine the economically accurate measurement by identifying the percent error in the metric given the specific characteristics of the utility and making an appropriate adjustment. At the very least, though, industry groups, technical assistance providers and utility managers should be cognizant of the systematic flaws inherent in these ratios and be prepared to think critically about the results before acting on them.

Appendix

Table A-1: Error in Operating Ratio – Inflation v. Investment Schedule

		Annual Inflation									
		0.0%	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%	4.5%
Investment Schedule	-0.13	0%	3%	7%	12%	18%	25%	33%	42%	53%	64%
	-0.10	0%	3%	7%	11%	17%	23%	31%	40%	50%	61%
	-0.08	0%	3%	6%	11%	16%	22%	29%	38%	47%	57%
	-0.05	0%	3%	6%	10%	15%	21%	28%	35%	44%	54%
	-0.03	0%	2%	6%	9%	14%	19%	26%	33%	41%	51%
	0.00	0%	2%	5%	9%	13%	18%	24%	31%	39%	47%
	0.03	0%	2%	5%	8%	12%	17%	22%	29%	36%	44%
	0.05	0%	2%	4%	7%	11%	16%	21%	27%	34%	41%
	0.08	0%	2%	4%	7%	10%	14%	19%	25%	31%	38%
	0.10	0%	2%	4%	6%	9%	13%	17%	23%	28%	35%
	0.13	0%	1%	3%	5%	8%	12%	16%	21%	26%	32%

Figure A-1: Error in Operating Ratio – Inflation v. Investment Schedule

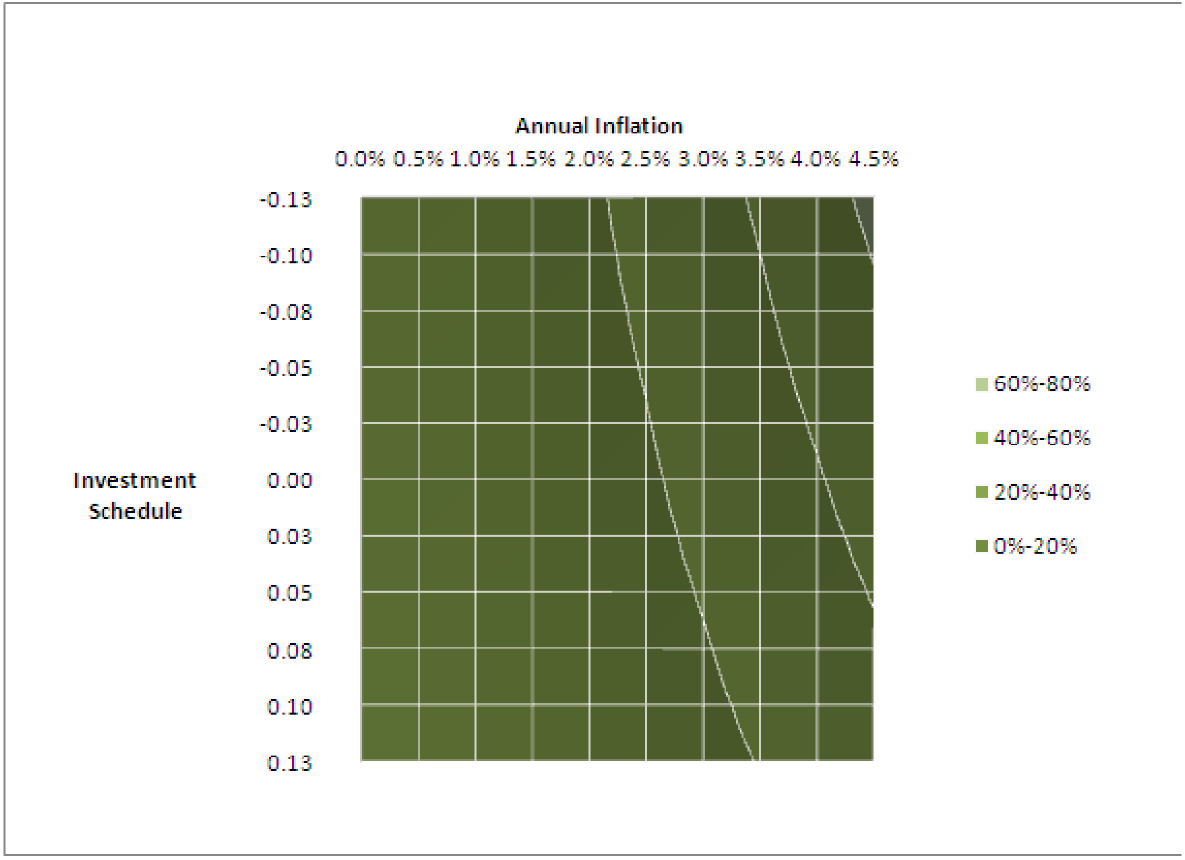


Table A-2: Error in Operating Ratio – Inflation v. Expected Life

	Annual Inflation									
Expected Life	0.0%	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%	4.5%
-0.5	0%	2%	5%	8%	12%	17%	23%	29%	36%	44%
-0.4	0%	2%	5%	8%	12%	17%	23%	29%	37%	45%
-0.3	0%	2%	5%	8%	13%	17%	23%	30%	37%	45%
-0.2	0%	2%	5%	8%	13%	18%	24%	30%	38%	46%
-0.1	0%	2%	5%	9%	13%	18%	24%	31%	38%	47%
0.0	0%	2%	5%	9%	13%	18%	24%	31%	39%	47%
0.1	0%	2%	5%	9%	13%	18%	25%	32%	39%	48%
0.2	0%	2%	5%	9%	13%	19%	25%	32%	40%	49%
0.3	0%	2%	5%	9%	14%	19%	25%	33%	41%	50%
0.4	0%	2%	5%	9%	14%	19%	26%	33%	41%	50%
0.5	0%	2%	6%	9%	14%	20%	26%	34%	42%	51%

Figure A-2: Error in Operating Ratio – Inflation v. Expected Life

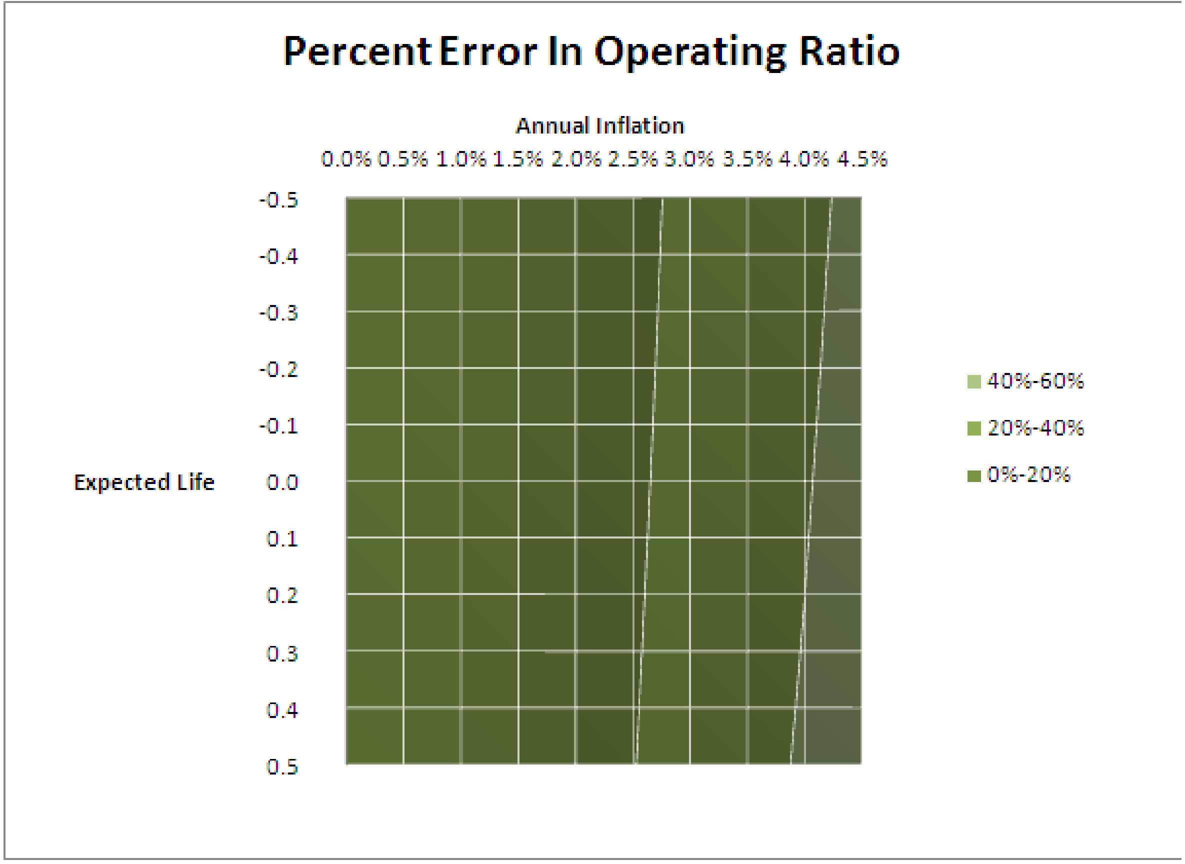


Table A-3: Error in Operating Ratio – Investment Schedule v. Expected Life

	Investment Schedule										
Expected Life	-0.10	-0.08	-0.06	-0.04	-0.02	0	0.02	0.04	0.06	0.08	0.10
-0.5	71%	66%	60%	56%	51%	47%	42%	38%	35%	31%	27%
-0.4	72%	67%	62%	57%	52%	47%	43%	39%	35%	31%	28%
-0.3	73%	68%	63%	58%	53%	48%	44%	40%	36%	32%	28%
-0.2	75%	69%	64%	59%	54%	49%	45%	40%	36%	32%	28%
-0.1	76%	71%	65%	60%	55%	50%	45%	41%	37%	33%	29%
0.0	78%	72%	66%	61%	56%	51%	46%	42%	37%	33%	29%
0.1	79%	73%	68%	62%	57%	52%	47%	42%	38%	33%	29%
0.2	81%	75%	69%	64%	58%	53%	48%	43%	38%	34%	29%
0.3	83%	77%	71%	65%	60%	54%	49%	44%	39%	34%	29%
0.4	84%	78%	72%	67%	61%	55%	50%	45%	40%	35%	30%
0.5	86%	80%	74%	68%	62%	57%	51%	46%	40%	35%	30%

Figure A-3: Error in Operating Ratio – Investment Schedule v. Expected Life

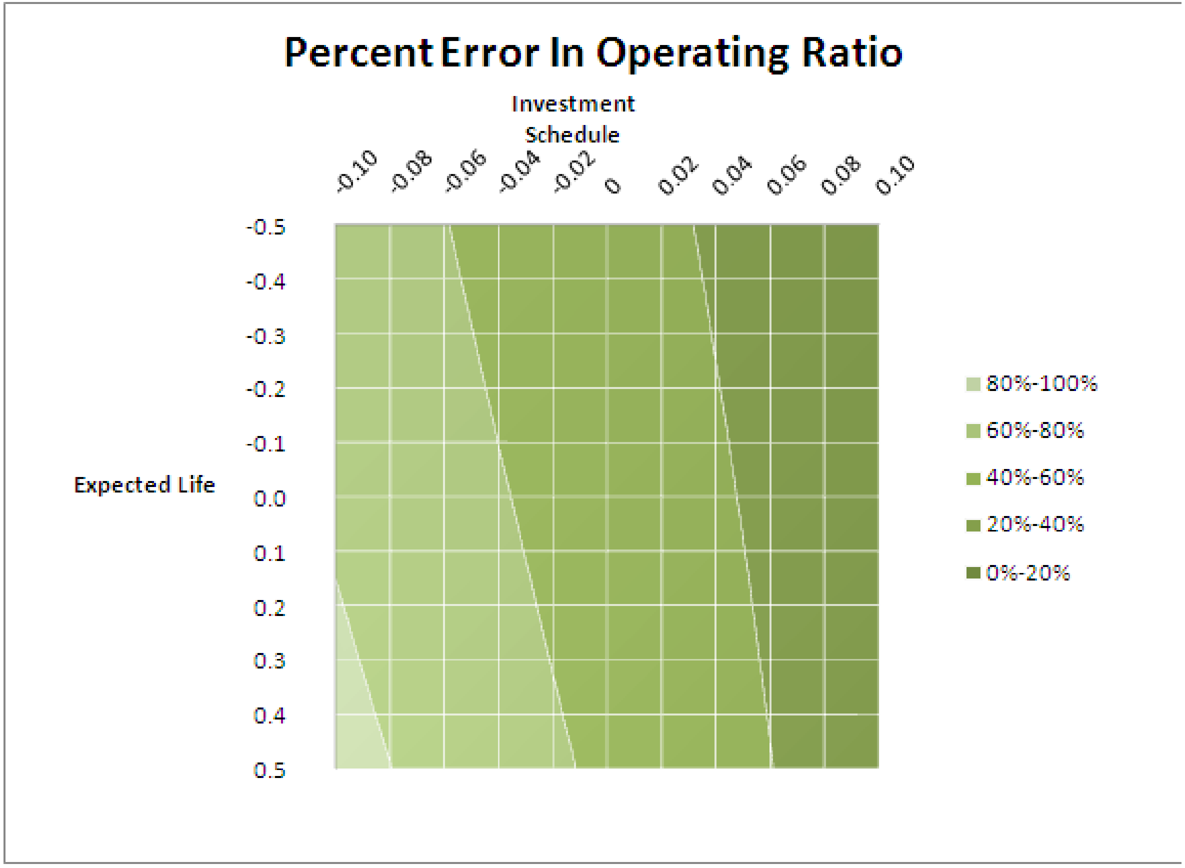


Table A-4: Error in Age of Plant -- Inflation v. Investment Schedule

	Annual Inflation									
Investment Schedule	0.0%	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%	4.5%
-0.10	0%	-1%	-3%	-4%	-6%	-7%	-8%	-10%	-11%	-12%
-0.08	0%	-2%	-4%	-6%	-9%	-11%	-13%	-15%	-18%	-20%
-0.06	0%	-3%	-5%	-8%	-11%	-14%	-17%	-20%	-23%	-25%
-0.04	0%	-3%	-7%	-10%	-13%	-16%	-20%	-23%	-26%	-29%
-0.02	0%	-4%	-7%	-11%	-15%	-18%	-22%	-25%	-29%	-32%
0.00	0%	-4%	-8%	-12%	-16%	-20%	-23%	-27%	-30%	-33%
0.02	0%	-4%	-9%	-13%	-17%	-20%	-24%	-28%	-31%	-34%
0.04	0%	-4%	-9%	-13%	-17%	-20%	-24%	-27%	-31%	-34%
0.06	0%	-4%	-8%	-12%	-16%	-20%	-23%	-26%	-29%	-32%
0.08	0%	-4%	-8%	-11%	-15%	-18%	-21%	-24%	-27%	-30%
0.10	0%	-3%	-6%	-10%	-13%	-15%	-18%	-21%	-23%	-26%

Figure A-4: Error in Age of Plant -- Inflation v. Investment Schedule

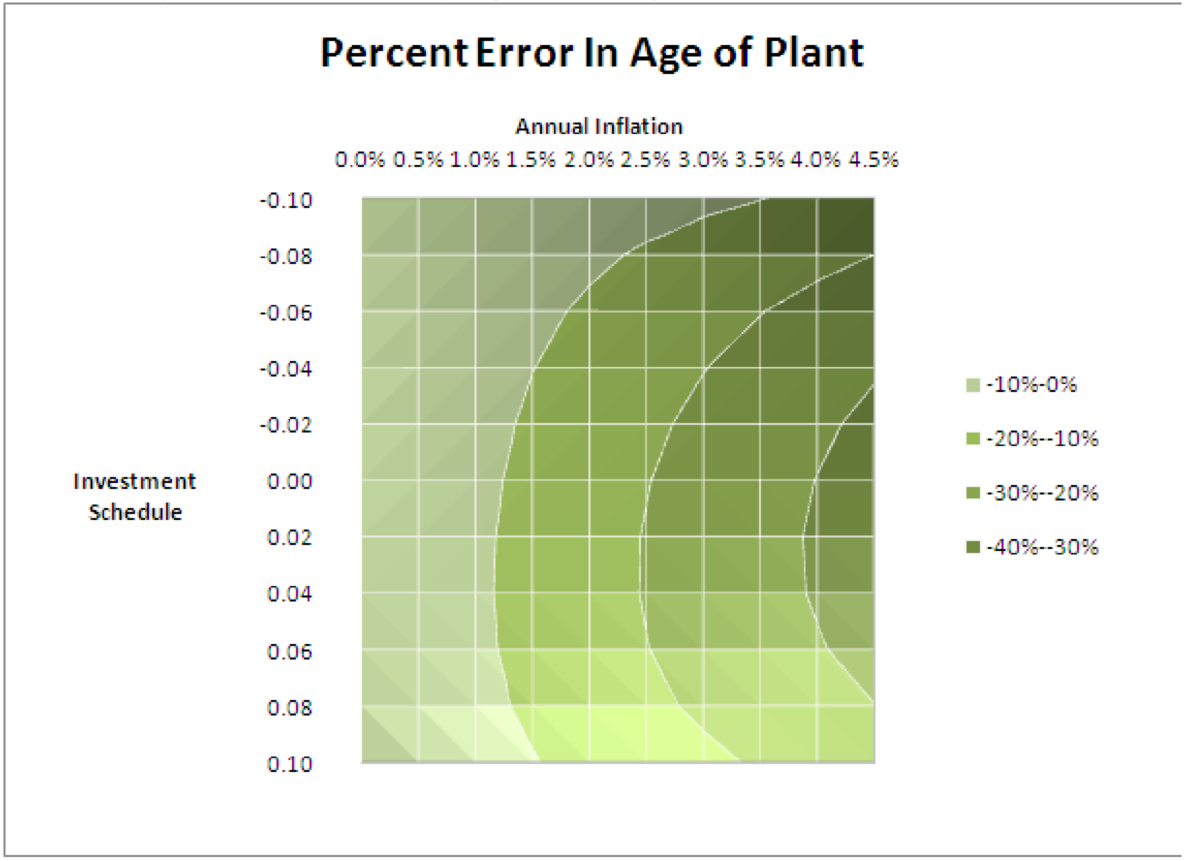


Table A-5: Error in Age of Plant – Inflation v. Expected Life

		Annual Inflation									
		0.0%	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%	4.5%
Expected Life	-0.5	0%	-4%	-9%	-13%	-17%	-21%	-24%	-28%	-31%	-34%
	-0.4	0%	-4%	-8%	-13%	-17%	-20%	-24%	-28%	-31%	-34%
	-0.3	0%	-4%	-8%	-12%	-16%	-20%	-24%	-27%	-31%	-34%
	-0.2	0%	-4%	-8%	-12%	-16%	-20%	-24%	-27%	-31%	-34%
	-0.1	0%	-4%	-8%	-12%	-16%	-20%	-23%	-27%	-30%	-34%
	0.0	0%	-4%	-8%	-12%	-16%	-20%	-23%	-27%	-30%	-33%
	0.1	0%	-4%	-8%	-12%	-16%	-20%	-23%	-27%	-30%	-33%
	0.2	0%	-4%	-8%	-12%	-16%	-19%	-23%	-26%	-30%	-33%
	0.3	0%	-4%	-8%	-12%	-15%	-19%	-23%	-26%	-30%	-33%
	0.4	0%	-4%	-8%	-12%	-15%	-19%	-23%	-26%	-29%	-33%
	0.5	0%	-4%	-8%	-11%	-15%	-19%	-22%	-26%	-29%	-32%

Figure A-5: Error in Age of Plant – Inflation v. Expected Life

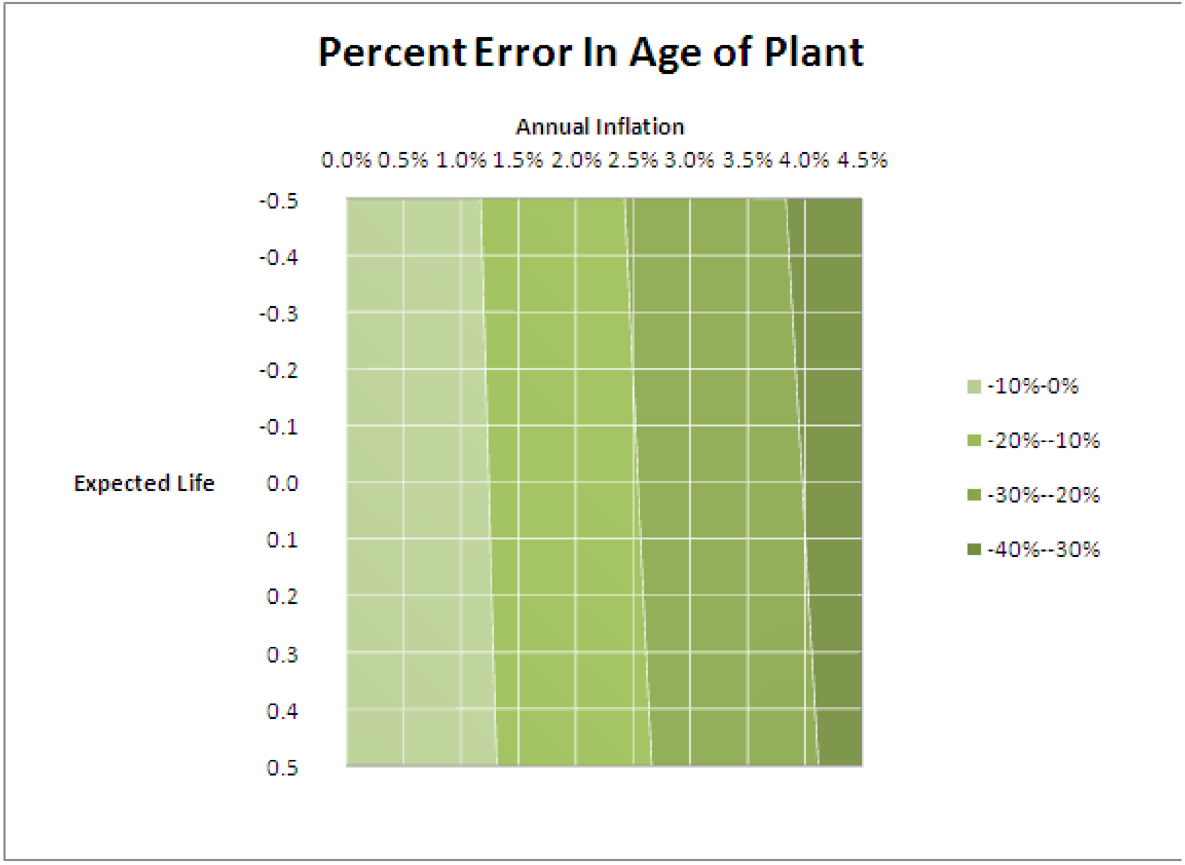


Table A-6: Error in Age of Plant – Investment Schedule v. Expected Life

Expected Life	Investment Schedule -0.10	-0.08	-0.06	-0.04	-0.02	0	0.02	0.04	0.06	0.08	0.10
-0.5	-19%	-28%	-33%	-36%	-38%	-38%	-38%	-36%	-33%	-30%	-25%
-0.4	-19%	-28%	-33%	-36%	-38%	-38%	-38%	-36%	-34%	-30%	-25%
-0.3	-19%	-28%	-33%	-36%	-37%	-38%	-38%	-36%	-34%	-30%	-25%
-0.2	-19%	-27%	-32%	-36%	-37%	-38%	-38%	-36%	-34%	-30%	-25%
-0.1	-19%	-27%	-32%	-35%	-37%	-38%	-38%	-36%	-34%	-31%	-25%
0.0	-19%	-27%	-32%	-35%	-37%	-38%	-38%	-36%	-34%	-31%	-26%
0.1	-19%	-27%	-32%	-35%	-37%	-38%	-38%	-37%	-34%	-31%	-26%
0.2	-19%	-26%	-31%	-35%	-37%	-38%	-38%	-37%	-35%	-31%	-26%
0.3	-19%	-26%	-31%	-35%	-37%	-38%	-38%	-37%	-35%	-31%	-26%
0.4	-19%	-26%	-31%	-34%	-37%	-38%	-38%	-37%	-35%	-31%	-26%
0.5	-19%	-26%	-31%	-34%	-36%	-38%	-38%	-37%	-35%	-32%	-26%

Figure A-6: Error in Age of Plant – Investment Schedule v. Expected Life

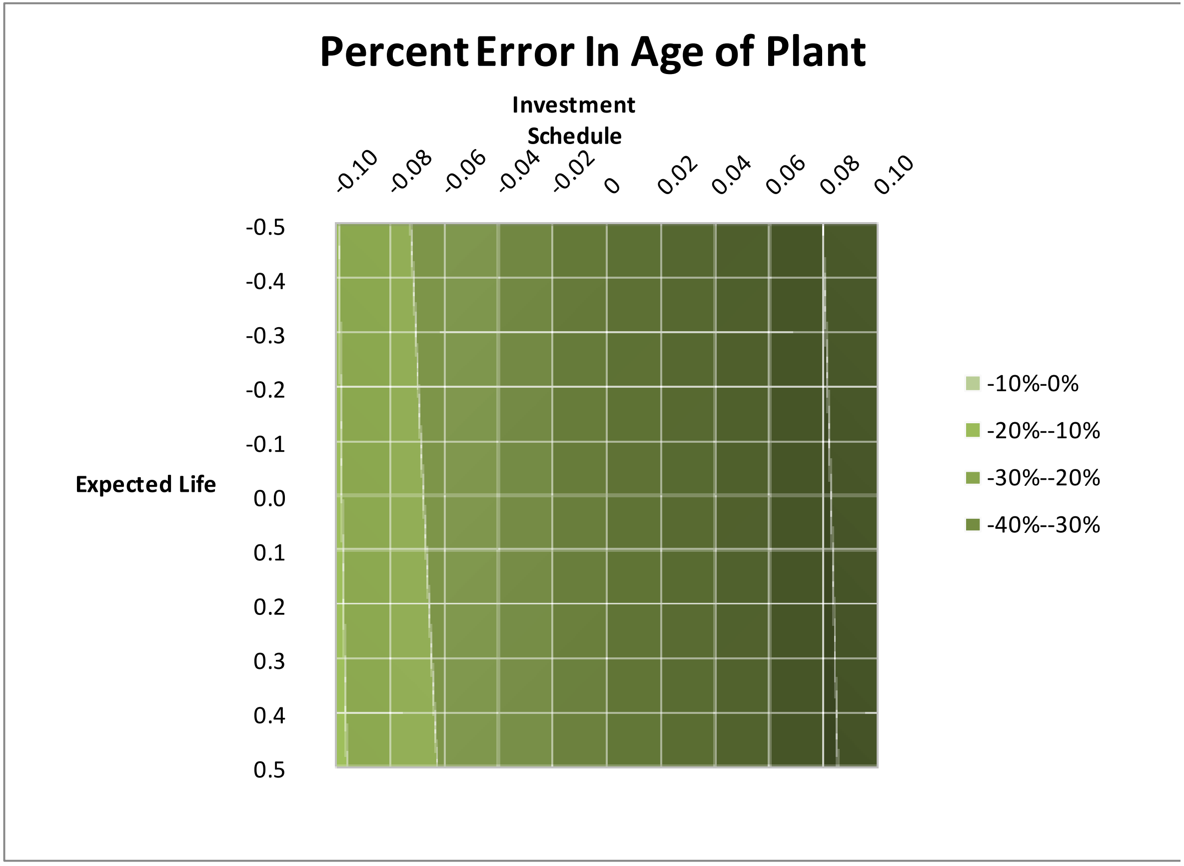


Table A-7: Error in Fixed Asset Turnover – Inflation v. Investment Schedule

		Annual Inflation									
		0.0%	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%	4.5%
Investment Schedule	-0.13	0%	17%	36%	57%	82%	110%	141%	176%	216%	261%
	-0.10	0%	15%	31%	49%	69%	91%	114%	140%	167%	197%
	-0.08	0%	13%	27%	43%	59%	77%	96%	115%	136%	158%
	-0.05	0%	12%	24%	38%	52%	66%	82%	98%	114%	131%
	-0.03	0%	11%	22%	33%	46%	58%	71%	84%	98%	111%
	0.00	0%	10%	20%	30%	41%	51%	63%	74%	85%	97%
	0.03	0%	9%	18%	27%	36%	46%	56%	66%	75%	85%
	0.05	0%	8%	16%	24%	33%	41%	50%	59%	67%	76%
	0.08	0%	7%	15%	22%	30%	37%	45%	53%	61%	69%
	0.10	0%	7%	13%	20%	27%	34%	41%	48%	55%	62%
	0.13	0%	6%	12%	18%	25%	31%	37%	44%	50%	57%

Figure A-7: Error in Fixed Asset Turnover – Inflation v. Investment Schedule

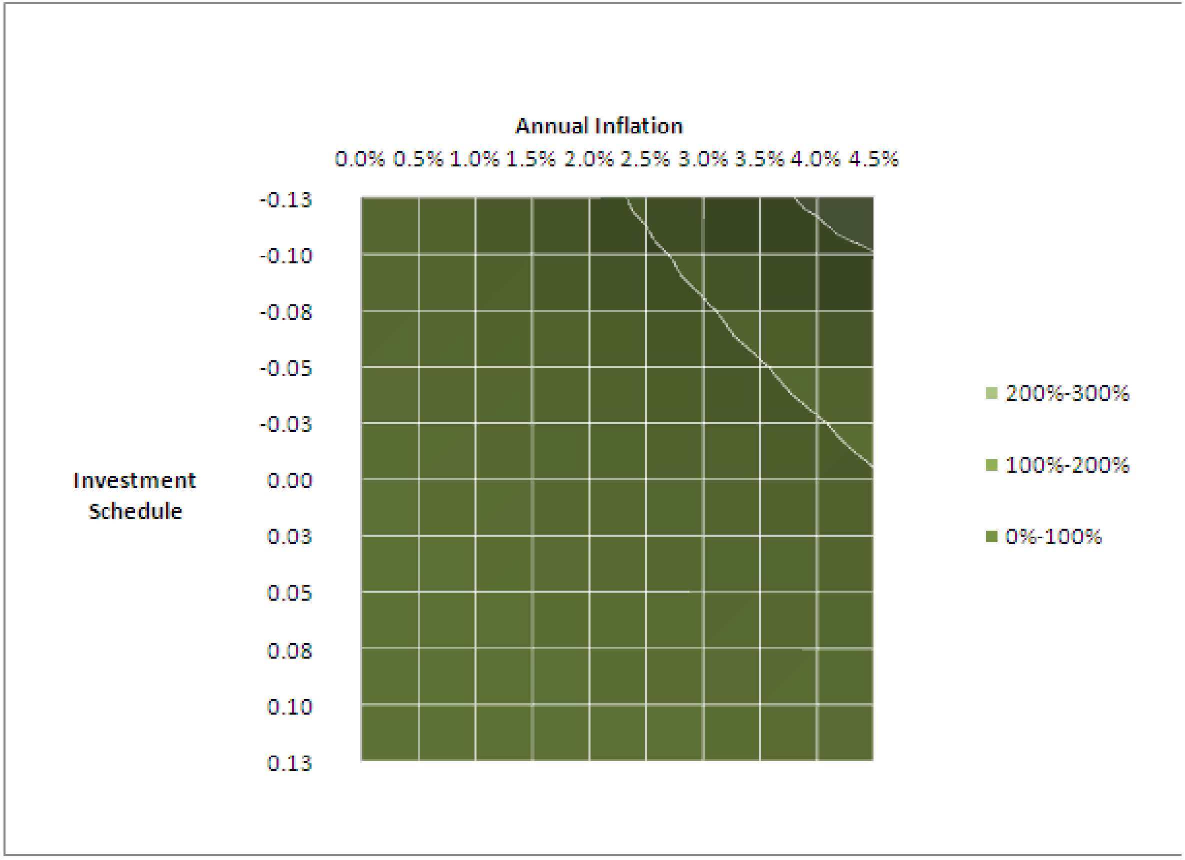


Table A-8: Error in Fixed Asset Turnover – Inflation v. Expected Life

Expected Life	Annual Inflation 0.0%	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%	4.5%
-0.5	0%	10%	21%	32%	44%	55%	67%	80%	92%	104%
-0.4	0%	10%	21%	32%	43%	55%	66%	78%	91%	103%
-0.3	0%	10%	21%	31%	42%	54%	66%	77%	89%	102%
-0.2	0%	10%	20%	31%	42%	53%	65%	76%	88%	100%
-0.1	0%	10%	20%	30%	41%	52%	64%	75%	87%	99%
0.0	0%	10%	20%	30%	41%	51%	63%	74%	85%	97%
0.1	0%	9%	19%	29%	40%	51%	61%	73%	84%	95%
0.2	0%	9%	19%	29%	39%	50%	60%	71%	82%	93%
0.3	0%	9%	19%	28%	38%	49%	59%	70%	80%	91%
0.4	0%	9%	18%	28%	37%	47%	58%	68%	79%	89%
0.5	0%	9%	18%	27%	36%	46%	56%	66%	77%	87%

Figure A-8: Error in Fixed Asset Turnover – Inflation v. Expected Life

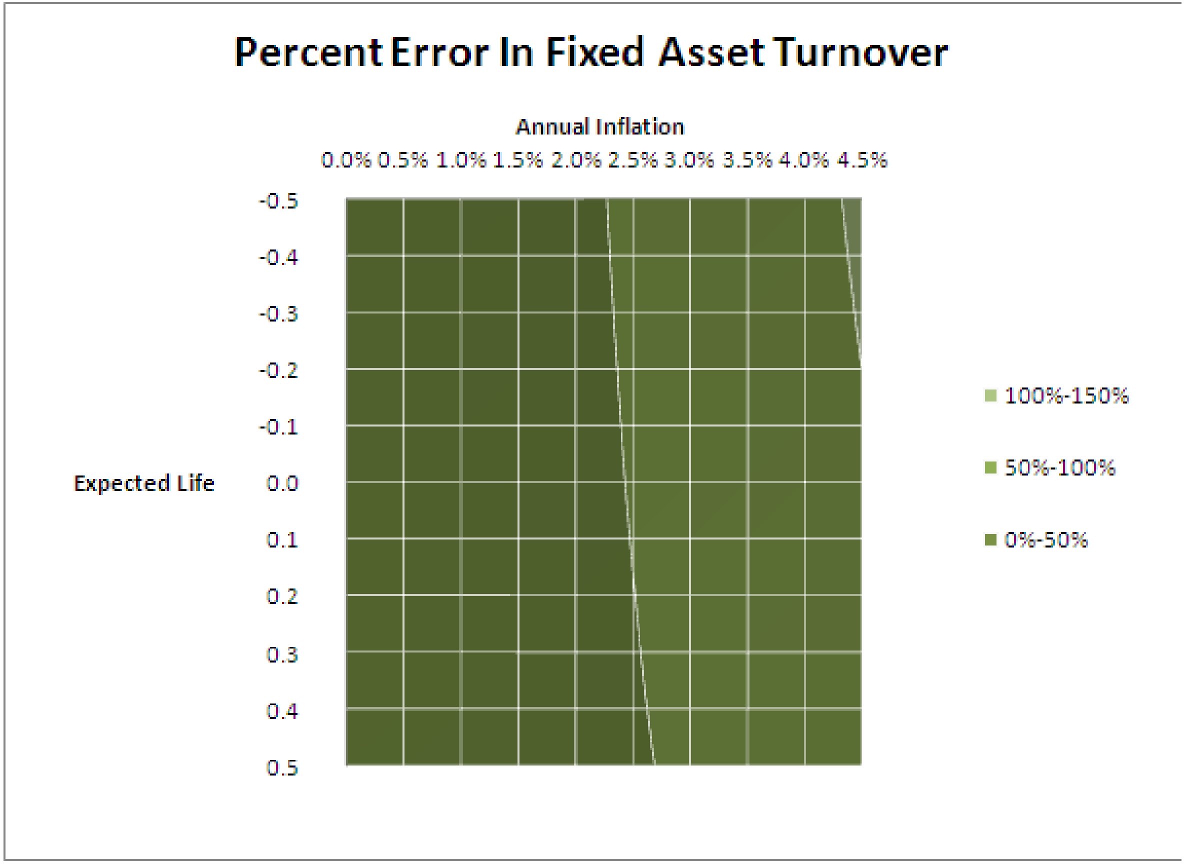


Table A-9: Error in Fixed Asset Turnover – Investment Schedule v. Expected Life

		Investment Schedule									
Expected Life		-0.10	-0.08	-0.06	-0.04	-0.02	0	0.02	0.04	0.06	0.08	0.10
	-0.5	274%	200%	155%	125%	103%	86%	73%	63%	54%	47%	41%
	-0.4	269%	196%	152%	122%	101%	85%	72%	62%	53%	46%	41%
	-0.3	263%	192%	149%	120%	99%	83%	71%	61%	53%	46%	40%
	-0.2	258%	188%	145%	117%	97%	81%	70%	60%	52%	46%	40%
	-0.1	252%	183%	142%	114%	94%	80%	68%	59%	52%	45%	40%
	0.0	245%	178%	138%	111%	92%	78%	67%	58%	51%	45%	40%
	0.1	238%	172%	134%	108%	90%	76%	66%	57%	50%	45%	40%
	0.2	230%	167%	129%	105%	87%	74%	64%	56%	50%	44%	40%
	0.3	222%	160%	125%	101%	85%	72%	63%	55%	49%	44%	40%
	0.4	213%	154%	120%	97%	82%	70%	61%	54%	48%	43%	39%
	0.5	203%	146%	114%	93%	79%	68%	59%	53%	47%	43%	39%

Figure A-9: Error in Fixed Asset Turnover – Investment Schedule v. Expected Life

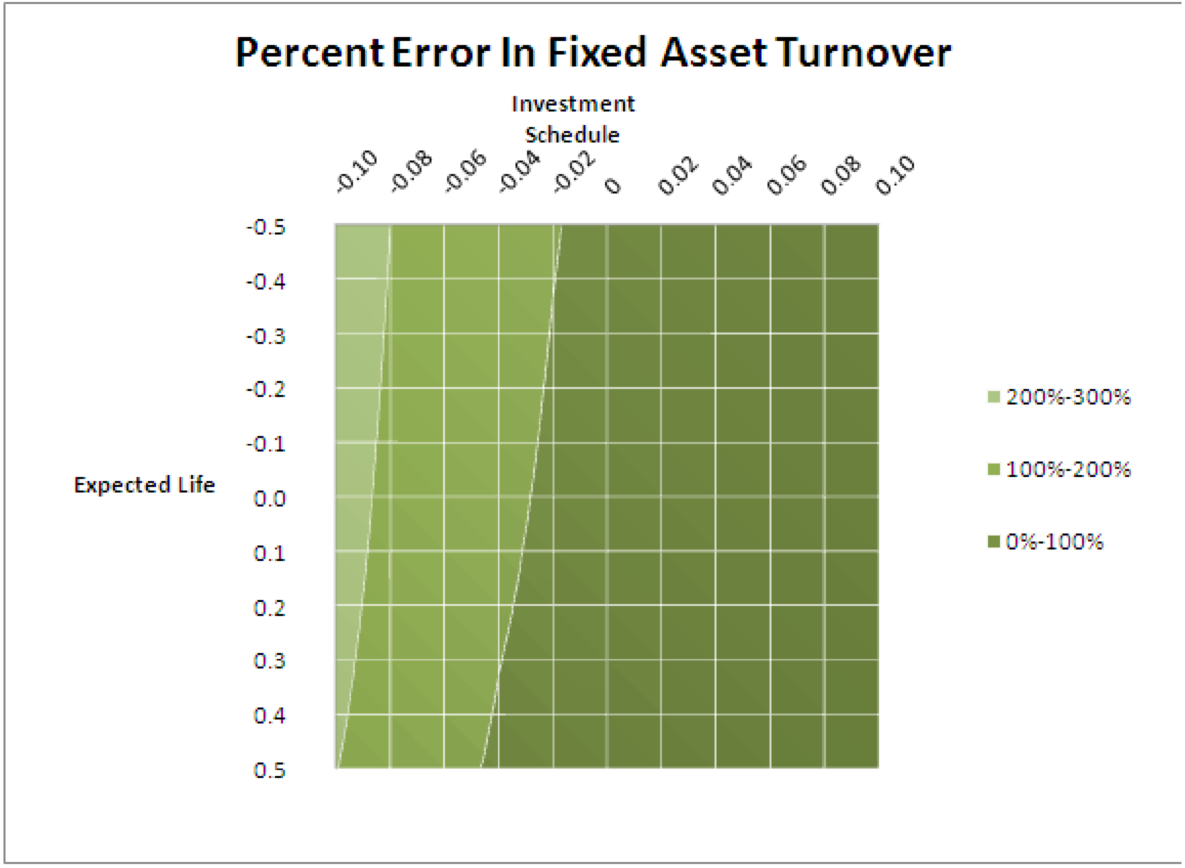


Table A-10: Error in Infrastructure Condition -- Inflation v. Investment Schedule

	Annual Inflation									
Investment Schedule	0.0%	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%	4.5%
-0.10	0%	-1%	-3%	-4%	-6%	-7%	-8%	-10%	-11%	-12%
-0.08	0%	-2%	-4%	-6%	-9%	-11%	-13%	-15%	-18%	-20%
-0.06	0%	-3%	-5%	-8%	-11%	-14%	-17%	-20%	-23%	-25%
-0.04	0%	-3%	-7%	-10%	-13%	-16%	-20%	-23%	-26%	-29%
-0.02	0%	-4%	-7%	-11%	-15%	-18%	-22%	-25%	-29%	-32%
0.00	0%	-4%	-8%	-12%	-16%	-20%	-23%	-27%	-30%	-33%
0.02	0%	-4%	-9%	-13%	-17%	-20%	-24%	-28%	-31%	-34%
0.04	0%	-4%	-9%	-13%	-17%	-20%	-24%	-27%	-31%	-34%
0.06	0%	-4%	-8%	-12%	-16%	-20%	-23%	-26%	-29%	-32%
0.08	0%	-4%	-8%	-11%	-15%	-18%	-21%	-24%	-27%	-30%
0.10	0%	-3%	-6%	-10%	-13%	-15%	-18%	-21%	-23%	-26%

Figure A-10: Error in Infrastructure Condition – Inflation v. Investment Schedule

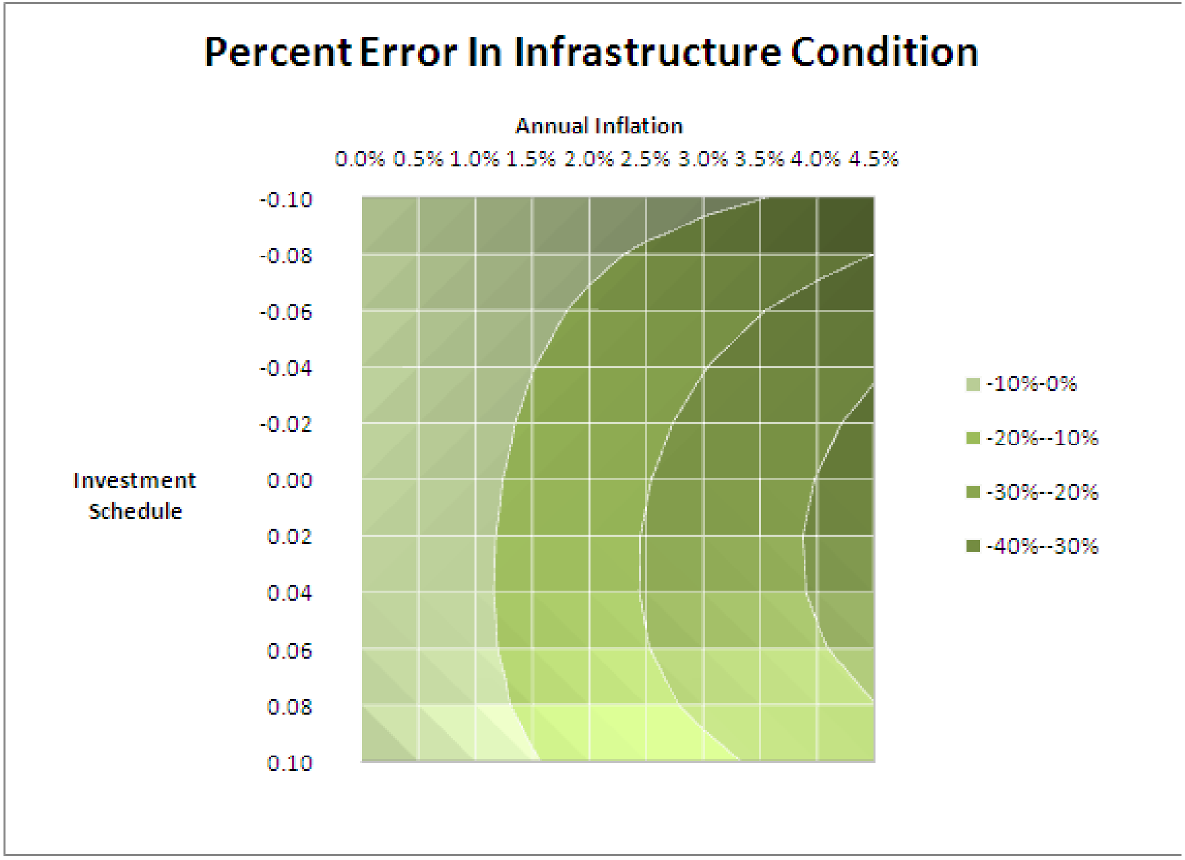


Table A-11: Error in Infrastructure Condition – Inflation v. Expected Life

	Annual Inflation									
Expected Life	0.0%	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%	4.5%
-0.5	0%	-3%	-7%	-10%	-14%	-17%	-20%	-23%	-27%	-29%
-0.4	0%	-4%	-7%	-11%	-14%	-18%	-21%	-24%	-27%	-30%
-0.3	0%	-4%	-7%	-11%	-15%	-18%	-22%	-25%	-28%	-31%
-0.2	0%	-4%	-8%	-11%	-15%	-19%	-22%	-25%	-29%	-32%
-0.1	0%	-4%	-8%	-12%	-15%	-19%	-23%	-26%	-29%	-33%
0.0	0%	-4%	-8%	-12%	-16%	-20%	-23%	-27%	-30%	-33%
0.1	0%	-4%	-8%	-12%	-16%	-20%	-24%	-27%	-31%	-34%
0.2	0%	-4%	-9%	-13%	-17%	-21%	-24%	-28%	-32%	-35%
0.3	0%	-4%	-9%	-13%	-17%	-21%	-25%	-29%	-32%	-36%
0.4	0%	-5%	-9%	-13%	-18%	-22%	-26%	-29%	-33%	-36%
0.5	0%	-5%	-9%	-14%	-18%	-22%	-26%	-30%	-34%	-37%

Figure A-11: Error in Infrastructure Condition - Inflation v. Expected Life

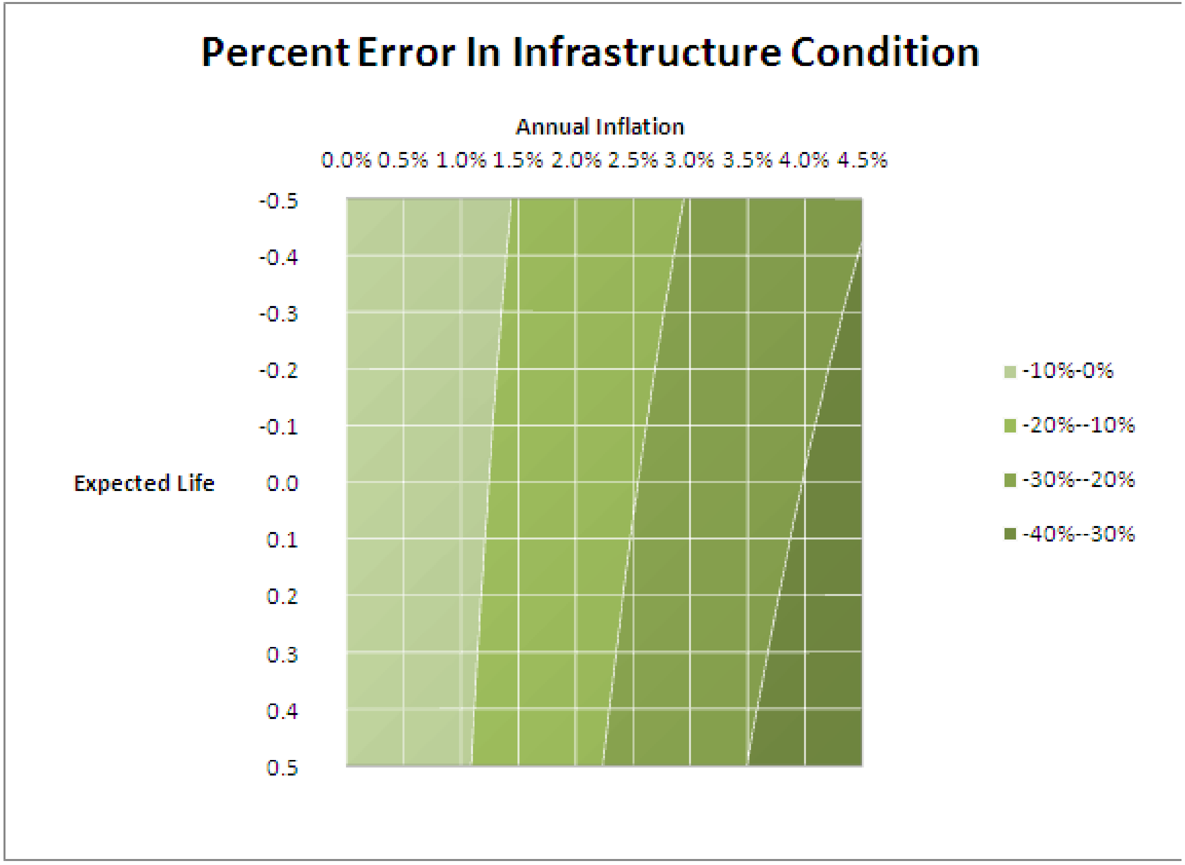


Table A-12: Error in Infrastructure Condition – Investment Schedule v. Expected Life

	Investment Schedule										
Expected Life	-0.10	-0.08	-0.06	-0.04	-0.02	0	0.02	0.04	0.06	0.08	0.10
-0.5	-15%	-22%	-27%	-30%	-32%	-33%	-33%	-32%	-30%	-27%	-23%
-0.4	-16%	-23%	-28%	-31%	-33%	-34%	-34%	-33%	-31%	-28%	-23%
-0.3	-17%	-24%	-29%	-32%	-34%	-35%	-35%	-34%	-32%	-28%	-24%
-0.2	-17%	-25%	-30%	-33%	-35%	-36%	-36%	-35%	-32%	-29%	-24%
-0.1	-18%	-26%	-31%	-34%	-36%	-37%	-37%	-36%	-33%	-30%	-25%
0.0	-19%	-27%	-32%	-35%	-37%	-38%	-38%	-36%	-34%	-31%	-26%
0.1	-20%	-28%	-33%	-36%	-38%	-39%	-39%	-37%	-35%	-31%	-26%
0.2	-21%	-29%	-34%	-37%	-39%	-40%	-40%	-38%	-36%	-32%	-27%
0.3	-22%	-29%	-35%	-38%	-40%	-41%	-41%	-39%	-37%	-33%	-27%
0.4	-23%	-30%	-36%	-39%	-41%	-42%	-41%	-40%	-38%	-34%	-28%
0.5	-23%	-31%	-36%	-40%	-42%	-43%	-42%	-41%	-39%	-34%	-28%

Figure A-12: Error in Infrastructure Condition – Investment Schedule v. Expected Life

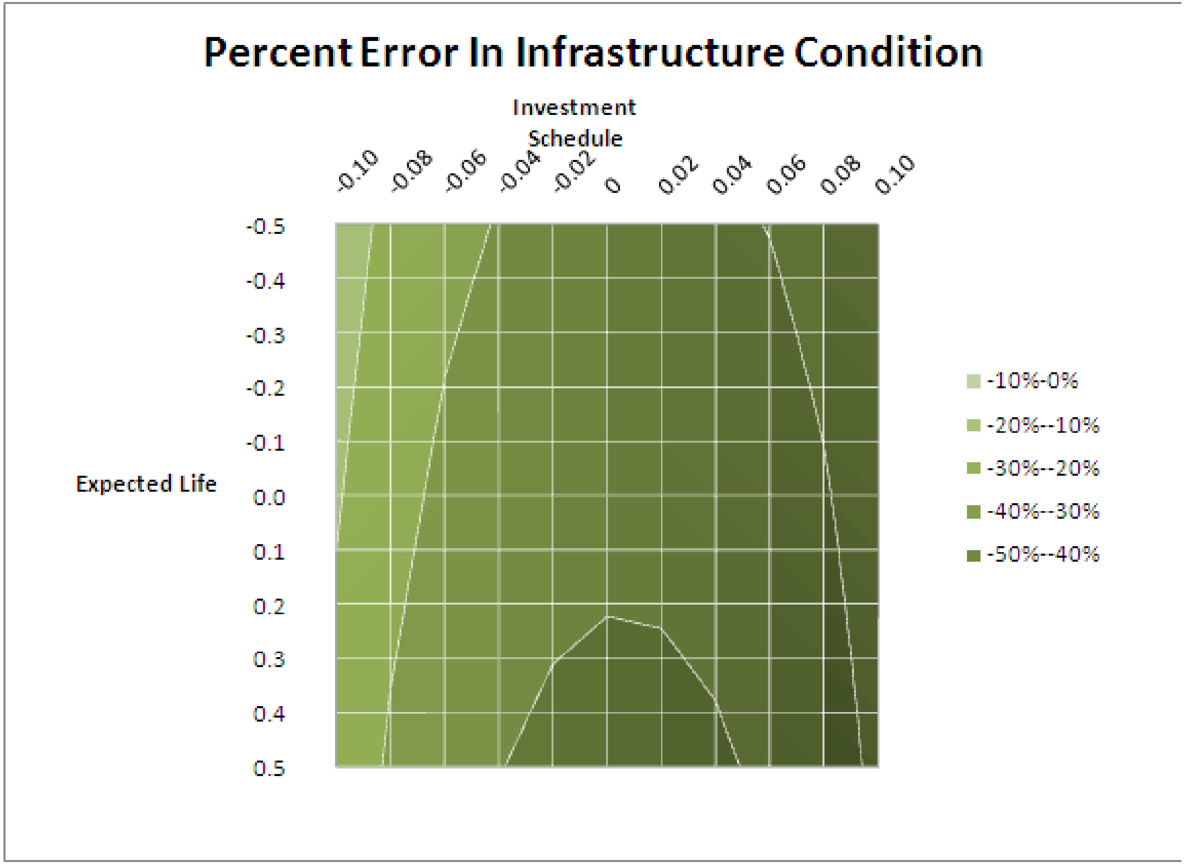


Table A-13: Formulas Describing Nominal v. Constant Dollar Error

	AY	AZ
32	=(1+'Control Panel'!$B$2)^(MAX($B32-AY$54,0))	=(1+'Control Panel'!$B$2)^(MAX($B32-AZ$54,0))
33	=(1+'Control Panel'!$B$2)^(MAX($B33-AY$54,0))	=(1+'Control Panel'!$B$2)^(MAX($B33-AZ$54,0))
34	=(1+'Control Panel'!$B$2)^(MAX($B34-AY$54,0))	=(1+'Control Panel'!$B$2)^(MAX($B34-AZ$54,0))
35	=(1+'Control Panel'!$B$2)^(MAX($B35-AY$54,0))	=(1+'Control Panel'!$B$2)^(MAX($B35-AZ$54,0))
36	=(1+'Control Panel'!$B$2)^(MAX($B36-AY$54,0))	=(1+'Control Panel'!$B$2)^(MAX($B36-AZ$54,0))
37	=(1+'Control Panel'!$B$2)^(MAX($B37-AY$54,0))	=(1+'Control Panel'!$B$2)^(MAX($B37-AZ$54,0))
38	=(1+'Control Panel'!$B$2)^(MAX($B38-AY$54,0))	=(1+'Control Panel'!$B$2)^(MAX($B38-AZ$54,0))
39	=(1+'Control Panel'!$B$2)^(MAX($B39-AY$54,0))	=(1+'Control Panel'!$B$2)^(MAX($B39-AZ$54,0))
40	=(1+'Control Panel'!$B$2)^(MAX($B40-AY$54,0))	=(1+'Control Panel'!$B$2)^(MAX($B40-AZ$54,0))
41	=(1+'Control Panel'!$B$2)^(MAX($B41-AY$54,0))	=(1+'Control Panel'!$B$2)^(MAX($B41-AZ$54,0))
42	=(1+'Control Panel'!$B$2)^(MAX($B42-AY$54,0))	=(1+'Control Panel'!$B$2)^(MAX($B42-AZ$54,0))
43	=(1+'Control Panel'!$B$2)^(MAX($B43-AY$54,0))	=(1+'Control Panel'!$B$2)^(MAX($B43-AZ$54,0))
44	=(1+'Control Panel'!$B$2)^(MAX($B44-AY$54,0))	=(1+'Control Panel'!$B$2)^(MAX($B44-AZ$54,0))
45	=(1+'Control Panel'!$B$2)^(MAX($B45-AY$54,0))	=(1+'Control Panel'!$B$2)^(MAX($B45-AZ$54,0))
46	=(1+'Control Panel'!$B$2)^(MAX($B46-AY$54,0))	=(1+'Control Panel'!$B$2)^(MAX($B46-AZ$54,0))
47	=(1+'Control Panel'!$B$2)^(MAX($B47-AY$54,0))	=(1+'Control Panel'!$B$2)^(MAX($B47-AZ$54,0))
48	=(1+'Control Panel'!$B$2)^(MAX($B48-AY$54,0))	=(1+'Control Panel'!$B$2)^(MAX($B48-AZ$54,0))
49	=(1+'Control Panel'!$B$2)^(MAX($B49-AY$54,0))	=(1+'Control Panel'!$B$2)^(MAX($B49-AZ$54,0))
50	=(1+'Control Panel'!$B$2)^(MAX($B50-AY$54,0))	=(1+'Control Panel'!$B$2)^(MAX($B50-AZ$54,0))
51	=(1+'Control Panel'!$B$2)^(MAX($B51-AY$54,0))	=(1+'Control Panel'!$B$2)^(MAX($B51-AZ$54,0))
52	1	0
53	='Control Panel'!AX10	='Control Panel'!AY10
54	1999	2000
55		
56	='Control Panel'!AX17	='Control Panel'!AY17
57	=AY56*AY$53	=AZ56*AZ$53
58	='Control Panel'!AX14	='Control Panel'!AY14
59	=AY54+AY58	=AZ54+AZ58
60	=SUM($C$57:AY57)	=SUM($C$57:AZ57)
61	=AY57/AY58	=AZ57/AZ58
62	=SUMIF($C$59:AY59,">"&AY54,$C$61:AY61)	=SUMIF($C$59:AZ59,">"&AZ54,$C$61:AZ61)
63	=AX63+AY62	=AY63+AZ62
64	=AY60-AY63	=AZ60-AZ63
65	=(SUMPRODUCT($C$56:AY$56,$C$3:AY$3)/'Control Panel'!$B$3)*AY$53	=(SUMPRODUCT($C$56:AZ$56,$C$2:AZ$2)/'Control Panel'!$B$3)*AZ$53
66		
67	**Statement of Net Assets**	
68	Property	75
69	Plant and Equipment	=AZ60
70	Less Accumulated Depreciation	=-AZ63
71	Total Fixed Assets	=SUM(AZ68:AZ70)
72		
73	**Statement of Revenues, Expenses and Changes in Net Assets**	
74	Operating Revenues	
75	Total Operating Revenues	='Control Panel'!B6
76	Depreciation Expense	=-AZ62
77	Repairs and Maintenance	=-AZ65
78	Other Operating Expenses	-50
79	Operating Income	=SUM(AZ75:AZ78)
80		
81	**Metrics**	
82	Operating Ratio	=AZ75/-(AZ76+AZ77+AZ78)
83	Age of Plant	=AZ70/AZ76
84	Fixed Asset Turnover	=AZ75/(AZ68+AZ69+AZ70)
85	Infrastructure Condition	=-AZ70/AZ69
86	Implied Expected Life	=AZ83/AZ85

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