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The life cycle depreciation (LCD) model

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by

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I. INTRODUCTION

The subject of capital recovery or depreciation has been receiving increasing attention in the telecommunications industry especially since companies have experienced significant depreciation reserve deficiencies over time. Some of which may be nonrecoverable. The total industry-wide deficiency, according to Fogarty (1), was about $26 billion as of December 31, 1984. This amount is equivalent to over 40 per cent of the equity invested in these companies. The deficiency is due to low depreciation rates resulting from life forecasts based on historical retirement analyses which did not adequately reflect the ongoing wave of technological change and competition. Technology Futures Inc. (2) made an investigation for the New York Telephone (NYT) company indicating that the accelerating pace of technological progress and change in the competitive environment have made the other traditional causes of property retirements secondary. It is well understood that historical life indications need to be modified by what is foreseen for the future to accommodate the changes of mortality forces. In this study, the life cycle approach can provide such improvement for the depreciation of telephone or other utility properties.

A. Regulatory Environment and Importance of Depreciation

Unlike other business enterprises which have the flexibility to recover capital investment as quickly as their income statement will allow, public utilities are regulated by governmental agencies due to their monopolistic nature. The regulatory process involves a pricing mechanism based upon the revenue requirement equation:

$$R.R. = O.E. + T + D + (V-DR) \times ROR \qquad (1)$$

where R.R. is the revenue requirement, O.E. is the operating expenses, T is the taxes, D is the depreciation expense, V is the gross valuation of the property serving the public, DR is the accrued depreciation, ROR is the rate of return on the rate base or net valuation (V-DR), and (V-DR) x ROR is the earnings allowed on the rate base. The basic idea of the revenue requirement is to cover the cost of service and provide a reasonable return on the net valuation of the property used and useful in serving the public. The essential purpose of such regulation is to achieve the results of competition in the form of reasonable prices, reasonable profits, and adequate service quality. Regulation attempts to insure that the utilities are not overcharging customers while receiving a reasonable return.

The capital recovery process of utilities is accomplished by identifying a portion of the funds generated from sales of service as depreciation expense. A utility will claim depreciation on property roughly according to the consumption of its usefulness, keeping the unclaimed portion in the rate base and, thus earn a return on it. The claimed depreciation is credited to and accumulated in the depreciation reserve which is then excluded from the rate base. Upon final retirement, total credits into the reserve should equal to the equipment's first cost less net salvage. However, a reserve deficiency is created if the accumulated credits are less than what should be in the reserve at that particular point in time. The relationship between the rate base and depreciation expense indicates that the present reserve deficiency in the telephone industry is still part of the rate base and can continue to earn a return on the unrecovered portion of it. This is not a reasonable result if the property has been retired and is not used in serving the public.

Depreciation expense constitutes a significant portion of the revenue requirement of regulated utilities because of the capital-intensive nature of the industry. For example, in the telephone industry "over 63% of funds are provided by internal sources and depreciation provides 60% of all the internal sources in aggregate," Homan (3) quoted in an address to the 1980 Utility Financing Conference. Further, the importance of depreciation as an internal funding source will increase as external capital becomes more expensive. As a result, if underaccrued, the reserve deficiency will severely limit the ability of these telephone companies to become competitive and to provide the low cost, efficient equipments and services for the social welfare.

Depreciation accounting is an allocation process whereby consumption of facilities is recognized in the financial statement of a business enterprise. Under regulation, the purpose of depreciation is to allocate costs according to the service rendered over the useful life of the property to the extent that not only will the capital investment be fully recovered but also appropriate timing of the recovery be achieved; that is, the ideal is to recover the investment incrementally as the service is rendered and completely by the retirement of the property. The utilities have to determine and justify the life span for capital recovery. The pattern of recovery is determined by identifying the pattern of the consumption of assets, or the pattern of customer benefits generated by the assets. The implementation is made through a depreciation study, i.e., life analysis and life estimates of the actual mortality characteristics of the property. However, it is not an easy task to fulfill because of the complexity and uncertainty of property placements and retirements involved. In some instances, mortality analysis of historical data has failed to recognize quickly changing life and retirement patterns, and thus reserve deficiencies have resulted.

Inadequate life estimation could result in the violation of regulatory philosophy. For a continuously protected and regulated monopoly, the pattern of capital recovery makes little difference. The economic value of the firm will equal to its net investment; that is, regardless of the selected pattern, the discounted value of an investment's combined return-on (authorized rate of return) and return-of (depreciation expense) capital will equal the original cost of the investment. However, if a utility moves from a regulated to a competitive, deregulated and divested environment, the resulting deficiency may be nonrecoverable and the urgency of recovering capital investment increases. Moreover, by overestimating the life span of the property the utility will experience underdepreciation and the cost of retired property effectively remains in the rate base to earn a return. On the contrary, overdepreciation means overpricing the service rendered to the customer which is not desirable nor acceptable to the regulators. Consequently, the "systematic and rational" concept of depreciation is to recover the investment in property adequately and timely over its useful life. This recovery period should be determined with care to reflect the truth of "life" of the property.

B. Current Issues of Depreciation in the Telephone Industry

The communication business is experiencing many changes as it moves further into competition, deregulation and divestiture. This has especially been the case in the area of capital recovery which has become a major concern for the industry and regulators alike. For instance, a study by the U.S. Telephone Association indicates that local operating companies could lose $8.4 billion in annual revenues by 1995 because large customers are "by passing" them, using alternate sources of telecommunication services (4). The reason for this is the presence of higher rates resulting in part from more rapid capital recovery. Thus, by increasing the rate of depreciation the telephone companies price themselves out of business. If lower rates of capital recovery are used, the lower customer rates would possibly prove profitable in the short run but would create higher prices and reserve deficiencies in the long run. In early 1984, the divestiture of Bell Operating Companies (BOCs) from AT&T was accompanied by modifications to the monopolistic climate of telephone industry. As competition increases for the BOCs depreciation becomes much more of a problem since it is a cost of doing business only claimable through market prices not rate making prices. Also, with deregulation, Robinson (5) has shown that the amount of the reserve deficiency resulting from the underdepreciation of old, retired equipment could possibly become nonrecoverable.

Rapidly advancing technology was the main impetus for the national policy of promoting competition in the telecommunications marketplace. This has led to the deregulation of customer premises equipment (CPE) and enhanced services, and to the divestiture of AT&T (1). The idea was to achieve the goals of enhanced technological innovation, lower customer rates, and network efficiency. Advances in both switching and transmission technologies have been reducing the costs of producing telecommunication service. For example, advances in digital technology have reduced the cost of switching technology. This declining cost function of the newer technology has produced more battles in the competition of telephone company offerings.

Technological change and the development of competition have greatly reduced the economic lives of the telephone assets resulting in significant depreciation impact. Dandekar (6) showed the trend of shortening lives over time for the telephone property, suggesting this might be the result of the changing mortality forces. While the lives of telephone properties are shortening, the historical mortality analysis may not be able to recognize these changing forces and is still producing long life estimates. As a result, life studies of these properties should be made using the more technological oriented life estimation approach.

Regulators and the industry are confronting two serious issues: First, how to recover the resulting significant reserve deficiency in a realistic time frame and, second, what further changes in depreciation methodology and regulation are necessary to assure that such a deficiency does not re-occurs. Regulators are reluctant to increase the higher rates of depreciation because they assume this result will be detrimental to the public interest. Fogarty (7) demonstrated that this notion is not only incorrect but also has created a false dilemma for regulators to admit more rapid capital recovery. He indicated that increased depreciation rates will preserve and foster, not threaten, the critical value of universal telephone service. Rate increases may be temporarily heightening revenue requirement; however, in the long run, as the rate base decreases total revenue requirements will decrease over time and eventually rate-payers will be charging lower rates. In addition, underdepreciation constrains the introduction of new technology and replacement of old equipment, restricts the maintenance and improvement of quality services, and ultimately limits the price competitiveness. Much more critical problems will occur because of the influence of deficiency if inappropriate depreciation rates are used.

C. The Life Cycle Depreciation Approach

Adequate capital recovery and consistent depreciation methods which reflect economic reality are essential to modern telephone company operations in an increasingly competitive market. Accurate life forecasts are a requisite of this objective. In fact, all the life estimations have to do with the forecasts of future. When using conventional life analysis procedures, it is difficult to demonstrate conclusively the effect future mortality forces such as technological obsolescence. Therefore, when larger and larger amounts of property start to be retired from service much earlier than life forecasts has suggested, it resulted in reserve deficiencies.

Even though in Docket No. 20188 the FCC (8) allows telephone companies to use equal life group (ELG) and remaining life (RL) depreciation rates, this adoption is not a complete solution to the deficiency problem. As is discussed later, the ELG and RL methods are only depreciation rate calculation methods which affect the pattern of recovery and rely on the same procedure of historical mortality analyses. They count heavily on the life forecasts of property using the historical life forecasting approaches which have not been successful in generating appropriate lives. To obtain appropriate depreciation results the accurate life forecasting is more essential than the depreciation methods. As a matter of fact, as long as the life estimation is made correctly, the total investment will be recovered by the end of property no matter which method is used.

Life cycle analysis of property investments and retirements has been used in a attempt to increase the accuracy of life estimation for the telecommunication properties. Clark (9) developed the required depreciation rates and required life estimates that should have been used to properly recover the property of the step-by-step account. He used the actual historical rates to obtain the required rates by computing the complete picture of investment and reserve. Similarly, Ocker (10) derived the life indication from life cycle data and forecasts of additions and retirements for the crossbar account based on the forward looking estimates of the effects of technological development. Both results give support to the life cycle analysis but do not convincingly provide theoretical life estimation in the life cycle depreciation procedure. Johnson (11) suggested that a remaining life be determined using a retirement rate method on the forecasted life cycle. This, in turn, would result in inaccurate life estimates if there were additions in the future. Kateregga (12) investigated the forecasting ability of technology substitution by comparing six different substitution/adoption models: Fisher-Pry, Gompertz, Normal, Weibull, Lognormal, and logistic model. Dandekar (13) discussed the concept of product life cycle and developed a set of standard investment life cycles to represent various technological impacts. Oh (14) set criteria for selecting technological growth models which help to reduce or control the potential source of judgmental error and inconsistencies in the analyst's decision. Tsai (15) investigated the impacts of property life cycles on depreciation requirements by generating life cycle curves using known vintage behavior which was simulated using type curves such as the Iowa curves and Bell system curves. The characteristics of life cycle depreciation were also examined. Nevertheless, without the forecast life data of additions and/or retirements, property life estimates can not be accomplished by using the forecasted life cycle alone.

In this study, the life cycle method establishes an envelope of constraints to the property in service over time. Coupled with past additions (and/or retirements) and expected future investments of the property, the life estimation can be made within the life cycle envelope to adjust for technological changes over time. That is, by recognizing the influences of the forces of market competition and technological development, the accuracy of life estimation can be improved for the life cycle properties.

The life cycle depreciation (LCD) model was established to give a systematic approach and solution to the current depreciation problems. In the following chapters conventional life estimation and depreciation methods will be reviewed and the life cycle depreciation model will be presented. Moreover, the validation of the model by using theoretical and actual application will be discussed.

II. AN OVERVIEW OF CONVENTIONAL DEPRECIATION PROCESS

The conventional depreciation process can be classified into three basic steps: data compilation, life analysis and estimation, and depreciation calculation. First, data are accumulated and compiled into depreciation categories from accounting databases. Second, the life analysis and estimation is to determine a life expectation for each overall account or category within the account. Third, the service life for a group of property can be calculated on the basis of broad group average life, vintage group average life, or even equal life group as well as using the concept of whole life or remaining life procedure for depreciation calculation. The determined life expectation is then incorporated with the salvage considerations to calculate a depreciation rate. A calculated reserve requirement, based on the life forecast, is also determined and served as an indicator to provide a measure of adequacy for capital recovery in the depreciation process. The three basic steps of the depreciation process have been computerized by the Interstate Commerce Commission (ICC) (16). The computerized process uses actuarial or SPR method for data handling and analysis, matches original curve with Iowa curve or actual balances with simulated balances, computes depreciation using simulated or actual surviving vintage balances, depending on whether vintage data are available or not.

The following material reviews the three basic steps of depreciation process and some related depreciation issues which will help to understand the approach of the Life Cycle Depreciation (LCD) model.

A. Data Compilation

The first stage, data collection and analysis, is crucial for the depreciation study. Data are collected from accounting records as well as engineering records, which are reviewed and inspected to ensure the type of source record, methods of maintenance (Unit, FIFO, average price, etc.), and nature of records involved. A field investigation usually gives good understanding of the actual physical property characteristics. Then, the causes of retirements can be identified and become helpful in the next stage of life estimation. Data are accumulated and compiled into depreciation categories according to standard accounts, such as the FCC Uniform System of Accounts, and categories within these accounts. In general, data from utility property records are either aged or unaged. Aged data use data with detailed record of the age of property item from the date of installation to the date of retirement. In contrast, for some property which is either too numerous or too expensive to record the age of each unit upon retirement, data are unaged, or contain only gross annual amounts, mainly installations and retirements. The data are analyzed to maintain their consistency and accuracy. A time series or trend analysis of the data can also disclose some of the characteristics of the data.

B. Life Analysis and Life Estimation

The objective of this stage is to estimate the mortality characteristics of industrial property, i.e., service life and survivor curve. The process is classified into two procedures: Life analysis and life estimation. Life analysis is the process of analyzing the age related historical retirement data about a property to estimate what has been happening to the property, which provides useful information in predicting the future retirement characteristics of the property. It is subdivided into two parts: The first part is concerned with the analysis of the data and the second part involves describing the mortality characteristics mathematically or graphically, which is usually referred to as curve fitting. Then, life estimation makes use of judgement in applying the results of life analysis to estimate the future mortality characteristics of a property. The data treatment and descriptive procedures are handled differently depending upon whether the data are aged or not. The actuarial methods are used to analyze aged data while semi-actuarial methods are used when aged data are not available.

1. Actuarial method - compiling retirement data

There are at least five methods of compiling retirement data using actuarial methods (17, 18, 19, 20). The annual rate or retirement rate (RR) method is the most common method and is computerized by the Interstate Commerce Commission (ICC). The individual unit (IU), original group (OG) and composite original group (COG) methods are restricted cases of the retirement rate methods. The multiple original group (MOG) relates an age distribution to the survivor characteristics of a group of property. All of the methods calculate a stub survivor curve or an observed life table which will be used to determine the mortality characteristics of a property. An observed life table is a tabulation of the amount of the portion of property surviving at each age from an original placement to the limit of indicated time or age; a stub (or observed) survivor curve is a plot of the amount surviving versus age. The five methods are described briefly as below.

a. Retirement rate method Retirement rate survivor curves are calculated by applying the retirement rate for an age interval to the percent surviving at the beginning of the interval to give the percent surviving at the end of the interval. A retirement rate is the percentage of the units or dollars of a given age in service at beginning of a certain year which were retired during the following year. Unless all installations have same life characteristics, the curve will vary depending upon the placement or experience band used to calculate the retirement rate. A placement band analysis uses a band of consecutive vintages following through each transaction year, which calculates a curve representing the actual history of these vintages. An experience band analysis uses the transactions from all vintages that pass through a band of consecutive transaction years to calculate the retirement rates.

b. Individual unit method The life table for the individual unit method is developed by cumulatively subtracting the retirements by age interval from the total of all retirements. This method uses only retirement data at an age interval in compiling the survivor curve; nether the method nor the original data take into account other units remaining in service during or at the end of the year. The resulting average service life is the average age at retirement which may not be a good indication of service life when a property is comparatively young. It is used only when the data available limit the analysis to the individual unit method or to provide preliminary information about an account.

c. Original group method The original group survivor curve is derived for a single vintage group by computing the percentage of the original group of units (or dollars) which survives in service at yearly intervals. The original group method, using placement band analysis, is particularly adapted to developing a series of survivor curves showing the trend in average service lives of the vintages over a period of time.

d. Composite original group method Unlike the original group method, the composite original group survivor curve is calculated for several vintage groups which are combined into a single group by summing the property surviving at each age in each vintage group.

e. Multiple original group The multiple original group survivor curve for an experience band is developed by dividing each vintage's survivors by its installations and plotting the quotients beginning with those for the recent vintages.

2. Actuarial method - curve fitting

In order to estimate life characteristics of property, the observed survivor curve should be extended and smoothed to zero percent surviving. The methods of extending and smoothing can be made either by mathematical curve fitting methods, or graphical matching to the type curves, along with the judgement of an analyst. The process of fitting curve or formula usually requires the aid of computer program. The most common methods of fitting actual data are Iowa curve matching. Some of the other methods are also described as the following.

a. Iowa curve matching   Iowa curves are a set of standard property survivor curves which are widely accepted. The curves were developed from empirically based data but are defined by mathematical equations. They are used to estimate mortality characteristics for properties (18, 21, 22).

b. Gompertz-Makeham fitting   The Gompertz-Makeham equation is most used by the Bell telephone companies to smooth and extrapolate observed life tables. The formula was developed from studies of human mortalities and later applied to the retirement experience of physical property by Bell system engineers (23).

c. Polynomial fitting   The polynomial integral equation is used to fit both survivor ratios and retirement ratios; however, the retirement ratios are usually preferred. The fitting process uses the method of least square as a criterion for the selection of good fit. An orthogonal polynomial method was developed by Fisher (24) to eliminate the laborious hand calculation processes.

d. h-curve fitting The "h-system" of survival functions based on the truncated normal distribution was introduced by Kimball (25) in 1947 as a general family of probability distributions which describes the retirement frequencies of physical property. In practice, the h-system curves have been computerized (26).

e. Weibull distribution The Weibull distribution based on the mathematical formula is also useful in the curve fitting (27).

Based on the curve fitting techniques, a type curve is selected to represent the appropriate life characteristic survivor curve of a property. The analyst's judgement is essential to the estimation of the past history and future life expectancy of the property. Estimation of life is based on "all things considered".

3. Semi-actuarial methods

Semi-actuarial methods are used to analyzed life characteristics when aged property records are not available. Three methods are currently available: simulated plant-record (SPR) method, computed mortality (CM) method, and turnover method (18, 19, 28, 29). Among them, the SPR method is the most common method for life analysis and estimation. They are discussed separately below.

a. Simulated plant-record method The SPR method is applied to the unaged data of industrial property to indicate a generalized survivor curve, usually Iowa type curve, which represents the life characteristics of a property. The SPR method can use one of the three different models (balances, annual retirements, period retirements) to indicate a life and survivor curve. In the balance model, the Iowa curves are ranked according to each curve's ability to simulate annual balances that are close to the actual annual balances for specified test years. The period retirements model finds a curve of each type such that the sum of the simulated retirements for the period matches the total actual retirements for the period. These curves are then ranked by least squares (minimum sum of squares) differences of the simulated and the actual retirements. The annual retirements model simply matches annual retirements under the least squares criterion. One assumption of the SPR is that all the vintages will have homogeneous life characteristics, which might limit the ability of SPR. Also, the maturity of a property is an important factor in making judgement of the results.

b. Computed mortality method The CM method is only used to simulate missing aged mortality data for an account of unaged data. The aged data may be used to make life analyses and calculate depreciation. The vintage survivors at the end of a year are simulated by applying an assumed dispersion pattern, such as that given by an Iowa curve, to the survivors at the beginning of the year. The ASL of the curve is varied until sum of vintage survivors matches the actual balance. These vintage survivors are used to simulate the next year's survivors, and so forth. An advantage of the CM method is that transactions other than additions and retirements, such as transfers and acquisitions, may be aged and incorporated with the simulated survivors in the year of the transaction. A disadvantage is that the curve type must be specified in order to simulate survivors.

c. Turnover methods The turnover methods are used to estimate the average life of property but indicate no mortality characteristics or survivor curve. The turnover period is the time required to exhaust a specified past balance. The turnover period (or number of years) are obtained by cumulating annual retirements backwards until the sum equals a previous balance. The half-cycle ratio model requires data for only one-half average life. The model, along with the asymptotic model, the geometric mean model, is based on the ratio of annual retirements to balance. The use of turnover methods is restricted by assumptions regarding uniform growth rates and homogeneous life characteristics among vintages.

Again, An expert's judgement is necessary for life estimation. The actuarial methods are preferred to the semi-actuarial methods if aged data are available.

C. Salvage Analysis

Salvage analysis is necessary for building into depreciation rate to include the net of salvage expected to be received and cost of removal to be incurred at the time of abandonment or removal. Depreciation accounting concept and regulatory rules require that the net salvage be excluded from depreciable service value. The salvage analysis is particular important as the net salvage value becomes negative. Net salvage value means the salvage value of property retired less the cost of removal. The salvage ratio for the rate calculation is defined as the net salvage value divided by the original cost of property to be retired. While life analysis is important, salvage analysis is also important especially when the net salvage has significant impact on the accrual rate and has not been highly developed because of the data problem (30).

D. Depreciation Calculation

An accrual rate is required for the depreciation calculation. First, the depreciation rate calculation method is selected. Then, in conjunction with the results of life analysis and salvage analysis, the accrual rate is determined for book depreciation. The system of calculation methods, according to Wroblewski (cited in Lamp 31), is defined by a depreciation cube which combines the selection of depreciation methods, procedures, and techniques. The depreciation methods refer to basic recovery patterns such as straight-line, double declining balance, sum of years digits, present worth, and sinking fund methods, etc., as defined for item property. The regulatory environment requires that utilities use straight-line method for book purposes. The nonstraight-line methods, which can be accelerated or decelerated, are also used for tax-purposes or income producing in the unregulated entities. The depreciation procedure indicates that a depreciation method will be applied to a group of units - such as equal life group, vintage group, or broad group. The depreciation technique distinguishes between the use of a function of whole life applied to the total cost of the asset, as opposed to a function of remaining life applied to the unrecovered cost of the asset i.e., whole life technique or remaining life techniques.

The group concept of depreciation practices has been used in the utilities for many years. It is simple to apply depreciation methods to a single unit; however, for utility properties calculating depreciation for a group of large number of items may be more efficient than depreciating each item separately. Under this concept, there is no attempt for the utilities to keep track of the depreciation applicable to individual items of property. Thus, the group method would use the average of many units, which allows for some units having relatively short lives and some units having relatively long lives without specifying whether a particular unit will have a short or long live. The commonly used depreciation procedures will be described in the following sections (19, 20). Also, in this study the methods are restricted to the straight-line method because of the requirement of regulatory agencies upon utilities.

1. Average life group (ALG) and equal life group (ELG)

There are two average life group procedures for depreciation practices: vintage group (VG) procedure and broad group (BG) procedure. The vintage group procedure treats the same type of property placed in service during the same year as a distinct group for depreciation purpose; therefore, an estimate of the average service life (ASL) and net salvage ratio (S) of each individual vintage group is necessary. The broad group procedure puts all vintages of the same type of property into a single broad group for depreciation purposes. In this case, only an estimate of the ASL is needed for the group to calculate the depreciation charge. Each vintage group is depreciated as a whole separately; as applied to a continuous group of broad group procedure, all vintages are considered as a whole. The vintage group procedure is a refinement of the broad group procedure; it calculates an accrual rate for each vintage whereas the broad group procedure calculates an accrual rate for the broad group of vintages in the account. The ALG method, though widely used for depreciation rate calculation, does not recognize the existence of retirement dispersion in the depreciation rate calculation.

The ELG procedure calculates the depreciation rate based on the expected life of each equal life component of the property rather than the average life of all components. The ELG is a refinement of the vintage group procedure. Each vintage is divided into several equal life groups (ELGs) such that all the property in a specific ELG has the same estimated life. The accrual rate for each ELG is based on the estimated life of the ELG. The vintage accrual rate for a specific calendar year is the weighted average ELG accrual rate for that calendar year. The accrual rate for an account for a specific calendar year is the weighted average accrual rate for that year. Unlike ALG procedure, the ELG recognizes the existence of retirement dispersion in the calculation.

2. Whole life (WL) technique and remaining life (RL) technique

The resulting mortality characteristics from life estimation are used to calculate ALG or ELG depreciation rates, both on either a whole life basis or a remaining life basis. The ALG and ELG procedures use the same set of mortality characteristics for rates calculation. The whole life technique indicates that the average service life of ALG or expected life of ELG be the number of years used in calculating the depreciation charge for a year. The remaining life technique utilizes the remaining life (average remaining life of ALG or expected remaining life of ELG) in calculating the accrual rate for a calendar year. The general formulas for depreciation rates calculation are as the following:

(1) Whole life depreciation rate

$$d = \frac{1 - \text{average net salvage\%}}{\text{average service life}} \qquad (2)$$

(2) Remaining life depreciation rate

$$d = \frac{1 - \text{future net salvage\%} - \text{reserve\%}}{\text{remaining life}} \qquad (3)$$

The depreciation rate then is applied to the depreciation base of the corresponding selected depreciation procedure to calculate depreciation charge for that calendar year. The depreciation base is average account balance for BG life procedure, average vintage balance for VG life procedure, and average "equal life group" balance for ELG procedure. In actual accounting the depreciable group generally contains many vintages and is open-ended (or continuous) such that early vintage may be completely or nearly retired and new vintages are added each year. Therefore, if based on the broad group procedure, the accrual rate for a calendar year is applied to an open-ended account's plant balance for computing depreciation charge. The account depreciation charge by using vintage group procedure is sum of all the vintage depreciation charges or calculated by applying the weighted average of the vintage accrual rate to the average account balance for that calendar year. Similarly, the account depreciation charge of ELG procedure is sum of all the ELG depreciation charges for all vintages or is calculated by applying the composite weighted average accrual rate to the average account balance.

Theoretically, the ELG recovers the capital investment in adequate and timely pattern upon retirements of property units. The ALG will over- or under-accrue depreciation during the life of a property because of the "average" nature of the service life but will recover all the investment by the end of property. The remaining life technique is applied to the unrecovered cost of the property at the beginning of the calendar year such that it would never over-depreciate property but will insure its final recovery. All in all, the accurate depreciation still relies on the accurate life estimation. Without accurate life estimation, there is no accurate depreciation and the above depreciation procedures make little differences for improvement.

The materials discussed on the above three sections can also be found in the papers written by Ferguson (32, 33, 34, 35).

3. Book reserve and calculated reserve requirement

The calculated reserve requirement is used to test the adequacy of book reserve resulting from the accumulation of annual depreciation charges. The calculated reserve requirement is derived from the results of the life forecasting process. It indicates the level that the reserve should be at as of the date. It is accurate only to the extent the property life assumptions and forecasts are valid. For a continuous group of property, the normal or stabilized reserve balances were developed for various families of survivor curves (such as Iowa curve or Bell system curves) with various rates of growth (36, 37).

Lamp (31) discussed the calculations of theoretical reserve. Thus, for a given property group with developed life characteristics, one can calculate its calculated reserve requirement at a certain point in time.

However, the conventional calculated reserve requirement may not be adequate any more because the forces of mortality from technological progress and market competition have overridden the historical mortality forces such as physical and functional forces. Understanding that the transition of such mortality forces may cause inadequacy of conventional life estimation, one can expect a new method of life estimation is necessary to give the adequate depreciation of utility properties. The life cycle depreciation (LCD) model is designed as such to incorporate with the technological life forecasting model for life estimates. This chapter briefly reviewed the conventional depreciation procedure. In the following chapters, the LCD will be presented.

III. OBJECTIVES OF STUDY

The subject of this study is the application of the property life cycle to the process of life estimation and capital recovery. It was brought about by the use of technological forecasting methods in predicting the property life cycle. The proponents of this forward-looking method believe that it can predict the future developments of a property better than the traditional analytical technique (9, 10, 11). Thus, the depreciation study for a property based on life cycle methodology would produce better capital recovery results than that with a conventional depreciation studies. The main objectives of this study are as follows:

1. develop a Life Cycle Depreciation (LCD) model for use with the technological forecasting methods to give a systematic approach and solution to the current depreciation problems.
2. utilize the LCD to increase the accuracy of life estimation, simplify the complicated depreciation procedure.
3. make comparisons of the current model with the conventional models for better understanding of the LCD procedure.
4. validate and investigate the LCD using theoretical simulation of life cycle accounts and application of actual data.
5. develop a computer software program for the LCD.

IV. LIFE CYCLE DEPRECIATION MODEL

The life cycle depreciation (LCD) model was primarily developed for the property life cycle forecasting to increase the accuracy of the life estimation for certain telecommunication properties. It also has application for other properties subject to technological cycles in all regulated utility industries. This would be the case when the conventional age related forces of mortality have been dominated by the mortality forces due to cyclical technological obsolescence or competitive factors.

The life cycle depreciation model utilizes a forward-looking model to predict the technological life cycle of a property which is the basis for an estimate of life for depreciation. First, the plant investment is disaggregated from the FCC account classification into homogeneous equipment types or technology groups. Then, the analyst, aided by subject matter experts (SMEs) who attempt to quantify the influence of the technological and competitive environment, makes a forecast of a life cycle. Then, utilizing this forecast and forecasts of future additions and future net salvage, the analyst determines the investment recovery life (IRL) and the remaining investment recovery life (RmIRL). The following sections will discuss the life cycle depreciation model's concept, assumptions, data requirements, and procedures.

A. Life Cycle Concept

Life cycle analysis was developed as a marketing tool for use in strategic planning. It is a forward looking technique used to predict the changes in marketplace demands over time for a product in order to make marketing strategic plan as the product moves from one stage of development to another. The model is based upon the birth - growth - maturity - death of a product. Applied to telecommunication properties, the life cycle is used to estimate life for depreciation calculations. A product life cycle can be characterized as having five basic stages: introduction, market leader, continue growth, replacement, and residual use (10). Figure 1 identifies the different stages of a life cycle and shows the shape and span of a life cycle in terms of annual sales volume and of investment in-service.

As indicated by the graph, the annual additions of new vintages are greater than the total retirements from current and previous vintages as long as the property continues growing. The case is reversed in the declining stage after the peak point of the life cycle where large amount of retirements occur and are not replaced by the items of the same technology. It is believed that the life cycle can best be used to describe the property development in which retirements are strongly influenced by the cycles of technological evolution.

Figure 2 illustrates the relationships between account balances, annual additions, and account retirements over a life cycle curve. The coordinates of a life cycle plot are in terms of time and the

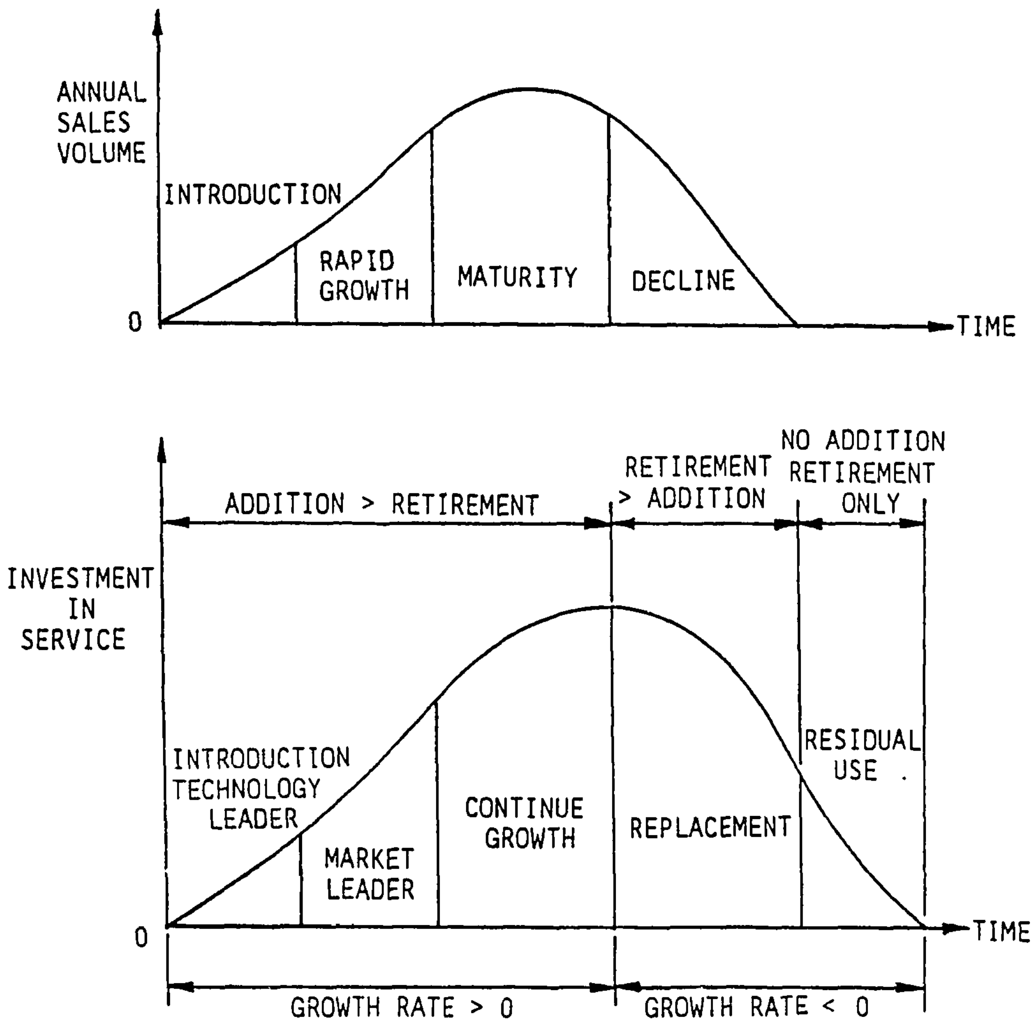

FIGURE 1. Life cycle stages, shape, and span - annual sales volume vs investment in service

investment in service. The latter reflects the magnitude of additions and retirements during the life cycle. Basically, the life cycle is a set of timely points defined by the end-of-year balance of a property study group. In a given year the addition is placed in service while some of the items of property from the previous vintages, and possibly the new addition, will be retired. Consequently, the end-of-year balance of the life cycle is the beginning year balance, increased by additions during the year, and decreased by the retirements during the year:

$$BAL_i = BAL_{i-1} + ADD_i - TRET_i \qquad (4)$$

Where $TRET_i = ARET_i + VRET_i$

$ARET_i$ = retirements of the ith year from new addition

$VRET_i$ = retirements of the ith year from previous vintages.

From equation (4), it is easy to see that a property life cycle is constituted of balances, additions, and retirements. The absolute magnitudes of annual gross additions and total retirements are also important factors in determining a life cycle. According to this relationship, the forecast of a life cycle merely gives an envelope of constraints to the property in service, which defines one of the three time variables in the life characteristic development of a property. Placing more addition and having more retirements in a given year, according to equation (4), is mathematically equivalent to placing fewer addition and having fewer retirement because they result in the

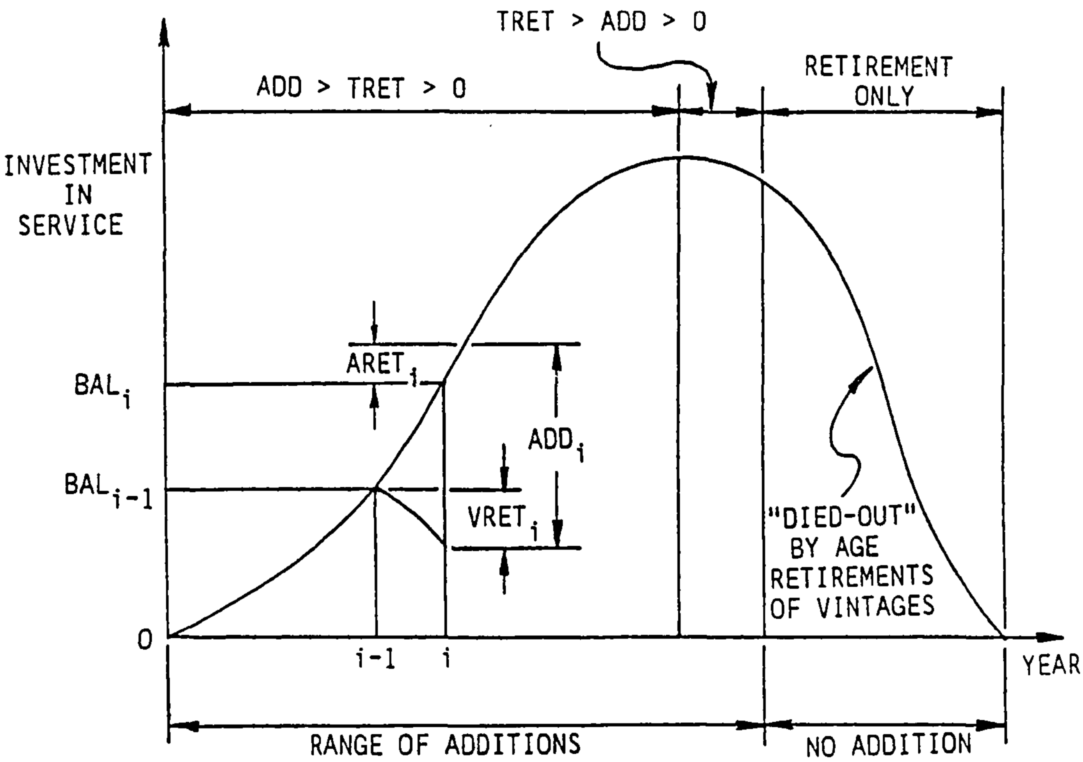

FIGURE 2. Relationship of balance, addition, and retirements of a life cycle

same end of year balance. This is true for every point in the life cycle.

However, this is not the same meaning from the standpoint of the capital recovery manager because the amount of invested capital in each case to be recovered is different. For this reason, one of the other two time-related variables (gross annual additions or total annual retirements) needs to be forecast in order to describe the life characteristics of a property properly. Once two of the variables are specified, the other can be calculated. Later in this study it will be shown that the composite life, derived from the property life cycle, is appropriate to use for depreciation purpose.

B. Assumptions

Four assumptions were made to facilitate the application of the life cycle depreciation (LCD) model in this study. They are as follows:

1. All the investments are depreciable.
2. The property is assumed homogeneous in the life cycle for the same technology group.
3. Perfect forecasting techniques are available.
4. Straight-line method, broad group average life procedure depreciation is utilized for either whole life or remaining life technique (SL-BG/ALP-WL or SL-BG/ALP-RL).

The first assumption indicates that the investments are depreciable assets and hence, the capital should be recovered over the useful life of the asset. Any assets which are not depreciable have been excluded. The useful life here means a depreciation life estimated using the LCD model, which gives rise to proper depreciation results for the life cycle property.

The second assumption implies that the technology property group in a life cycle is physically and functionally identical except for the timing of placement. The life cycle consists of many vintages of identical property items providing the same class of service. Consequently, it is reasonable to charge customers (or rate-payers) the same rate of depreciation for the same class of service provided over time. This implies that an overall life indication such as investment recovery life (IRL) or remaining investment recovery life (RmIRL) can be used to depreciate a given type of life cycle property. Moreover, as will be demonstrated later, the broad group depreciation based on IRL will give the same capital recovery results as conventional vintage group depreciation if this assumption is true. The assumption that property items are grouped by technology is a requisite of the life cycle depreciation model.

Since this is a study of the efficacy of the LCD model and not life forecasting procedures, the third assumption is made. The quality of forecasting techniques has been evaluated elsewhere (12, 13, 14). Actually, many forecasting techniques, qualitative or quantitative, are well developed and ready for use. Some technological forecasting models have also been designed and computerized for the life cycle forecasting in the telecommunication industry. Later, in the next chapter, some of the forecasting models will also be discussed.

The fourth assumption is the same as that used in the conventional depreciation process confining the examples to the broad group depreciation procedure. The straight-line depreciation method is commonly used and required in the regulatory process. The LCD is limited to the use of the broad group depreciation concept since no individual vintage information is available for depreciation purposes.

C. Data Requirement

Unlike some conventional depreciation approaches, the life cycle depreciation model does not required detailed vintage retirement data for the property; instead, future data are required for the LCD application. The data are disaggrégated from the FCC account classification to as close as technically homogeneous groups of property as possible. The LCD utilizes only annual data and end of year records of a life cycle account. The life cycle account is an account of data for the disaggregated property, which contains a complete set of yearly data required for the life cycle depreciation model. The set of data is made up of actual (past) data and forecasted (future) data. The actual data are taken from the accounting records while the future data are predicted using any of the recognized forecasting techniques. Combining the actual and forecasted annual data, the life estimations can be made using the life cycle procedures. The data required are as follows:

- Actual data - yearly balances, gross additions and/or total retirements, and gross salvage and costs of removal.
- Forecasted data - forecasted life cycle, future gross additions, gross salvage and cost of removal ratios.

Note that the yearly data are cumulative record comprising information from all the existing vintages in any given year in the life cycle. The historical data are used as input to the forecasting models to predict the future data.

In summary, the LCD requires a forecast of the complete life cycle account which consists of five elements: balances, gross additions, retirements, gross salvage and costs of removal. The first three elements are used to make life estimation for the depreciation rate calculation. As discussed earlier, the future data of only two of the three elements are predicted. The third one is determined once the other two are specified. Similar to the conventional depreciation models, net salvage (gross salvage less cost of removal) is also important and required in determining the depreciation rate.

D. Life Cycle Depreciation Procedure

Like the conventional depreciation procedure, the life cycle depreciation model requires the following stages:

1. data compilation
2. life cycle forecasting and other estimates
3. life estimation and depreciation calculation

The three stages complete the depreciation study using the life cycle depreciation model. They are described as below.

1. Data compilation

The data collection and analysis in this stage mainly deals with the actual data (historical data) in the life cycle account. The first step is breaking down the mass account into depreciation category as mentioned earlier. The specification of property types can be determined by capital recovery managers and/or subject matter experts. The data are collected from the accounting records or field records and examined carefully to ensure their consistency and accuracy. An auditing and a querying process are necessary to correct errors and sort out unneeded data. Adjustments may have to be made to correct any existing discrepancies in the data as to continuity. That is, according to equation (4) balances, additions, and retirements should be in agreement over time in the accumulation process.

The traditional data compilation procedure is suitable for this stage of the LCD model. Data are analyzed to get better indication of life trends and characteristics. For the new technology property account, very little data may be in the record. If this is the case, the depreciation rate for this new generation can be forecast in the next stage. Or, the depreciation rate of a group with similar technology cycles can be used for depreciation calculations until there is enough experience upon which a more valid estimate of depreciation rate can be made.

2. Life cycle forecasting and other estimates

The LCD is based on a forward looking analysis, projecting into future, exploring the true life characteristics of the technology property groups. The accuracy of life estimation by using this model depends most significantly upon the forecasting ability of technological forecasting models. Thus, employing the forecasting models prudently is crucial to the LCD model. Many technological forecasting models have been empirically tested and shown to be capable of predicting eras or time spans of a particular technology, especially in the telephone industry (2, 6, 12).

The future data of the life cycle account are estimated in this stage by using reliable forecasting techniques and best judgement of experts. First, the life cycle (i.e., the end of year balances of the categorized depreciation property) is forecast using technology life cycle forecasting models which will be briefly presented in the next chapter. The life cycle defines the total investment of a property existing in service over the life span of its technology. That is, it establishes an envelope of usage for a property type into future based on the best estimates of the forecasting models and expert's judgement. The envelope is related to the gross additions and retirements over the whole life cycle. Because the life cycle forecasting has significant impact on the depreciation model, it may be worthwhile to construct a forecasting interval for securing a possible range of depreciation results. The most commonly used life cycle forecasting tools are recommended in the following. They will be presented later.

- Substitution / adoption models - Fisher Pry, Gompertz, Normal and Log-normal, Logistic, and Weibull application. These models can also be in linear or nonlinear form.
- Product life cycle model

The second forecast to be made is either annual gross additions or retirements. Which one of them depends upon the data available and confidence the analyst has in his accessibility to the best estimating tool. The retirements of property during a life cycle generally increase significantly in the declining stage because of the effect of the technological obsolescence. It is not easy to predict the future retirements accurately since in most instances there is no obvious foreseeable pattern. Thus, forecasts of retirement patterns are not usually recommended. The annual gross additions, on the other hand, do have a general pattern in the life cycle. According to the life cycle simulation results using Iowa curves as mortality input (15), the pattern of the yearly additions were found to experience fluctuations as it grows toward a maximum before the peak of the life cycle, and then diminishes regularly toward the demise of the property group. Also, observations of the actual accounts of crossbar and analog-ESS for several telephone companies confirm the above generalizations. At the present time the life cycle for the crossbar technology group is almost complete and analog-ESS has reached beyond the peak of its life cycle.

Besides, there is always a relation among balances, additions, and retirements. If equation (4) is rearranged, then the growth rate ($grate_i$) of the ith year of the life cycle:

$$grate_i = \frac{BAL_i - BAL_{i-1}}{BAL_{i-1}} = \frac{ADD_i - TRET_i}{BAL_{i-1}} \qquad (5)$$

Thus, the equations (4) and (5) can be used as constraints to the forecasts of these variables. Finally, the future net salvage ratio is estimated. The ratio is used to determine depreciation rate for the depreciation charges. The estimation process is the same as that of conventional salvage estimation process, as described earlier.

The forecasting results are determined using knowledge, reasoning, empirical evidence, and at times, recognized mathematical models. It is necessary to provide this supporting information for a better understanding of the estimates so that the results will be acceptable by the public. In actuality, there always exists the risk of uncertainty with the forecasts of the future no matter which method is employed. Thorough and detailed analyses, correctly accomplished, minimize the possibility of excessive error.

3. Life estimation and depreciation calculation

This stage utilizes the forecasting results of the last stage to estimate depreciation lives for different product life cycles. The broad group life indication, either in whole life or remaining life, is calculated to represent the overall life characteristics of the life cycle. The whole life method, called investment recovery life (IRL), calculates a single life for the complete life cycle of a technology group by dividing the total area under the life cycle by the summation of total gross additions, past and forecast. Similarly, the remaining investment recovery life (RmIRL) method estimates the average remaining life of property for each consecutive year over the life cycle. It is derived by dividing the total remaining expected service of the life cycle (i.e., area under the life cycle to the right of the study year) by the summation of expected future total additions and existing plant in service at the beginning of the study year. The depreciation rate is computed in the same manner as the conventional approach. The formulae for depreciation calculation are as follows:

(a) IRL depreciation rate ($d_x = d =$ constant)

$$IRL = \frac{\text{Area under the life cycle}}{\text{Summation of total additions}}$$

$$= \frac{\sum_{j=1}^{m} BAL_j}{\sum_{i=1}^{n} ADD_i} \tag{6}$$

$$d = \frac{1 - s_a}{IRL} \tag{7}$$

(b) RmIRL depreciation rate (variable), at year x

$$RmIRL_x = \frac{\text{Area under the life cycle to the right of the study year}}{\text{summation of existing balance at beginning year of x and expected total future additions}}$$

$$= \frac{\frac{1}{2} BAL_{x-1} + \sum_{j=x}^{m} BAL_j}{BAL_{x-1} + \sum_{i=x}^{n} ADD_i} \tag{8}$$

$$d_x = \frac{1 - s_{f,x} - RR_{x-1}}{RmIRL_x} \quad (9)$$

(c) depreciation expense and depreciation reserve (for the xth year)

$$D_x = \frac{BAL_x + BAL_{x-1}}{2} \times d_x \quad (10)$$

$$DR_x = DR_{x-1} + D_x - RET_x + GS_x - COR_x \quad (11)$$

$$RR_x = DR_x / BAL_x \quad (12)$$

where d_x = the depreciation rate for the xth year

s_a = average net salvage ratio

$s_{f,x}$ = expected future net salvage at the study year

RR_{x-1} = accrual reserve percent at the beginning of year x

x = the study year

m = the maximum life span of the life cycle, year

n = the number of annual additions in the life cycle

BAL_x = account balance at the end of xth year

ADD_x = account addition during the xth year

RET_x = total retirements during the xth year

D_x = depreciation expense for the xth year

DR_x = depreciation reserve for the xth year

RR_x = reserve ratio for the xth year

GS_x = gross salvage for the xth year

COR_x = cost of removal for the xth year

Note that the IRL ≡ RmIRL, and $BAL_{x-1} = 0$ at study year x=1.

The above formulas will give full recovery of the total investment at the end of the life cycle if the forecasts are made correctly. In fact, both IRL and RmIRL are theoretically derived as will be shown later. They are the same as the direct weighted average whole life and direct weighted average remaining life for all the vintages such as that developed in the conventional method. Thus, the IRL and RmIRL are both broad group lives because the LCD uses no detailed vintage information. The whole life, IRL, is calculated as an average service life for all the vintages staying over the life cycle so that it will over- or under-accrue over time depending on the long or short lives of the vintages but will ensure the final recovery. Similarly, the remaining life, RmIRL, is an average remaining life which always looks into future, depreciating the unrecovered portion of the investment, getting full recovery but not over-accrual. For a dynamic depreciation process such as the life cycle model, the RmIRL is a better model to use since it adjusts itself to the forecasts of the life cycle. While the IRL calculates only one rate, the RmIRL calculates different rates at different points in time in the life cycle. The rates are adjusted as future development of property becomes known. Actually, these concepts are much the same as those of the conventional depreciation models in broad group sense. The IRL and RmIRL are more desirable since they are derived from what is believed to be a better life forecasting process.

The life cycle depreciation model is a method of "semi-mortality" analysis. Even though the LCD does not make life analysis on the mortality information of the vintages, it does have incorporated all the mortality effects of the vintages in the IRL and RmIRL by the forecasts of the life cycle and annual investment (additions) over time. The relationship of additions, retirements, and life cycle through time makes it possible to use the IRL and RmIRL calculation. Consequently, the IRL and RmIRL are products of the integration process which gathers the overall mortality characteristics of the life cycle. The semi-mortality analysis is so named because it is a mortality analysis concept but using forecasting technique for the life estimation.

The calculated reserve requirements are developed by applying the IRL or RmIRL to the life cycle account, which can be used as an indication of adequacy of recovery over time. For every life cycle, there is a certain pattern of depreciation reserve requirement. There is no possibility of stabilizing over time as is the case for the continuous property because the life cycle properties are finally retired at the end of the life cycle. Equations (10) through (12) are used for the depreciation and reserve calculations.

E. Derivation of IRL and RmIRL

As noted above, the IRL and RmIRL are critical to the life cycle depreciation model. They can be derived for any technological group using a data account such as that in Table 1. The life cycle balances are recorded at the bottom of the table, and additions at the left-hand column. Because the life cycle account contains no vintage surviving data, the real mortality patterns of the vintages were assumed for the derivation purpose. The mortality patterns were represented by the type curves such as Iowa curves, and average service lives. The notations were used as the following:

ADD_i : amount of the ith addition, i = 1, 2, ⋯, n

BAL_j : account balance at end of the jth year, j = 1, 2, ⋯, m

$VBAL^{TCi}_{x-i-0.5}$: the ith vintage balance at the beginning of the study year x with type curve TC, i = 1, 2, ⋯, n

$PS^{TCi}_{x-i+0.5}$: percent surviving of the ith vintage at age x-i+0.5 with a type curve TC, i = 1, 2, ⋯, n

ASL_i : average service life of the ith vintage

RL^{TCi}_{x} : remaining life of the ith vintage at year x

mi : maximum life of the ith vintage, i = 1, 2, ⋯,n

Note there are n additions (vintages) for the life cycle account which has maximum life span of m years. Each addition is presumably defined by a survivor curve and an average service life. The half year convention was used. From Table 1, the surviving balance of a vintage at the end of each year is calculated by multiplying the amount of the ith addition by its age surviving percent of a type curve. The average

Table 1. The life cycle account with presumed vintage survivor curves

	year											
	1	2	3	4	5	...	n-1	n	n+1	...	m-1	m
ADD_1	$PS^{TC1}_{0.5}$	$PS^{TC1}_{1.5}$	$PS^{TC1}_{2.5}$	$PS^{TC1}_{3.5}$	$PS^{TC1}_{4.5}$	...	$PS^{TC1}_{n-1.5}$	$PS^{TC1}_{n-0.5}$	$PS^{TC1}_{n+0.5}$	...	...	
ADD_2		$PS^{TC2}_{0.5}$	$PS^{TC2}_{1.5}$	$PS^{TC2}_{2.5}$	$PS^{TC2}_{3.5}$	...	$PS^{TC2}_{n-2.5}$	$PS^{TC2}_{n-1.5}$	$PS^{TC2}_{n-0.5}$	...	...	
ADD_3			$PS^{TC3}_{0.5}$	$PS^{TC3}_{1.5}$	$PS^{TC3}_{2.5}$	...	$PS^{TC3}_{n-3.5}$	$PS^{TC3}_{n-2.5}$	$PS^{TC3}_{n-1.5}$	...	...	
ADD_4				$PS^{TC4}_{0.5}$	$PS^{TC4}_{1.5}$	...	$PS^{TC4}_{n-4.5}$	$PS^{TC4}_{n-3.5}$	$PS^{TC4}_{n-2.5}$	...	...	
⋮					⋮	⋮	⋮	⋮	⋮	⋮	⋮	
ADD_{n-1}							$PS^{TCn-1}_{0.5}$	$PS^{TCn-1}_{1.5}$	$PS^{TCn-1}_{2.5}$	...	$PS^{TCn-1}_{m-n+0.5}$	
ADD_n								$PS^{TCn}_{0.5}$	$PS^{TCn}_{1.5}$	...	$PS^{TCn}_{m-n-0.5}$	0
	BAL_1	BAL_2	BAL_3	BAL_4	BAL_5	...	BAL_{n-1}	BAL_n	BAL_{n+1}	...	BAL_{m-1}	BAL_m

service life is the area under the survivor curve. The end-of-year life cycle account balances are summation of all the existing vintages at the end of each year. That is,

End of the Year

$$BAL_1 = ADD_1 \times PS^{TC1}_{0.5}$$

$$BAL_2 = ADD_1 \times PS^{TC1}_{1.5} + ADD_2 \times PS^{TC2}_{0.5}$$

$$BAL_3 = ADD_1 \times PS^{TC1}_{2.5} + ADD_2 \times PS^{TC2}_{1.5} + ADD_3 \times PS^{TC3}_{0.5}$$

$$\vdots$$

$$BAL_n = ADD_1 \times PS^{TC1}_{n-0.5} + ADD_2 \times PS^{TC2}_{n-1.5} + ADD_3 \times PS^{TC3}_{n-2.5} + \cdots$$

$$+ ADD_{n-1} \times PS^{TCn-1}_{1.5} + ADD_n \times PS^{TCn}_{0.5}$$

$$\vdots$$

$$BAL_{m-1} = \cdots + ADD_{n-1} \times PS^{TCn-1}_{m-n+0.5} + ADD_n \times PS^{TCn}_{m-n-0.5}$$

$$BAL_m = 0$$

and the area under the life cycle is equal to summation of all the end-of-year life cycle balances, i.e.,

$$\sum_{j=1}^{m} BAL_j = ADD_1 \times \sum_{i=1}^{m1} PS^{TC1}_{i-0.5} + ADD_2 \times \sum_{i=1}^{m2} PS^{TC2}_{i-0.5} + \cdots + ADD_n \times \sum_{i=1}^{mn} PS^{TCn}_{i-0.5}$$

$$= ADD_1 \times ASL_1 + ADD_2 \times ASL_2 + \cdots + ADD_n \times ASL_n$$

$$= \sum_{i=1}^{n} (ADD_i \times ASL_i) \qquad (13)$$

= Area under survivor curves of (1st vintage + 2nd vintage + 3rd vintage + ⋯ + nth vintage)

= Sum of all the area under each vintage survivor curve

= Area under the life cycle curve

whereas, as defined,

$$\text{the direct weighted average service life} \equiv \frac{\sum_{i=1}^{n} (ADD_i \times ASL_i)}{\sum_{i=1}^{n} ADD_i} \tag{14}$$

thus, from equation (13),

$$\text{the direct weighted average service life} = \frac{\sum_{j=1}^{m} BAL_j}{\sum_{i=1}^{n} ADD_i} \tag{15}$$

As a result, equation (15) is the definition of investment recovery life (IRL), i.e.,

$$IRL \equiv \text{the direct weighted average service life} = \frac{\text{Area under the life cycle}}{\text{Summation of total additions}}$$

Similarly, the RmIRL can also be derived in this way, that is

RmIRL ≡ the direct weighted remaining life.

Using Equation (14), the direct weighted remaining life (DWRL) can be defined for the study year x as:

$$DWRL = \frac{\sum_{i=1}^{n} (VBAL_{x-i-0.5}^{TCi} \times RL_{x}^{TCi})}{\sum_{i=1}^{n} VBAL_{x-i-0.5}^{TCi}} \tag{16}$$

The VBAL (vintage balances) of the above equations can be separated at the study year x as follows:

At the beginning of year x, for ith vintage,

if $i < x$, vintage balance = $VBAL_{x-i-0.5}^{TCi}$

$$\text{and } RL_{x}^{TCi} = \frac{\text{area under ith vintage survivor curve to the right of age x-i-0.5}}{\text{amount surviving at age x-i-0.5}}$$

$$= \frac{\frac{1}{2}VABL_{x-i-0.5}^{TCi} + \sum_{j=x}^{mi} VBAL_{j-i+0.5}^{TCi}}{VBAL_{x-i-0.5}^{TCi}} \tag{17}$$

if $i \geq x$, vintage balance = future addition = ADD_i,

and $RL_{x}^{TCi} = ASL_i$ = area under the ith survivor curve.

From equation (16),

$$\text{the denominator} = \sum_{i=1}^{x-1} VBAL_{x-i-0.5}^{TCi} + \sum_{i=x}^{n} ADD_i$$

$$= BAL_{x-1} + \sum_{i=x}^{n} ADD_i$$

$$= \text{summation of existing balance at beginning of year x and total future additions} \tag{18}$$

Using Equations (16) and (17),

$$\text{the numerator} = \sum_{i=1}^{n} \left(\frac{1}{2}\text{VABL}_{x-i-0.5}^{TCi} + \sum_{j=x}^{mi} \text{VBAL}_{j-i+0.5}^{TCi} \right)$$

$$= \frac{1}{2} \sum_{i=1}^{x-1} \text{VBAL}_{x-i-0.5}^{TCi} + \sum_{i=1}^{n} \sum_{j=x}^{mi} \text{VBAL}_{j-i+0.5}^{TCi}$$

$$(\because \text{VBAL}_{x-i-0.5}^{TCi} \equiv 0 \text{ at beginning of year } x \text{ if } i \geq x)$$

$$= \frac{1}{2}\text{BAL}_{x-1} + \text{the second term}$$

The second term can be expanded as

$$\begin{array}{llllll}
 & j = x & x+1 & x+3 & \cdots & m \\
i=1 & \text{VBAL}_{X-0.5}^{TC1} & + \text{VBAL}_{X+0.5}^{TC1} & + \text{VBAL}_{X+1.5}^{TC1} & + \cdots + & \\
i=2 & \text{VBAL}_{x-1.5}^{TC2} & + \text{VBAL}_{x-0.5}^{TC2} & + \text{VBAL}_{x+0.5}^{TC2} & + \cdots + & \\
i=3 & \text{VBAL}_{x-2.5}^{TC3} & + \text{VBAL}_{x-1.5}^{TC3} & + \text{VBAL}_{x-0.5}^{TC3} & + \cdots + & \\
\vdots & & & & & \\
i=n & \text{VBAL}_{x-n+0.5}^{TCn} & + \text{VBAL}_{x-n+1.5}^{TCn} & + \text{VBAL}_{x-n+2.5}^{TCn} & + \cdots + & \text{VBAL}_{m}^{TCn} \\
\hline
 & = \text{BAL}_{x} & + \text{BAL}_{x+1} & + \text{BAL}_{x+2} & + \cdots + & \text{BAL}_{m}
\end{array}$$

$$\text{Thus, the numerator} = \frac{1}{2}\text{BAL}_{x-1} + \sum_{j=x}^{m} \text{BAL}_{j}$$

$$= \text{Area under the life cycle to the right of year } x \qquad (19)$$

From equations (18) and (19),

$$DWRL_x = \frac{\text{Area under the life cycle to the right of year } x}{\text{Summation of existing balance at beginning of year } x \text{ and total future additions}} \quad (20)$$

$$= RmIRL_x$$

From the above derivation, it can be seen that both the IRL and RmIRL are direct weighted broad group lives as used in the conventional depreciation methods.

F. Characteristics of Life Cycle Depreciation

Some characteristics of the life cycle depreciation have been shown in this study and earlier study (15). First of all, it is a broad group concept. Second, it recognizes future mortality characteristics of a property. Third, it will recover total investment for the life cycle property if the forecasts are correct. Finally, the reserve requirements are functions of various life characteristics but, most significantly, are functions of the time span of the related life cycle which is determined by the yearly investment and retirements over time. In summary, the observation can be described by the following:

1. The shorter the IRL, the higher the level of the reserve requirements.
2. The highly concentrated retirement frequencies result in high level of reserve requirements with more fluctuations.

3. The general pattern of reserve requirements first increases rapidly, then fluctuates or stabilizes in the range before the modal year of the life cycle, finally increases monotonically toward the end of life cycle with full recovery.
4. The shorter the life cycle span, the higher the reserve requirements developed and the shorter the period of recovery reached.
5. The higher the growth rates, if other things are unchanged, the lower the reserve requirements.
6. The pattern of additions first grows, at times erratically, toward the maximum before the peak of the plant in service, then diminishes regularly toward the end of the life cycle.

Furthermore, from the formulae indicated above, several things can be expected. They also will be shown later.

- The shorter the IRL, the higher the depreciation rate.
- The lower the average net salvage ratio, the higher the depreciation rate.
- For a given life cycle, the higher the amount of total additions, the higher the depreciation rate.
- When negative average net salvage is produced the reserve requirements will reach over 100%.

V. TECHNOLOGICAL FORECASTING MODELS FOR THE LCD

Several quantitative technological forecasting models are available for the life cycle forecasting (12, 13, 14). These models can be classified as substitution/adoption models and product life cycle model. The substitution/adoption models are a group of deterministic exploratory models called growth models attempting to predict the behavior of technologies. Many of these growth models assume that a technology will progress along an S shape of growth. The S growth shape curve reflects a slow start followed by exponential growth, and then levels off again at some upper limit produced by nature or technical capabilities. Conceptually, substitution may be defined as the process when one technology replaces another providing the same service to a potential market. In contrast, adoption may be defined as the development of the market for a new technology providing a specific service. Both concepts are similar and use the growth models. The product life cycle model, as mentioned earlier, was based on the nature of the product passing through definable stages of birth - growth - maturity - death over the span of their position in the market. Under this concept, the product life cycle attempts to predict and identify stages of technologically grouped properties.

One of the techniques used in the technological forecasting methods is mathematical curve fitting utilizing the forecasting models. This forecasting procedure uses the statistical procedure of the least square method for identifying values of parameters which give the best fitting curve. Six substitution/adoption models and one product life cycle model are presented below.

A. Substitution/Adoption Models

The growth models use linear or nonlinear estimating procedures. The linear technique transforms the S curve data into a linear form before the parameters of the model are estimated. Since many growth curves have formulations with exponential functions, logarithmic transformations are necessary to linearize them. Nonlinear estimation, on the other hand, derive the model parameters without relying on any transformation.

1. The logistic model

The logistic curve was developed by Pearl (38) and originally used in biological growth studies. He found the biological growth exhibit the S-shape growth pattern and formulated it into what is know as the Pearl-Reed or logistic curve. The curve is a symmetric S-shape growth curve and has equation:

$$y = \frac{L}{1 + e^{\alpha+\beta t}} \qquad (21)$$

where y = the penetration level achieved at time t

L = the upper limit that can be achieved by y

$\beta < 0$ and α are constant.

The penetration level is the portion of the ultimate concentration achieved by a technology at a point in time. Like the biological growth patterns, technologists have also observed S shape patterns in technological growth situations. Lenz (39) is one of the pioneers who linked the biological to the technological and adopted the same formulas. The logistic curve has proven to be valuable in the technological forecasting process (12).

2. The Fisher - Pry model

The model was studied and applied to a number of substitution cases by Fisher and Pry (40). It is generally used in the form:

$$\ell n \frac{y}{1-y} = \beta(t - t_o) \qquad (22)$$

where y = the penetration level achieved at time t

β, t_o = the parameters of the model

ℓn = the natural logarithmic function

Fisher and Pry explained a technology as a set of substitution processes which tend to proceed exponentially in the early years, and to follow the S-shape curve. Such a model is appropriate for newer technology which exhibits relative improvement in performance over older technology. The model is frequently used in the telecommunication industry. It is a linear transformation of the logistic model but using different form of fitting model.

3. The Gompertz growth model

The Gompertz growth curve has been used extensively in technology forecasting (41, 42). It was originally used as a law governing mortality rates. The mathematical form of this curve is:

$$y = Le^{-Ge^{-kt}} \tag{23}$$

where y = the penetration level achieved at time t,

L = the upper limit of that technology capability

G, k = the parameters of the model.

Similar to the logistic and Fisher - Pry model, the Gompertz ranges from zero to L. On the other hand, the Gompertz curve is not symmetric with respect to the inflection point in the S-shaped curve form.

4. The extended logistic model

The extended logistic was developed by Mahajan et al. (43) from correcting a weakness in the Bass model (44). The model is different from the earlier logistic model by the assumption of an existing level of penetration at the earliest observation time. Also, this model can not be linearized and has the mathematical form of:

$$y(t) = \frac{m - pZ(t)}{1 + \frac{q}{m}Z(t)} \tag{24}$$

where

$$Z(t) = \frac{(m-a)e^{-(p+q)t}}{p + \frac{qa}{m}} \tag{25}$$

y(t) = the penetration level achieved at time t

m = the upper limit of y(t)

a = the existing level of penetration at the earliest observation time

p, q = the parameters of the model.

The extended logistic is one of the newest models in the literature and has been used to model market behavior.

The above models are basically empirical behavioral models. Some of the growth models are derived from statistical and probability theory because their cumulative distribution functions display the S growth shape.

5. The normal model

The normal distribution is also useful in the technological forecasting. Stapleton (45) applied the normal cumulative curve as a growth model to fit the technological substitution of synthetic for nature fiber. It has the statistical formula of:

$$y(t) = \int_{-\infty}^{t} (2\pi\sigma^2)^{-\frac{1}{2}} \exp[-\frac{(t-\mu)^2}{2\sigma^2}]\, dt \qquad (26)$$

where y(t) = the penetration level achieved at time t

σ, μ = the parameters of the model

exp = the exponential function.

The normal model is characterized by the mean, μ, and variance, σ^2. Many statistical computer packages can generate this normal curve's cumulative distribution. Thus, it is easy to fit the model with the add of the statistical packages.

6. The Weibull model

The Weibull distribution was proposed by Sharif and Islam (46) as a growth model for technological forecasting. The formula is:

$$y = 1 - e^{-\left(\frac{t-\mu}{\eta}\right)^{\beta}} \qquad (27)$$

where y = the penetration level achieved at time t

β, η, μ = the parameters of the model.

For the above models, Kateregga (12) suggested that the linear estimation technique be used in the earlier stage of growth; while, as more data for a specific substitution or adoption become available (such as after 25% penetration level), the nonlinear estimation can be used, which will improve the forecasting ability of the model especially at higher penetration levels. Oh (14) also proposed methods of choosing appropriate growth model for the forecasts of a technology.

After the substitution/adoption analysis is finished, the forecasted S curves should be transformed to the property life cycle. This can be obtained by analyzing the different rates of substitution for the different products that provide a relatively similar service.

For example, assume there are three products in the market at time t_3, A, B, and C. Originally, there is only one product A at time t_1. Then, product B was introduced and has penetrated the market at time t_2. At t3, the newest product entered the market. A substitution analysis of (B+C) for A would give the last portion of the life cycle for A. The substitution analysis of C for (A+B) would give the future progress of C. With A and C known, the life cycle for B can be developed. Sharif and Kabir (47) have used this approach together with dynamic programming to arrive at the life cycles of a particular technological product.

B. Product Life Cycle Model

The product life model proposed by Dandekar (13) is called investment life cycle which is basically an empirical polynomial curve representing different technologies. The generalized model was developed and tested using the actuarial data of step-by-step, panel, crossbar, and analog-ESS from telephone companies. It has the following form:

$$\ell n\left(\frac{b(t)}{1-b(t)}\right) = a + bt^3 + ct^4 \qquad (28)$$

where $b(t) = BAL_t/BAL^*$

BAL_t = the end of year balance of the life cycle at time t

BAL^* = the upper limit of the amount of investment in service, the peak of the life cycle

ℓn = the natural logarithmic function a, b, c = the parameters of the model.

The statistical procedure of general linear model (GLM) can be used for fitting data to this model. A set of standardized type investment life cycles were also developed by Dandekar for the life cycle curve fitting.

The life cycle forecasted then is used for the life estimation of a property. Again, forecasting itself is not an easy task. The expert's knowledge about a specific product should be incorporated into the forecasting process. Using and comparing the different results from different models are also valuable in deriving an accurate forecasting.

VI. VALIDATION OF THE LIFE CYCLE DEPRECIATION MODEL

As mentioned earlier, the LCD is a mortality analysis concept but using forecasting techniques for the life estimation. Whether the model will recover the investment property depends upon the forecasts of the future. The LCD utilizing the forward-looking method of technology forecasting is considered by its proponents to be better than the conventional mortality forecasting model at indicating property lives. However, there always exists the risk of uncertainty when things involve forecasts of future. One never knows for sure about the future until it has come. Life estimation for depreciation purposes requires the forecasts of future either using the LCD or the conventional model.

In the following, the LCD is compared with the conventional model for elucidating the differences and similarities between them. Then, a theoretical simulation is employed to compare the depreciation results by using both models to the generated life cycles assuming both forecasts of future are correct. In the next chapter the effects of life cycle depreciation will be shown by applying the LCD to the actual accounts of telephone companies.

A. Comparisons of the LCD With the Conventional Model

The LCD model, even though using different life estimation approach, does have some characteristics similar to the conventional life estimation approach. To better understand their relationships, their similarities and differences are discussed below with regard to three aspects: model assumptions, data requirements, life estimation method and depreciation procedure.

1. Comparisons of model assumptions

First, the conventional model was developed for continuous properties in mass accounts or groups of depreciation category which, by assumption, will exist in service forever by replacements of similar units. Thus, the property will keep growing and this investment in service may fluctuate up and down or approach stability. It's a never ending situation. However, the LCD utilizes the nature of property life cycle which has different stages in its life span. The property in service balance will grow and then decline to zero. The requirement for this assumption is by disaggregation of property into similar technology products or homogeneous groups. The LCD is applicable only to property subject to technological cycles. Second, the conventional model is assumed that the future retirements of each vintage will follow the age relationship of historical data life indications. On the other hand, the LCD recognizes the future forces of mortality by using forecasting techniques to foresee the future development of the property assuming the forecasts are correct. Third, the conventional model can use equal life group, vintage group or broad group depreciation method while the LCD can only use broad group depreciation method. The reason is that the LCD does not require the detailed vintage information.

2. Comparisons of data requirements

For life forecasting, the conventional model requires historical (actual) aged or unaged data from property accounts while utilizing no future (expected) data forecasts. In contrast, the LCD takes the past (actual) and future (forecasted) data into account. The vintage data are not required by the LCD. However, account data are disaggregated into the technologically homogeneous groups. All forecasts are made with regard to these groups.

3. Comparisons of life estimation method and depreciation procedure

As mentioned before, the life estimation of the conventional model is accomplished by using mortality analysis to the historical vintage data. The life indications is estimated for broad group, vintage group, or equal life group depreciation procedures. Consequently, each vintage or equal life group would have its own life. In contrast, the LCD is a mortality concept but using forecasting techniques. The property life cycle is forecasted and incorporated into the life estimation process. Coupled with the forecasts of future additions, life can be determined for the property. The life determination is different but simple; that is, an IRL is developed using the so-called semi-mortality analysis within the envelope of the life cycle. In other words, the IRL derived to represent the overall life characteristics of the life cycle is the same as the direct weighted broad group life derived from the conventional mortality analysis.

Also, as shown earlier, the RmIRL is the same as the direct weighted remaining life of the conventional model. Because the LCD uses no detailed vintage data, it is restricted to the broad group method.

The SPR method is similar to the LCD in the sense that both models have homogeneous assumptions and use no vintage data. However, the SPR creates the simulated aged data and uses the historical life analysis. The LCD employs the forecasting technique of the IRL approach.

The depreciation calculation procedure is the same for both LCD and conventional model using straight-line, broad group, and whole life or remaining life method.

As the comparisons were made, it can be seen that there is not much difference in the life estimation concept except that the approach is different. Actually, the LCD is equivalent to the conventional model if the forecasting capability of both models is the same. The LCD is intended to correct the problems caused by the aggressive future mortality forces which are not recognized by the conventional model because of the historical mortality assumption inherent in it. Thus, by considerations of overall picture of the property life cycle the LCD is able to recover the investment if the forecasts are accurate. This is attainable since many technological forecasting methods are readily accessible.

B. Simulation of the Life Cycle Depreciation

As derived earlier in the Section E of Chapter IV, the IRL is identical to the direct weighted average service life of the conventional model. That the IRL represents the LCD is not much different from the conventional model. A computer program was created to simulate the life cycle depreciation using broad group (IRL) method and conventional vintage group method in order to ensure the validity of the LCD. In the simulation both models were assumed having correct forecasts of the simulated property. The vintage group method has been used in the utility depreciation practices. If the IRL method is equivalent to the vintage depreciation, then the LCD will be an acceptable and effective tool to use because it has more accurate life estimation prospects than the conventional model. By generating life cycle curves from known vintage behavior such as Iowa Curves, the depreciation using broad group (IRL) method and vintage group method can be studied. The IRL method calculates broad group depreciation charges while the vintage method calculates vintage depreciation charges and then sum them up. Hence, the IRL method is a direct weighting method and the vintage method is a reciprocal or indirect weighting method. The formulas were used as follows:

(a) IRL method

$$D_x = \frac{BAL_x + BAL_{x-1}}{2IRL} \tag{29}$$

(b) vintage group method

$$D_x = \sum_{i=1}^{x} \left(\frac{VBAL^{TCi}_{x-i+0.5} + VBAL^{TCi}_{x-i-0.5}}{2ASL_i} \right) \qquad (30)$$

Note that zero net salvage was assumed, and the notations can be found in Chapter IV. The next section presents the theoretical expectation of the models.

1. Expectation of the LCD

The LCD is expected to recover the invested capital as the conventional model was expected. From equations (29) and (30), the summation of total depreciation charges should equal to the total investment (total additions) which will be retired totally at the end of the life cycle. That is, at the end of the life cycle (year m),

(a) the current IRL method

$$\sum_{x=1}^{m} D_x = \frac{1}{2IRL} \sum_{x=1}^{m} (BAL_x + BAL_{x-1})$$

$$= \frac{2 \text{ (Area under the life cycle)}}{2IRL}$$

$$= \text{total additions} = \text{total investment}$$

where $BAL_0 = 0$ and $BAL_m = 0$.

(b) the conventional vintage method (n vintages)

$$\sum_{x=1}^{m} D_x = \sum_{x=1}^{m} \sum_{i=1}^{n} \left(\frac{VBAL_{x-i+0.5}^{TCi} + VBAL_{x-i-0.5}^{TCi}}{2ASL_i}\right)$$

$$= \sum_{i=1}^{n} ADD_i = \text{total additions}$$

where $\sum_{x=1}^{m} (VBAL_{x-i+0.5}^{TCi} + VBAL_{x-i-0.5}^{TCi}) = 2\ ASL_i \times ADD_i$

$$= 2 \text{ (Area under the ith survivor curve)}$$

Also, if $ASL_1 = ASL_2 = \cdots = ASL_n = ASL$, then, from equations (13) and (30), ASL = IRL and,

$$D_x = \frac{1}{2ASL} \sum_{i=1}^{x} (VBAL_{x-i+0.5}^{TCi} + VBAL_{x-i-o.5}^{TCi})$$

$$= \frac{BAL_x + BAL_{x-1}}{2IRL}$$

i.e., the conventional vintage depreciation is the same as the LCD model, IRL method. In addition, because the IRL is an overall average life, it can be expected that it will be over- and under-depreciating property when the true lives of the property are varying in the life cycle. This is the same as the ASL in the conventional model.

2. Theoretical simulation

A life cycle, as mentioned, consists of many vintages each with its own possible life characteristics. For this reason, the life cycles were simulated using standard type curves, such as Iowa or Bell type curves, so that the underlying vintage age characteristics of property were known. Then, depreciation charges and reserve were calculated for the simulated life cycle property using the IRL (broad group) method and the conventional vintage depreciation method. This simulation assumed that both current model and conventional model have the same correct forecasts of the property. Other things unchanged, four groups of different life characteristics of the life cycles were investigated (20 vintages were assumed in the life cycle):

1. All the vintages have identical life characteristics, i.e., same type curve and same average service life. The following account data, Iowa Curve - ASL, were used for the investigation:

   R_3-12, R_2-10, R_3-8, R_3-5, L_4-12, L_3-10, L_3-8, L_3-5, S_1-12, S_3-10, S_3-8, and S_3-5.

2. The vintages have same average service life but different age characteristic transitions. The type curves were arbitrarily changed for every five vintages so that four different type curves were used in the same life cycle. The six data used were type curve transitions of

   (2a) L_1-L_2-L_3-L_4, (2b) R_1-R_2-R_3-R_4 with ASL = 15.

   (2c) L_5-S_4-R_3-L_2, (2d) R_3-L_4-S_2-R_1 with ASL = 12.

(2e) S_1-S_3-R_2-L_3, (2f) S_2-L_2-R_3-R_1 with ASl = 8.

3. The vintages have same type curve but different average service life transitions. Similarly, four average service lives were used to represent the transitions of vintage lives. The ten data accounts used were vintage life transitions of

   (3a) 16-15-14-13, (3b) 16-14-12-10 with R_3

   (3c) 16-13-10-7, (3d) 16-15-13-10 with S_2

   (3e) 7-10-13-16, (3f) 10-12-14-16 with S_2

   (3g) 10-11-12-13, (3h) 10-12-10-12 with L_3

   (3i) 12-10-12-10, (3j) 9-11-12-10 with R_3

4. The vintages have different transitions of type curves and average service lives. Like groups 1 and 2, this group used four transition period in the life cycle. The data sets were arbitrarily chosen to represent the variety of the life characteristics.

   (4a) R_3-17, R_1-14, S_2-11, L_2-8

   (4b) L_4-16, L_2-14, R_3-12, S_4-10

   (4c) R_2-16, S_3-15, L_2-13, R_1-10

   (4d) S_1-13, L_2-12, R_3-11, S_3-10

   (4e) S_1-10, L_2-12, R_3-14, S_3-16

   (4f) S_4-9, S_1-13, L_1-14, R_2-17

   (4g) S_3-9, R_2-8, L_3-12, L_1-11

   (4h) L_4-15, L_1-10, S_1-12, R_1-11

   (4i) L_1-13, S_5-10, L_2-11, R_5-9

(4j) R_5-11, L_5-10, S_4-13, L_3-12

Note that R, S, L denote the right, symmetric, and left model of Iowa curves and the subscripts represent the indices of the Iowa curves. The numbers above are the vintage average service lives of the type curves. As shown in the third data accounts, the (3a), (3b), (3c), and (3d) were designed to monotonically decrease the vintage lives over time by 1, 2, and 3 years. On the other hand, the (3e), (3f), (3g) were reversed to monotonically increase the vintage lives over time by 3, 2, 1 year, respectively. The (3h), (3i), (3j) were mixed with changing lives. In other words, the data sets were designed so that the differences of IRL and vintage depreciation can be investigated. Meanwhile, the fourth group of data accounts used the same idea. Some of them were selected so that the effects of mortality pattern on depreciation can be examined.

3. Simulated results

The simulated reserve requirements were used for the comparisons between the two methods. The differences of the reserve requirements were calculated over time and then averaged to see the differences on the average. Also, the maximum differences were listed to indicate the significance of the models. The results showed that there is no difference between the IRL method and vintage method for the first two groups of data. This was expected as mentioned earlier. However, the last two groups of simulations showed that there are slightly different between the two models. The results were as below. Note there are three numbers in the brackets. The first one is the maximum calculated reserve difference of the IRL method over the vintage method in the life cycle. The second is also a maximum while it is the difference where the IRL method is below the vintage method. Thus, the first is positive while the second is negative. The third number is the average of differences over time. The sign indicates whether the reserve of IRL method is above or below that of the vintage method. Also, the numbers are calculated reserve differences in percentage since the calculated reserve requirements are calculated as percentages of the depreciation reserves to the balances at the end of the year over the life cycle.

(1) For the third group (accounts (3a) through (3j)), the reserve differences (%) are

(3a)	[1.5, 0, 0.6]	(3b)	[3.7, 0, 1.6]
(3c)	[7.3, 0, 3.0]	(3d)	[3.2, 0, 1.4]
(3e)	[0, -8.5, -2.4]	(3f)	[0, -3.8, -1.2]
(3g)	[0, -2.2, -0.6]	(3h)	[0.7, -1.8, -0.9]
(3i)	[1.2, -0.9, 0.6]	(3j)	[1.6, -2.3, 0.2]

(2) For the fourth group (accounts (4a) through (4j)), the reserve differences (%) are

(4a)	[6.1, 0, 2.8]	(4b)	[3.6, 0, 0.8]
(4c)	[4.5, -2.6, 0.9]	(4d)	[2.3, 0.2, 1.0]
(4e)	[0, -3.8, -1.1]	(4f)	[0, -5.4, -1.0]
(4g)	[0.1, -5.0, -1.2]	(4h)	[2.6, -1.4, 0.4]

(4i) [3.2, -3.1, 0.2] (4j) [0.7, -2.6, -0.1]

According to the above results, the difference is the largest when the vintage service lives have the biggest change over time. For example, account (3e) has transitions of vintage service lives changing from 7 to 16 years which results in a maximum difference of 8.5% below. However, the average differences indicate that the two methods are not significantly different. For instance, the maximum average difference of all the accounts is only 3%, and mostly, the average difference is in the range of -1.0% to 1.0%. In addition, when the vintage service lives are monotonically decreasing over time, the IRL method has higher reserve requirements than the conventional vintage method. It is reversed when the service lives are monotonically increasing. This is because the IRL method is an direct-weighted method of the vintage lives such that it will under- or over-accrue. Consequently, when the service lives are alternatively increasing and decreasing the differences tend to be reduced between the two methods. The least differences of the reserve requirements happen in the central part of the life cycle.

Comparing the last two groups, it can be found that the mortality patterns are indifferent to the depreciation methods (IRL and vintage methods). They have an influence on the pattern of the reserve requirements but not as significant as the average vintage service lives. As discussed above, the simulation results can be summarized as below.

1. IRL = direct weighted average service life.

2. For both models at the end of the life cycle,

   depreciation reserve = 0, and

   total additions = total retirements

   = total depreciation charges.

3. The IRL depreciation method is the same as the vintage depreciation method as long as the vintage lives of the life cycle do not change over time. The depreciation methods are indifferent to the mortality patterns of the vintages, which only have effects on the pattern of capital recovery.

4. The IRL depreciation method is not much different to the vintage depreciation method even when vintage lives are changing. The differences are not significant, which on average in the range of -1.0% to 1.0%.

5. If vintage lives monotonically increase (or decrease) over time the reserve requirement is slightly lower (or higher) for the IRL method than for the conventional vintage method.

6. When the vintage lives fluctuate up and down, the IRL and vintage methods approach the same reserve requirements.

All in all, it was shown that the IRL depreciation method is approximately equivalent to the conventional vintage depreciation method when their forecasting capabilities are the same. Also, since the LCD is close to the theoretical vintage group depreciation method, it is likely to be better in the life estimation approach if it recognizes the future mortality forces.

VII. EFFECTS OF LIFE ESTIMATION ON RESERVE REQUIREMENTS - AN APPLICATION OF LCD USING ACTUAL DATA

The previous chapters discussed the theory and characteristics of the life cycle depreciation model. In this chapter the LCD is demonstrated using actual data of the telecommunication industry. The purposes were to test the effects of life estimation on depreciation reserve requirements and to validate the life cycle depreciation model. The studies were accomplished using the PC LOTUS-123. They are described as follows.

A. Data Analysis and Application Process

The actual data used were crossbar, analog-ESS, and digital-ESS accounts provided by the telecommunication industry. The Crossbar switching machines were first installed by the telephone companies in the late 1940s. Peaks were reached in both working lines and investment in the late 1970s. This technology has now reached the residual phase of the life cycle. The final retirement is expected in a few years. Analog electronic switching systems (ESS) were introduced in the late 1960s to the earlier 1970s providing a vehicle with more flexibility than the crossbar switch. For most companies the analog switch reached its peak of the life cycle in 1985-1986 and is approaching the replacement stage of the life cycle because the newer technology, digital-ESS, has been growing rapidly since in the earlier 1980s. With more advanced features, the digital has evolved toward the market leader stage of its life cycle. As technology replacement grows faster, there will be a need to update the effects of life estimation under the impact of this new technological wave.

There were a total of twenty-three data accounts - crossbar (5), analog (13), and digital (5). The data were collected from different companies in different states. Each set of data includes information such as balances of plant in service (end-of-year), plant additions, total retirements, and plant adjustments from the earliest installation in the account up to 1986. Past yearly data on gross salvage, costs of removal, and estimated future net salvage ratios were given. Other relevant information such as actual company depreciation reserve levels (1982-1986) and descriptions of the account historical depreciation rates were also provided. Prior to 1986, because there is no record of actual reserve, the reserve levels were calculated using the composite historical rates and the past retirement data given.

The data were first examined to ensure their consistency and accuracy. Some adjustments had to be made to correct certain discrepancies in the data. These were accomplished from the knowledge of their accounting relationships and by consulting with the companies supplying the data.

As stated earlier, future data are required for the application of the LCD. Thus, the life cycle and future additions (or retirements) must be forecast. In this study, to keep the analysis consistent all the life cycle forecasts were performed using the product life cycle

(PLC) model developed by Dandekar (13). The General Linear Model (GLM) procedure of the Statistical Analysis System (SAS) was used along with the PLC model to forecast the life cycles. In the process, the required inputs of peak years and balances were provided for the crossbar and analog-ESS accounts while they had to be estimated for the digital-ESS accounts by the companies. The PLC model standardized and transformed the input data to generate the forecasted life cycles of the accounts using the least square fitting method as a criteria. The forecasted life cycles were then transformed back to the amount in dollars. The model gave forecasts of the future account balances which extended the actual life cycle to its termination date. To facilitate the application, it was assumed that the PLC model could forecast the property life cycle correctly for these data.

Limited by the forecasted life cycle, the future additions and/or retirements were estimated either by the telephone companies (i.e., managerial planning and estimates) and/or by the pattern of account additions in the life cycle. The pattern of additions, as mentioned before, grows, at times erratically, toward a maximum before the peak of the life cycle, then diminishes regularly toward the end of the property.

In summary, the historical data as well as the forecasted data used in the the research is given in the Appendix. The historical data are those provided for years up to 1986 while, beyond that point, are forecasted or estimated data. Note that the modal year is where the life cycle reaches its peak and modal BAL is the corresponding balance. The total plant service to be rendered is the area under the life cycle. The total plant investment is the sum of total additions (past and future) over the life cycle. The investment recovery life (IRL), by theory, is calculated by dividing the total plant service by the total plant investment. The data also show gross salvage and costs of removal (COR), past and future. The average net salvage ratio is weighted from past and future net salvage ratios.

The life cycle depreciation model was applied to the data using the IBM PC spreadsheet software, LOTUS-123. The reserve requirements were calculated using the depreciation rates developed from the model including the effects of the average net salvage. The IRL method was used for whole life depreciation while the RmIRL method was used for remaining life depreciation. The results were compared with the actual reserve levels to determine the extent of deviation. As shown in the Appendix, the depreciation results are calculated using the IRL method. The following section will discuss the application of actual data to the model, and the results.

B. Application and Results

Three stages were implemented to accomplished the application: First, crossbar and analog-ESS central office equipments (COE) data were used to examine the life cycle depreciation model. The reserve requirements of each category of plant were calculated using IRL whole life method and RmIRL remaining life method, and were compared to the actual company reserve levels for these categories at various points of the product life cycle. Second, a sensitivity analysis was accomplished using the actual data of analog-ESS account to develop a range of possible variation of the reserve requirements. The results of the sensitivity analysis were also compared with the actual reserve levels provided by the companies. Similarly, a new category of plant, digital-ESS, was also studied to forecast its possible range of reserve requirements for the telephone companies.

1. Application of crossbar and analog-ESS accounts to the model

The first stage of the research was to examine the feasibility and effects of the life cycle depreciation model by simply applying the actual data to the model. A total of ten sets of data, 5 crossbar and 5 analog, were provided by five Ameritech companies (Illinois, Wisconsin, Michigan, Ohio, and Indiana Bell). Since the crossbar gave almost completed life cycles, a better indication of reserve deficiencies were revealed by comparisons of the calculated reserve levels derived from the model and those actually reported by the companies.

As indicated by the results, the methods of IRL and RmIRL depreciation are both correct since they recoup the total investment as indicated by the 100% reserve ratio at which time the depreciation reserve account and plant account show zero balances. The reserve patterns of the results are the same as that described in the Section F of Chapter IV. Figures 3 through 6 show examples of the reserve ratio requirements for two crossbar and two analog accounts using the IRL method, RmIRL method compared with the actual reported reserve ratios. As shown, the pattern of reserve ratio levels compared are similar. They increase over time toward the final recovery of total investment. However, the reserve ratio levels of IRL depreciation are more than twice as much as that of the actual level at least in the early years of the life cycle, and reserve ratio levels of RmIRL depreciation fall in between the levels of the actual and IRL depreciation. This result of higher IRL reserve level than the RmIRL reserve level is developed by the use of the weighted broad group life accounting. The broad group life is a weighted average life for a group of property with long and short life vintages. The shorter life vintages accumulate more depreciation than the longer life vintages. Consequently, more depreciation is accrued by using weighted average broad group life when the vintages have longer lives than average. In this case, the life cycle has longer-life vintages in the earlier years and shorter-life vintages in the latter years such that the overall weighted IRL accumulates more depreciation in the earlier stage which carries over the full life cycle. On the other hand, the RmIRL always looks ahead using the remaining concept which puts little weight on the past so that it can reduce the over-under-accrued effect even though it is also a weighted life.

The reserve deficiencies of the actual reserve ratio levels are significant for the accounts studied, which mean that the companies have been charging too low depreciation rate for the property. The companies will have to make up the costs of depreciation in the latter stage of the life cycle or would never recover the property.

Table 2 illustrates the statistics collected from the application of the LCD for the crossbar and analog-ESS accounts. The first column indicates the data account of a company: ILL - Illinois, MIC - Michigan, OH - Ohio, WIS - Wisconsin, and IND BEL - Indiana Bell. The second column is the area under the life cycle, i.e., total plant service (billion \$ - year), and the third column is the total additions (million \$ - year) over the life cycle. The second column divided by the third column gives the results of IRL (year) in column 6. The Sa (%) is the average net salvage and d (%) is the IRL depreciation rate in percent. The peak year and peak balance, and the final year of the life cycle are as headed. As the results shown, the depreciation rates of the crossbar account vary from 6.3% to 8.1%, and for analog, change from 6.7% to 10.1% - equivalent to the investment recovery lives of 12.5 - 17.0 years for crossbar and 10 - 14.5 years for analog. The rates differ from company to company. The average net salvages estimated are negative for crossbar and positive for analog-ESS. The crossbar life cycle is expected to end in 1991 - 1992, while, for analog-ESS, 1996 - 1999 defines the terminal period. Unlike IRL depreciation, the RmIRL has depreciation rates changing over time

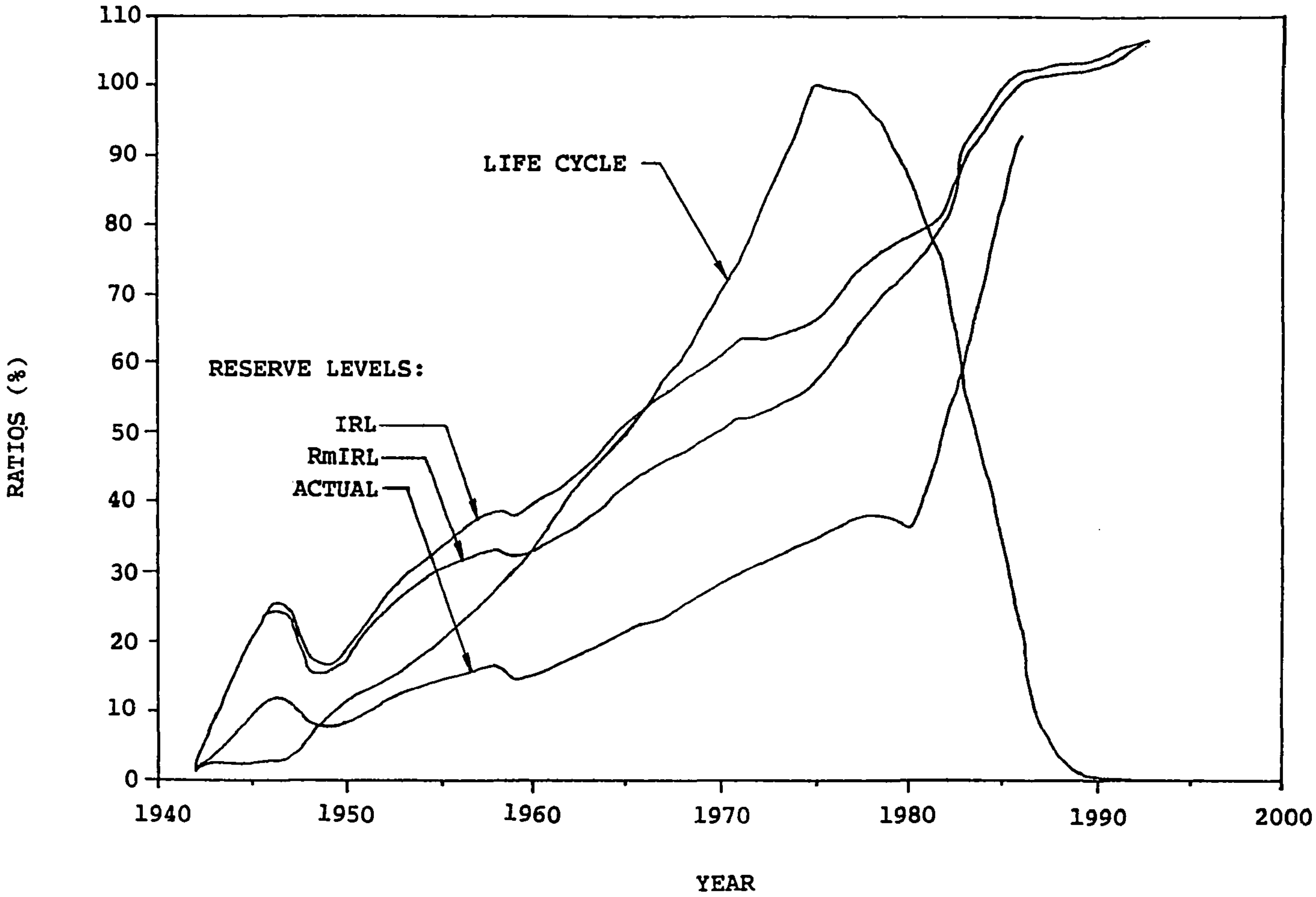

FIGURE 3. Calculated reserve requirements for Illinois Bell crossbar account

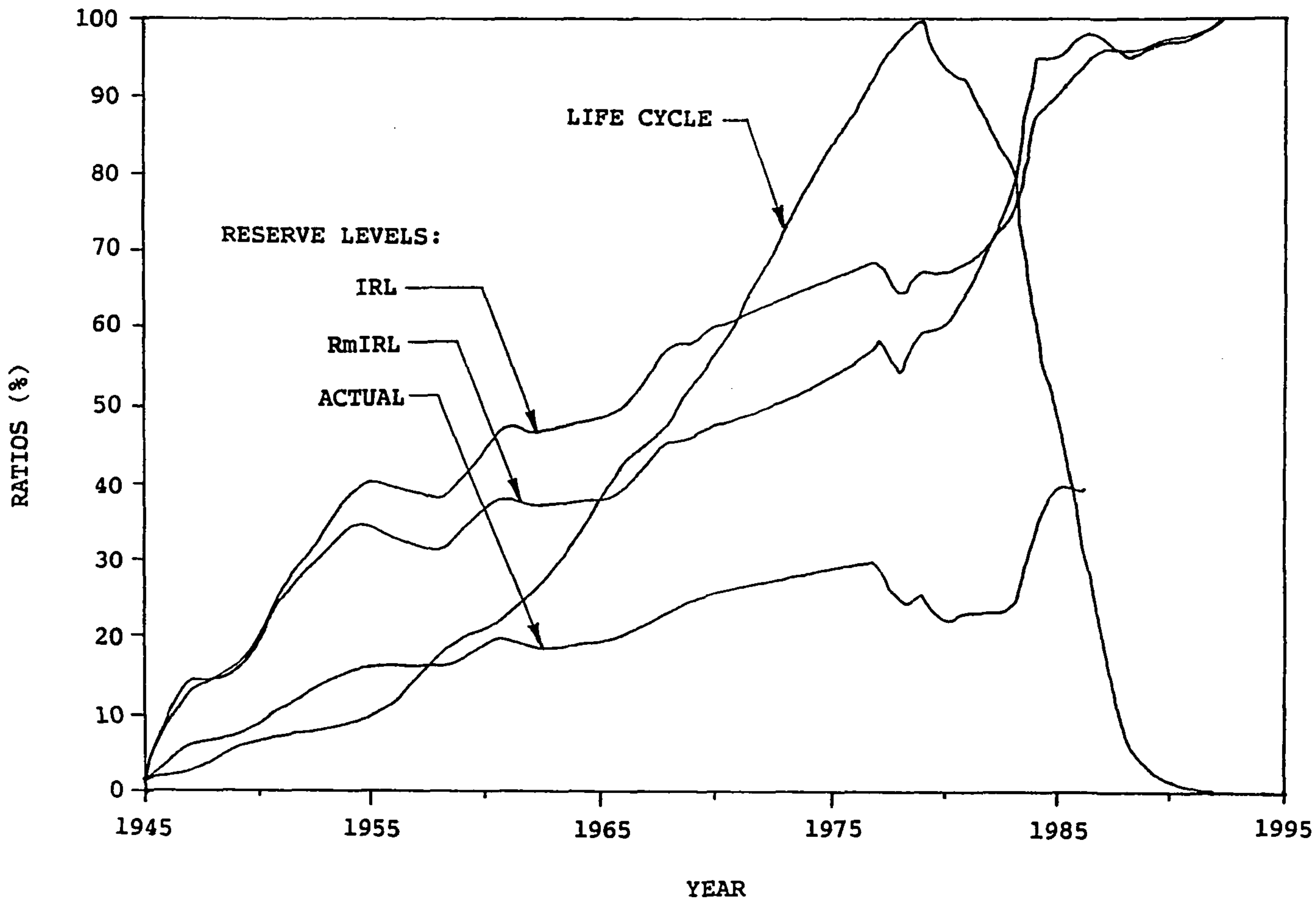

FIGURE 4. Calculated reserve requirements for Ohio Bell crossbar account

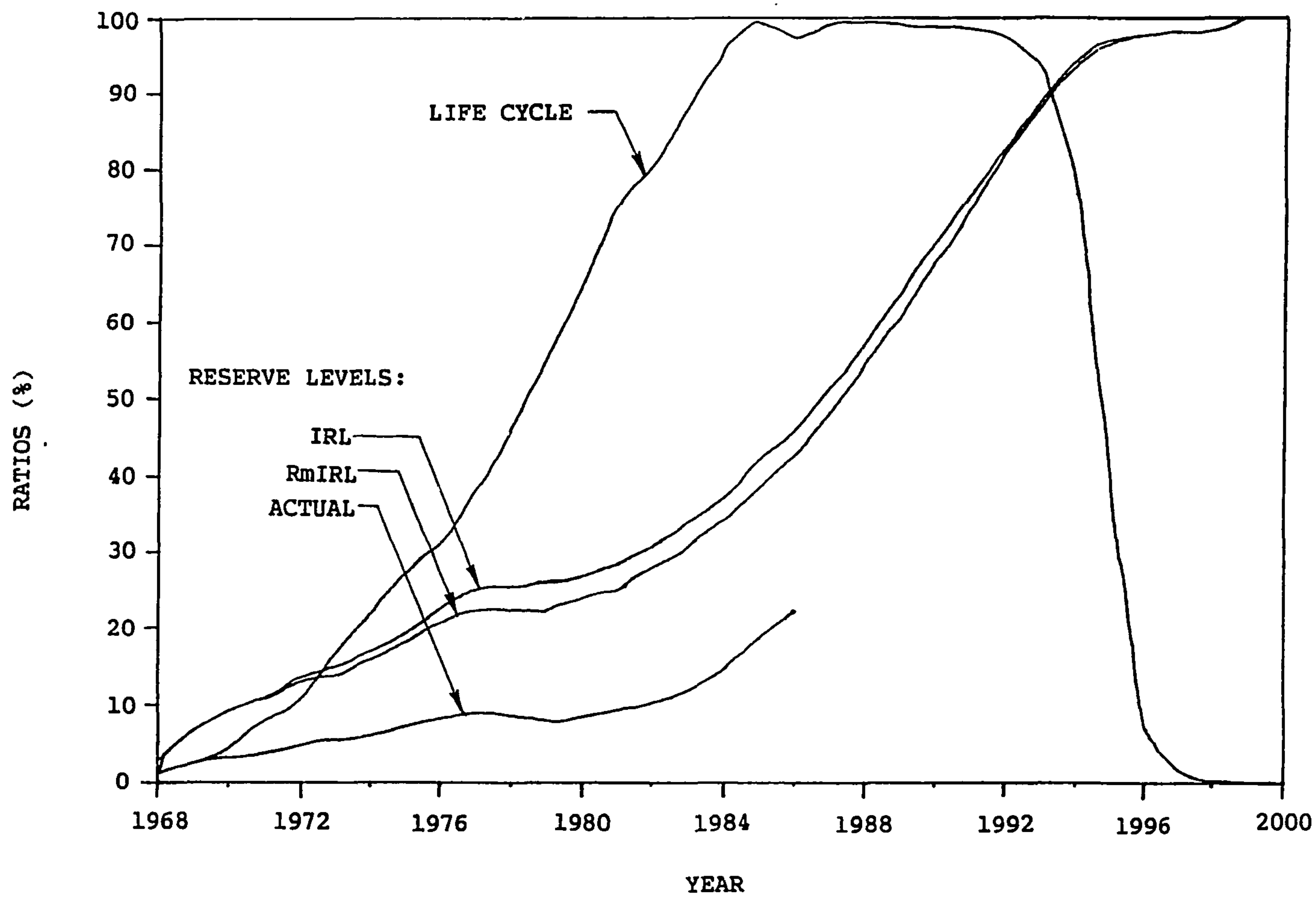

FIGURE 5. Calculated reserve requirements for Illinois Bell analog-ESS account

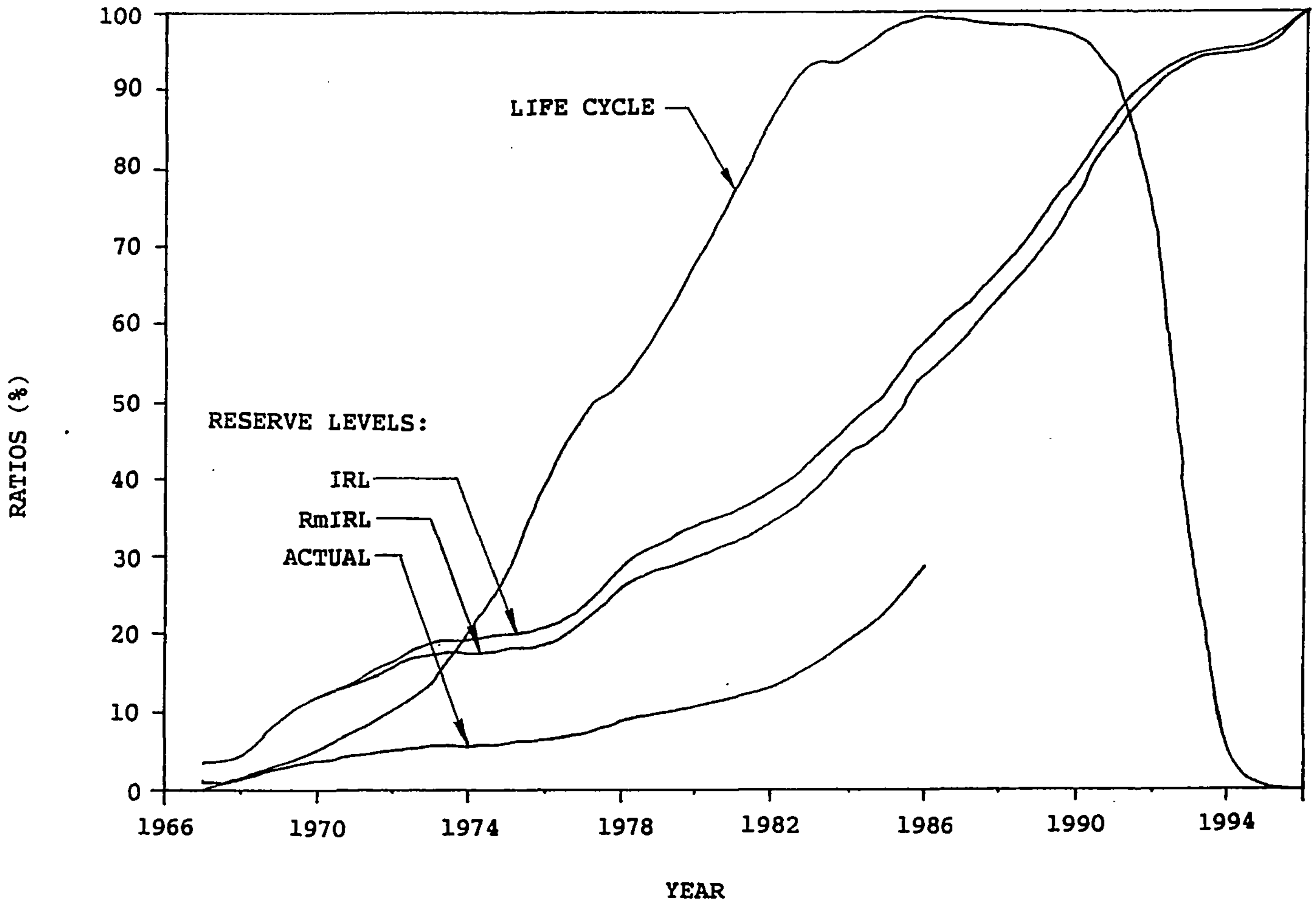

FIGURE 6. Calculated reserve requirements for Michigan Bell analog-ESS account

because of the dynamics of the remaining life concept. However, the results are much the same as those discussed above.

In summary, the life cycle depreciation model gives correct depreciation results which show the following relationship for the recovery of total investment at the end of the life cycle:

total additions = total retirements

= total depreciation charges.

For the crossbar, the actual reserve levels increase slowly during the first half of its life cycle while increase rapidly after the peak of its life cycle. In contrast, the reserve levels of the model is higher than that of the actual levels and is smoother toward its final recovery.

The results indicate that the reserve levels of the actual should have been higher than it is now and the rates were too low to adequately recover the investments. Since the crossbar life cycle is almost complete, it can be seen that the model has better indication of reserve levels for the crossbar since it charges more consistent depreciation rate throughout the life cycle. The actual reserve levels grow slowly for most stages of the life cycle and increase abruptly in the final stage of the life cycle in order to recover the investment.

In the same manner, if the forecasted life cycles and future additions are approximately accurate, the analog-ESS account is also facing the same problem of reserve deficiency because of the low prescribed depreciation rates applied to the companies actual balances.

TABLE 2. Statistics of IRL depreciation

A. Crossbar accounts

	TOTAL PLANT SERVICE	TOTAL PLANT ADDITIONS	PEAK BALANCE	PEAK YEAR	IRL	Sa (%)	d (%)	END OF LIFE CYCLE
ILL BEL	14.3Byr	854M	709M	1975	16.79	-4.9	6.25	1992
MIC BEL	8.2Byr	500M	441M	1979	16.42	-3.9	6.33	1992
OH BEL	5.4Byr	378M	300M	1979	14.33	-2.6	7.16	1992
WIS BEL	2.3Byr	158M	138M	1977	14.71	-1.1	6.87	1991
IND BEL	1.5Byr	117M	111M	1979	12.72	-2.4	8.05	1992

B. Analog-ESS accounts

	TOTAL PLANT SERVICE	TOTAL PLANT ADDITIONS	PEAK BALANCE	PEAK YEAR	IRL	Sa (%)	d (%)	END OF LIFE CYCLE
ILL BEL	16.8Byr	1181M	993M	1989	14.21	1.8	6.91	1999
MIC BEL	11.1Byr	906M	737M	1986	12.29	4.8	7.75	1996
OH BEL	10.5Byr	782M	569M	1990	13.37	4.6	7.13	1999
WIS BEL	5.2Byr	375M	309M	1989	13.91	7.1	6.68	1998
IND BEL	4.0Byr	409M	335M	1984	9.86	0.3	10.11	1996

Tables 3 and 4 summarize the comparisons of reserve levels for three points at 1976, 1980, and 1986 of the life cycles for IRL method, RmIRL method, and the actual data. The average reserve deficiencies are averaged over the three points for the reserve differences of IRL minus actual and RmIRL minus actual. As can be seen, the average reserve deficiencies also differ from company to company. For crossbar, they vary from 24% to 46% among the companies studied, and for analog, from 15% to 22%. The results show that both accounts are accumulating reserve deficiencies over time if the life forecasts are correct. The older account, crossbar account, results in more significant reserve deficiencies than the newer analog-ESS account.

2. Sensitivity analysis on the analog-ESS accounts

The second stage applied sensitivity analysis to the actual data of the analog-ESS account to develop a range of possible reserve requirements and to examine the variation with respect to life cycle forecasts. The primary data used were the analog-ESS accounts. For most of the companies, this type of switching machine has been in service for at least 18 years. Considerable experience exists so that technological forecasting techniques can be used to predict its life cycle. In addition to the five analog-ESS data accounts provided by the Ameritech Bell companies, eight others were collected from the following companies by state: Cincinnati Bell (Ohio and Kentucky State), New England Bell (Maine, Massachusetts, New Hampshire, Vermont,

Table 3. Comparisons of reserve levels for crossbar accounts

Crossbar reserve levels (%)

	1976			1980			1986			Average Reserve Deficiency (%)	
	IRL	RmIRL	ACTUAL	IRL	RmIRL	ACTUAL	IRL	RmIRL	ACTUAL	IRL	RmIRL
ILL BEL	68.9	61.3	36.1	78.1	74.3	36.6	100.8	105.2	95.8	26.4	24.1
MIC BEL	58.8	54.4	29.0	65.7	66.9	33.2	101.2	111.7	72.2	30.4	32.8
WIS BEL	64.7	55.6	26.4	75.0	74.1	31.0	103.9	130.3	96.8	29.8	35.3
OH BEL	67.6	55.9	29.0	66.5	60.0	21.6	94.1	98.4	39.3	46.0	41.5
IND BEL	49.0	38.2	19.2	52.7	51.2	11.4	95.6	105.8	88.3	26.1	25.4

Table 4. Comparisons of reserve level for analog-ESS accounts

Analog-ESS Reserve Levels (%)

	1976 IRL	1976 RmIRL	1976 Actual	1980 IRL	1980 RmIRL	1980 Actual	1986 IRL	1986 RmIRL	1986 Actual	Average Reserve Deficiency (%) IRL	Average Reserve Deficiency (%) RmIRL
ILL BEL	22.9	20.9	8.1	27.4	24.3	8.5	45.6	42.5	21.8	19.2	16.4
MIC BEL	20.2	18.2	6.1	33.8	30.0	10.6	58.0	53.8	28.7	22.2	18.9
WIS BEL	18.7	17.1	6.0	26.5	24.1	8.7	43.6	40.8	24.0	16.7	14.4
OH BEL	20.0	18.8	6.2	28.7	26.3	9.5	47.3	43.0	22.4	19.3	16.7
IND BEL	19.5	16.7	4.9	26.3	23.1	6.5	47.5	42.6	20.8	19.4	16.7

and Rhode Island State), and New York Bell (total company). The company's abbreviations are: CN - Cincinnati, NY - New York, NE - New England, and KTY - Kentucky State, OH - Ohio State, RHD - Rhode Island, VMT - Vermont, NHM - New Hampshire, MAS - Massachusetts, MAN - Maine State. The data were diversified enough coming from many states, so that they can well represent the development of the analog-ESS account in general for the telecommunication industry.

a. Procedure

The sensitivity analysis employed an upper and lower limit of the forecasted life cycles to test the possible variation of the reserve requirements calculated from the model. The upper and lower limit interval was used as the possible range of the forecasting errors of the product life cycle model. The range interval of the life cycle was developed by modifying the forecasted 95% confidential interval (95% CI) created along with the life cycle forecasted. The 95% CI is a statistical interval measuring the amount of variation around the means of a forecasted life cycle, assuming that the forecasting errors were normally distributed. It means that 95% of the forecasts will fall into the confidential interval for the given forecasting model. In this study, the 95% CI was just used as an instrument to facilitate the analyses by creating a consistent upper and lower limit around the forecasted life cycle. The data fitting to the PLC model were assumed having the required statistical inferences for the forecasts of the 95% confidential interval.

Each set of historical data were extrapolated to form three life cycles - the lower limit, the mean, and the upper limit. The reserve requirements for each data set were then calculated for these life cycles and compared with the actual reserve levels for deficiency checking.

b. Results and discussions

The results were similar to the above discussed for crossbar and analog-ESS accounts. Table 5 illustrates the statistics of the sensitivity analysis, including data as described previously. Note that the average reserve deficiency was calculated by averaging the reserve ratio differences, calculated reserve ratio minus the actual reserve ratio, over the life cycle up to 1986. The L, M, U denote the lower limit, the mean, and the upper limit forecasted life cycle, respectively. For the sensitivity analysis, the total additions, peak year and balance, and average net salvage were held constant. As shown, the analog-ESS will reach their terminal year possibly in the period 1992 - 2003. The lower limit life cycles have the shortest life cycles for the range interval; therefore, they result in the highest depreciation rates and indicate the greatest reserve deficiency for the actual reserve levels. The investment recovery life, IRL, is shorter and total service expected is less for the shorter life cycle. As mentioned earlier, the shorter the life cycle span, the higher the reserve requirements developed and the shorter the period of recovery reached. On the other hand, the upper limit life cycles show the reverse situation.

Table 5. Statistics of IRL depreciation - sensitivity analysis of analog-ESS accounts

		TOTAL PLANT SERVICE	TOTAL PLANT ADDITIONS	PEAK BALANCE	PEAK YEAR	IRL	Sa (%)	d (%)	AVERAGE DEFICIENCY (%) /YR	END OF LIFE CYCLE
ILL BELL	L	12.5BYR	1181M	993M	1985	10.61	1.8	9.26	23.6	1996
	M	16.8BYR				14.21		6.91	14.6	1999
	U	18.4BYR				15.61		6.29	12.3	2003
MIC BELL	L	8.8BYR	906M	740M	1986	9.68	4.8	9.84	24.2	1993
	M	11.1BYR				12.29		7.75	16.5	1996
	U	13.9BYR				15.40		6.19	10.7	2002
OH BELL	L	7.7BYR	782M	570M	1990	9.89	4.6	9.65	21.6	1996
	M	10.3BYR				13.20		7.23	13.7	2000
	U	12.2BYR				15.59		6.12	10.0	2005
WIS BELL	L	3.9BYR	375M	308M	1988	10.52	7.1	8.83	21.6	1995
	M	5.2BYR				13.91		6.68	13.4	1998
	U	6.5BYR				17.34		5.36	8.5	2003
IND BELL	L	3.3BYR	409M	335M	1983	8.12	0.3	12.27	29.6	1992
	M	4.0BYR				9.86		10.11	22.5	1996
	U	5.3BYR				12.86		7.75	14.8	2000
CN BELL	L	0.23BYR	27M	25M	1984	8.58	9.5	10.55	31.4	1993
KTY	M	0.27BYR				9.96		9.08	25.4	1995
	U	0.35BYR				13.05		6.93	16.6	1999
CN BELL	L	1.4BYR	144M	121M	1984	9.38	7.7	9.84	32.6	1993
OH	M	1.5BYR				10.50		8.79	27.6	1994
	U	1.8BYR				12.37		7.46	21.4	1997

Table 5 (continued)

		TOTAL PLANT SERVICE	TOTAL PLANT ADDITIONS	PEAK BALANCE	PEAK YEAR	IRL	Sa (%)	d (%)	AVERAGE DEFICIENCY (%) /YR	END OF LIFE CYCLE
NY BELL	L	18.6BYR	2135M	2079M	1985	8.72	5.8	10.80	25.7	1993
TOTAL	M	21.4BYR				10.02		9.40	21.1	1995
	U	27.8BYR				13.00		7.25	13.9	1998
NE BELL	L	1.0BYR	101M	79M	1984	9.73	1.3	10.15	29.0	1996
RHD	M	1.3BYR				12.63		7.82	19.8	2000
	U	1.5BYR				15.13		6.53	14.7	2004
NE BELL	L	0.42BYR	56M	47M	1984	7.43	0.2	13.44	24.8	1993
VMT	M	0.48BYR				8.59		11.63	20.0	1994
	U	0.59BYR				10.42		9.58	14.6	1996
NE BELL	L	0.59BYR	79M	70M	1984	7.45	0.8	13.31	31.6	1992
NHM	M	0.66BYR				8.38		11.83	27.0	1994
	U	0.82BYR				10.38		9.56	19.9	1996
NE BELL	L	5.7BYR	699M	589M	1984	8.15	1.3	12.11	34.0	1993
MAS	M	6.5BYR				9.27		10.64	28.6	1995
	U	9.2BYR				13.20		7.48	16.8	1999
NE BELL	L	0.40BYR	63M	49M	1986	6.45	1.6	15.26	33.2	1992
MAN	M	0.48BYR				7.64		12.89	26.5	1994
	U	0.61BYR				9.74		10.11	18.6	1998

In general, the results are summarized as below.

	Range Interval	
	lower limit	upper limit
Investment recovery lives	8 - 10 years	10 - 15 years
Depreciation rates	10% - 13%	6% - 9%
Average reserve deficiencies	22% - 32%	10% - 18%
End of the life cycle forecasted	1992 - 1996	1996 - 2003

Note that the results differ from company to company. The depreciation rates for the analog-ESS accounts should be higher than the rates suggesting for the upper limit life cycles in order to avoid reserve deficiencies. Whereas, the depreciation rates should not be charged higher than the rates suggesting for the lower life cycles to reduce the chance of over-depreciation. In this results, the historical depreciation rates are even lower than the rates indicated for the upper limit life cycles. For all the data examined, the average reserve deficiencies vary from 10% to 18% for the upper limit life cycles up to 1986 and from 22% to 32% for lower limit life cycles. It indicates that, in all cases, the historical depreciation rates are too low to properly recover the investment of the analog-ESS. The IRL depreciation results of the analog-ESS accounts are shown in the Appendix for the upper limit life cycles.

Graphs 7 to 11 also illustrate examples of reserve requirement analyses for several companies with IRL method or RmIRL method. Note, as shown in the graphs, the shortest (lower limit) life cycles have the fast recovery of reserve pattern while the longest (upper limit) life cycles have the slowest recovery pattern. The mean reserve requirements and mean forecasted life cycle stay in between the upper's and the lower's. The recovery pattern is consistent with the life cycle pattern and span for the life cycle depreciation model. Also, the range of reserve requirements in between the lower and upper limit was increasing over time from 5% to 35%.

In summary, two groups of reserve patterns were observed from the analysis: one with fluctuations in the earlier stage of the life cycle and one without fluctuations. The fluctuations are pattern of reserve ratio levels moving up and down by the influences of the life cycle growth pattern as well as the retirement activities over time. They are summarized as follows:

Reserve requirement pattern

Fluctuations	No fluctuations
New England Bell	Michigan Bell
* Rhode Island State	* Michigan State
Maine State	Ohio Bell
New Hampshire State	* Ohio State
Indiana Bell	Wisconsin Bell
Indiana State	Wisconsin State
Cincinnati Bell	Illinois Bell
* Kentucky State	Illinois State
	Cincinnati Bell

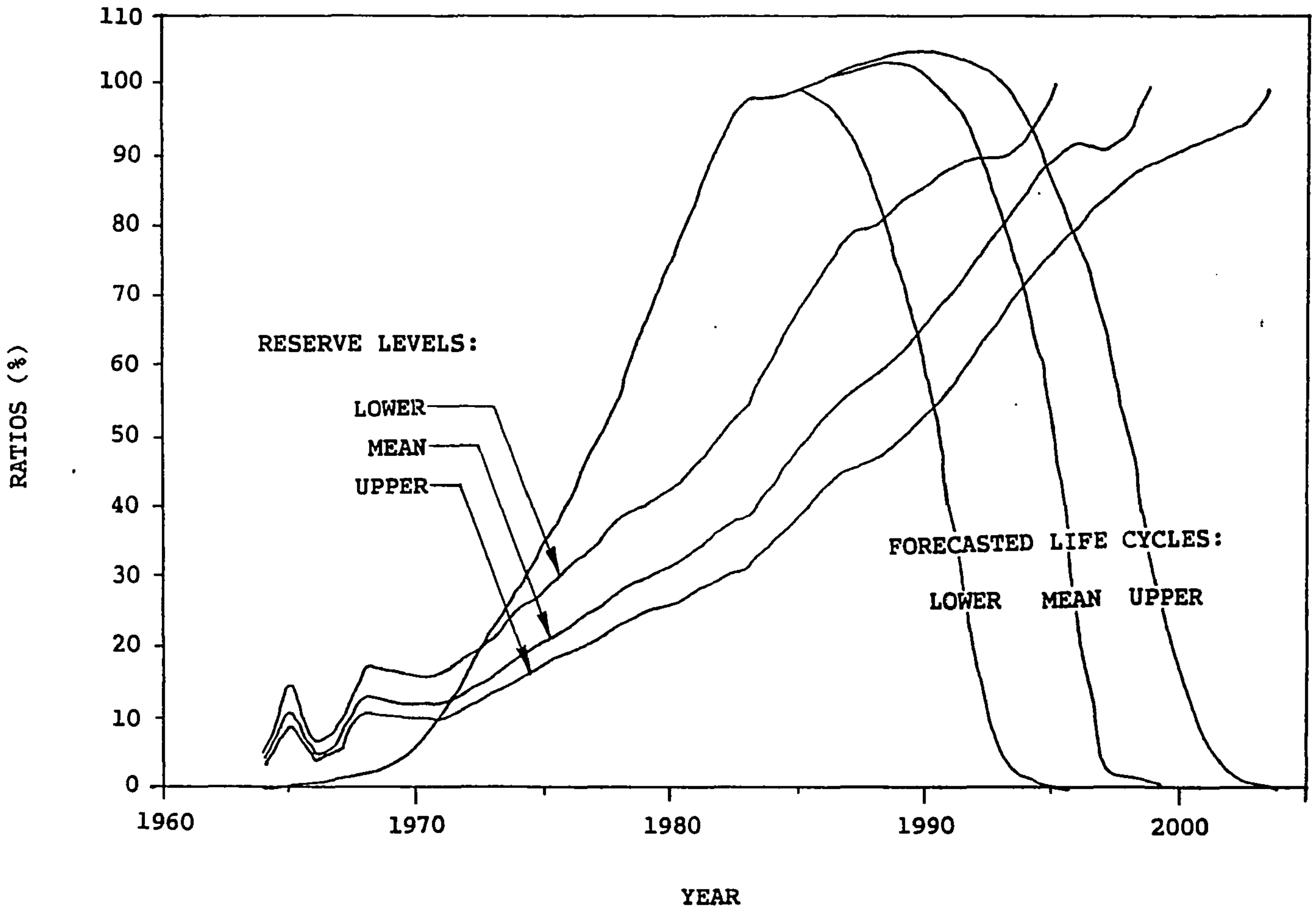

FIGURE 7. Sensitivity analysis of calculated reserve requirements for Ohio Bell analog-ESS account - IRL method

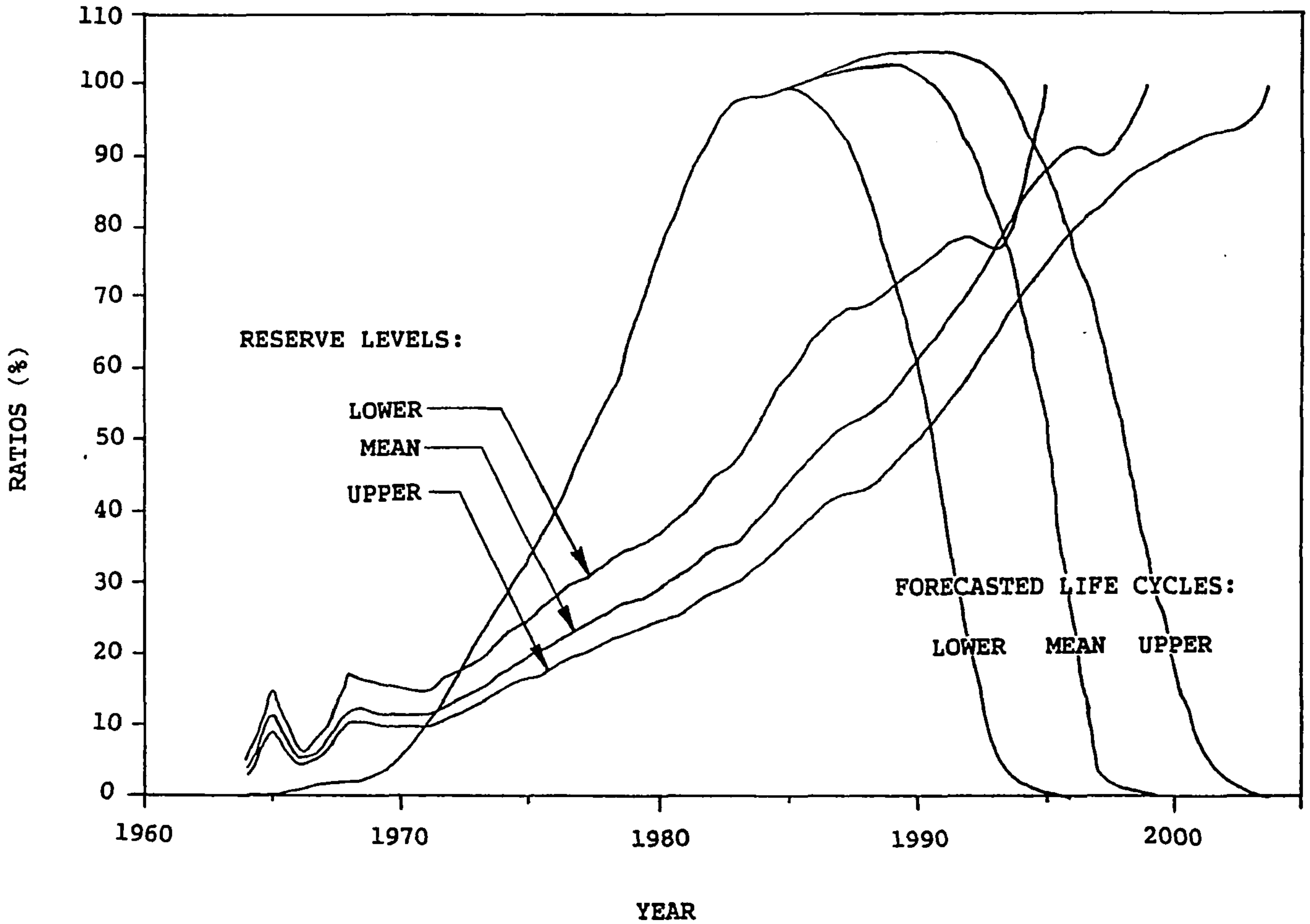

FIGURE 8. Sensitivity analysis of calculated reserve requirements for Ohio Bell analog-ESS account - RmIRL method

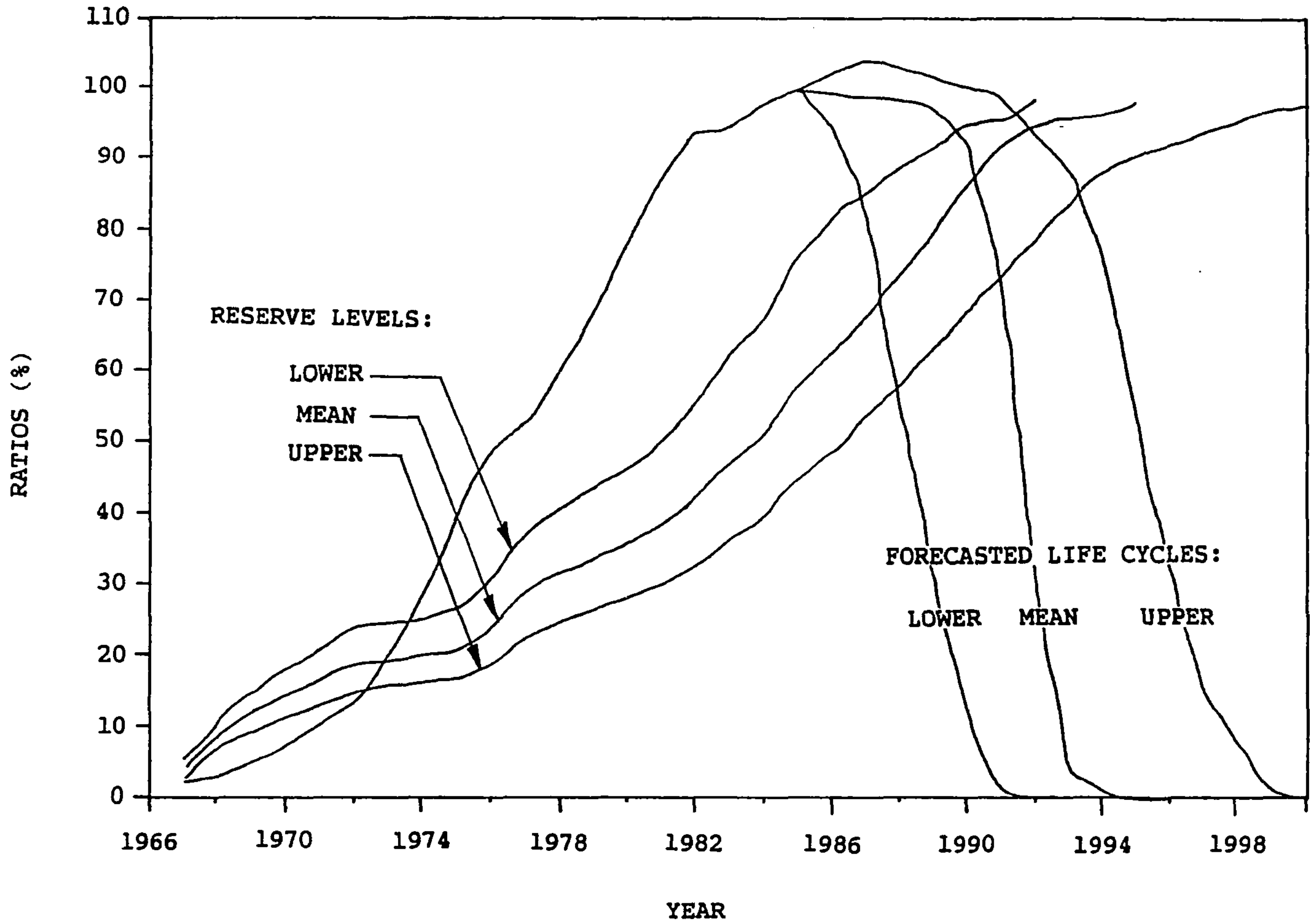

FIGURE 9. Sensitivity analysis of calculated reserve requirements for Michigan Bell analog-ESS account - IRL method

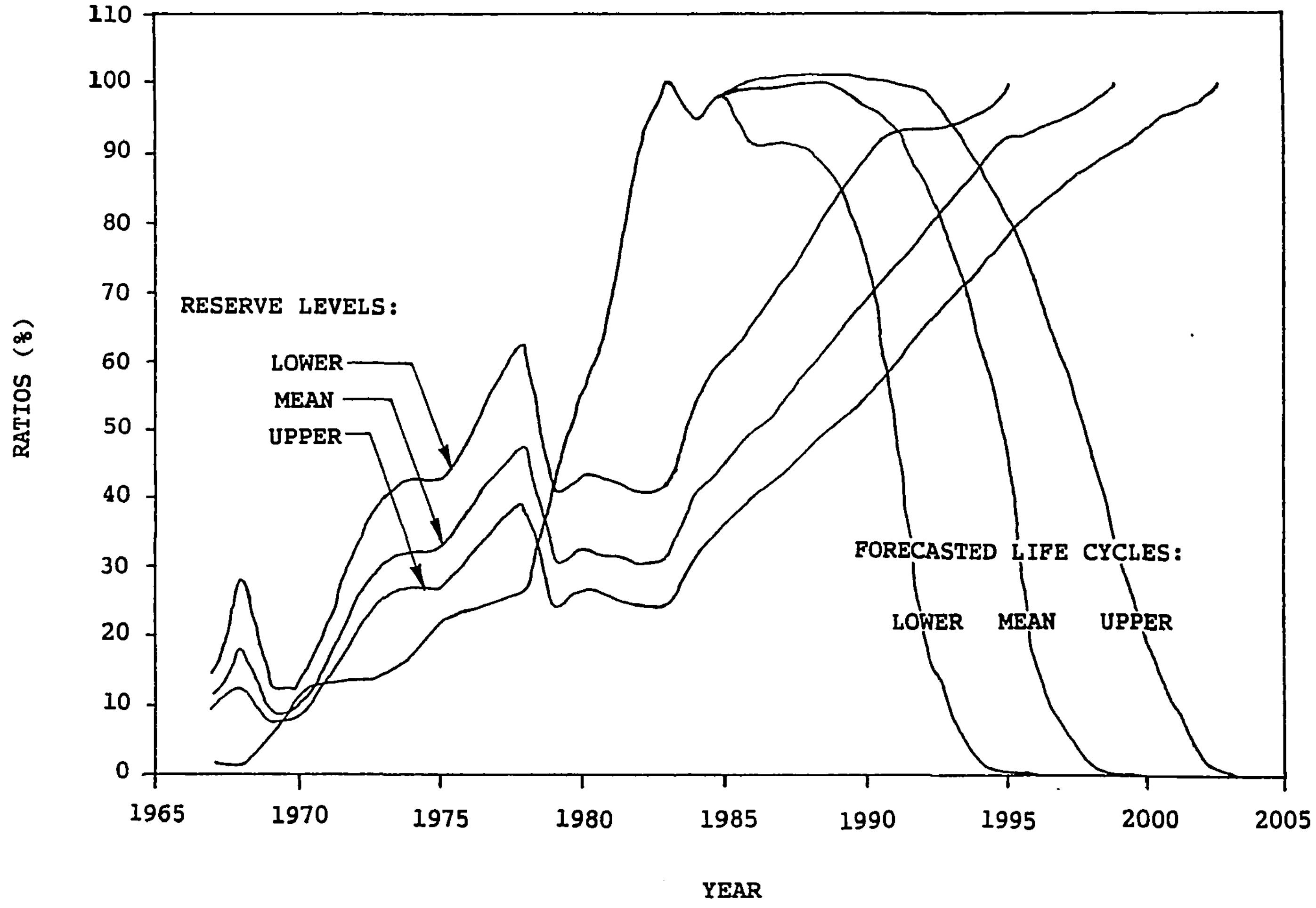

FIGURE 10. Sensitivity analysis of calculated reserve requirements for New England Bell Rhode Island state analog-ESS account - IRL method

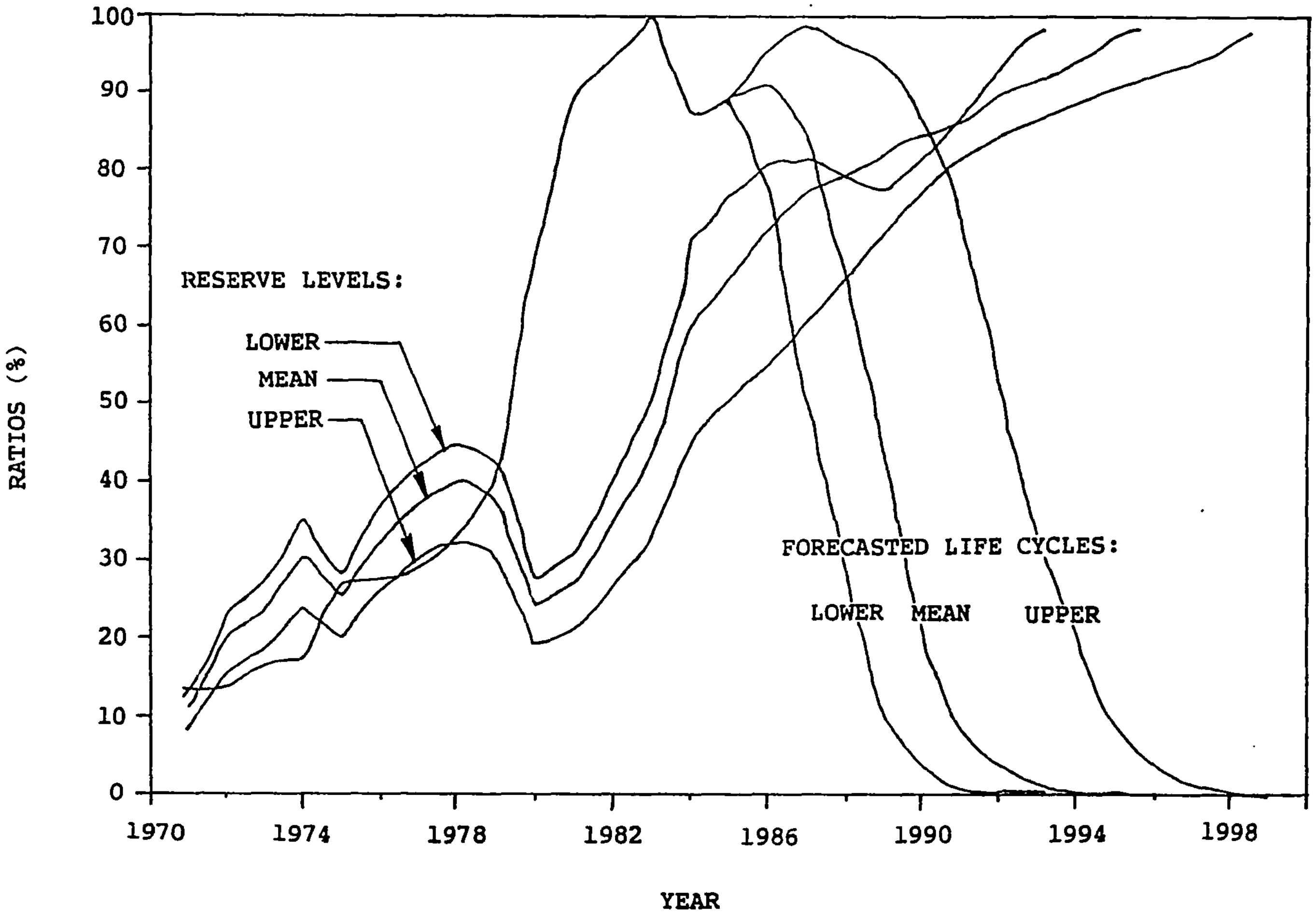

FIGURE 11. Sensitivity analysis of calculated reserve requirements for Cincinnati Bell Kentucky state analog-ESS account - RmIRL method

Ohio State

New England Bell

Vermont State

Massachusetts State

New York Bell

Total company

Note the symbol * denotes that the graph is presented for illustration. The group with reserve pattern fluctuations indicate that the retirements of the life cycle vintages were highly concentrated, i.e., with the range of ages at retirement very narrow. The concentrated retirements around the mean of the life cycle vintages caused the oscillations of the reserve pattern. Whereas, with the life cycles having low modal frequency of retirement pattern, the retirements occurred more nearly uniform over the years which resulted in smoother reserve requirement patterns (15).

Table 6 shows the reserve levels for each account at selected points in the life cycle for the lower and upper limit range. The reserve level range, denoted by R, is the difference between the lower and the upper limit reserve requirements. It can be seen that the range increased over time. The forecasted ranges of the life cycles at the terminal year vary from 4 to 9 years. The RmIRL remaining life depreciation showed the similar results as the IRL's. However, its reserve requirements are lower than that of the IRL depreciation.

Table 6. Sensitivity analysis of analog-ESS reserve requirements

		YEAR 1975	1878	1981	1984	1987	1990	ENDING YEAR
ILL BEL	L	25.9	35.1	39.6	52.2	72.9	91.9	1996
	U	17.5	23.0	25.3	33.1	45.2	61.9	2003
	R	8.4	12.1	14.3	19.1	27.7	30.0	7
MIC BEL	L	25.7	36.7	46.3	62.1	81.3	91.7	1993
	U	16.0	22.6	27.8	36.4	49.2	62.6	2002
	R	9.7	14.1	18.5	25.7	32.1	28.1	9
OH BELL	L	25.0	34.0	43.0	54.0	74.3	83.5	1996
	U	15.5	20.5	25.7	31.0	42.8	49.8	2005
	R	9.5	13.5	17.3	23.0	31.5	33.7	9
WIS BEL	L	24.2	27.6	34.4	47.8	67.3	85.2	1995
	U	14.2	16.1	17.5	25.2	37.0	51.0	2003
	R	10.0	11.5	16.9	22.6	30.3	34.2	8
IND BEL	L	37.6	33.1	43.8	70.1	88.6	94.5	1992
	U	23.1	20.3	25.2	41.6	53.3	70.9	2000
	R	14.5	12.8	18.6	28.5	35.3	23.6	8
CN BELL	L	38.3	47.5	51.1	64.0	89.3	94.8	1993
OH	U	28.9	35.4	37.5	46.4	66.0	79.4	1997
	R	9.4	12.1	13.6	17.6	23.3	15.4	4
CN BELL	L	37.9	50.2	35.9	51.2	85.0	88.1	1993
KTY	U	24.7	32.8	22.2	32.0	55.7	73.0	1999
	R	13.2	17.4	13.7	19.2	29.3	15.1	6

Table 6 (continued)

		YEAR 1975	1878	1981	1984	1987	1990	ENDING YEAR
NY BELL	L	29.4	39.2	50.1	64.0	86.4	87.7	1993
TOTAL	U	19.4	25.5	31.4	39.8	58.0	75.8	1998
	R	10.0	13.7	18.7	24.2	28.4	11.9	5
NE BELL	L	36.7	49.3	56.4	65.3	98.6	113.2	1993
MAS	U	22.3	29.8	33.2	37.3	57.6	71.2	1999
	R	14.4	19.5	23.2	28.0	41.0	42.0	6
NE BELL	L	42.6	56.0	43.1	41.8	64.9	83.3	1996
RHD	U	27.1	35.4	26.6	24.3	40.4	50.6	2004
	R	15.5	20.6	16.5	17.5	24.5	32.7	8
NE BELL	L	33.0	30.0	39.6	55.4	95.0	99.5	1992
NHM	U	23.7	21.4	28.3	38.0	67.1	79.5	1996
	R	9.3	8.6	11.3	17.4	27.9	20.0	4
NE BELL	L	-	7.1	31.3	50.6	83.3	89.9	1993
VMT	U	-	5.0	22.1	34.6	60.2	75.6	1996
	R	-	2.1	9.2	16.0	23.1	14.3	3
NE BELL	L	7.6	22.2	35.9	60.1	95.4	106.5	1992
MAN	U	5.1	14.7	23.7	36.9	61.1	73.6	1998
	R	2.5	7.5	12.2	23.2	34.3	32.9	6

As discussed above, it can be seen that the actual reserve levels are significantly deficient over time even for the longest (upper limit) forecasted life cycles. This shows that the prescription rates for the telephone companies were too low to adequately recover the investment of the analog-ESS.

3. Reserve Requirement Forecasts of the Digital-ESS Accounts

The third stage involved the forecasts of the digital reserve requirements. The digital-ESS is a relatively new technology compared to that of crossbar and analog-ESS. It has been installed for several years and is now near the market leader stage in the life cycle. The data for this technology were collected from Illinois Bell, Michigan Bell, Ohio Bell, Cincinnati Bell (Ohio State), and Pacific Bell. The required analysis inputs of the peak date and balance and the future part of the life cycle were forecasted by the individual companies. The same procedure as used in the previous study stages was run to develop a range of reserve requirements for digital-ESS technology.

Table 7 illustrates the resulting statistics of the IRL depreciation and Figures 12 and 14 show examples of the reserve analysis. As shown, the reserve deficiencies are in the range of 1% - 8% which is not large comparing with those of analog analysis. For the newly developed digital account, there is no strong evidence showing that the depreciation rates are not adequate. In summary, they are indicated as below:

	Range Interval	
	lower limit	upper limit
Investment recovery lives	8 - 10 years	13 - 15 years
Depreciation rates	9% - 12%	5% - 8%
Average reserve deficiencies	5% - 8%	1% - 5%
End of the life cycle forecasted	2003 - 2004	2008 - 2010

The reserve requirements also vary from company to company indicating no general form. Similarly, the analysis indicates that the reserve requirements are sensitive to the life cycle pattern and span, which makes the life cycle forecasting more significant. In all cases, the longest forecasted life cycles have higher calculated reserve levels than the actual levels. Like Table 6, Table 8 shows the reserve levels and their ranges at selected points in the life cycle for each account.

The results of this stage were similar to those of the analog-ESS; while, the years the life cycle ended are different and the reserve deficiencies for the actual data were not as large as those discussed above for the crossbar and analog-ESS accounts.

C. Application Considerations

The use of the LCD requires corner for certain problem areas. They are as follows:

1. The data must be consistent, maintaining the correct relationship of balances, additions, retirements. A step in the data analysis which determines and adjusts for discrepancies is desirable.

Table 7. Statistics of IRL depreciation - sensitivity analysis of digital-ESS accounts

		TOTAL PLANT SERVICE	TOTAL PLANT ADDITIONS	PEAK BALANCE	PEAK YEAR	IRL	Sa (%)	d (%)	AVERAGE DEFICIENCY (%) /YR	END OF LIFE CYCLE
ILL BELL	L	18.6BYR	2288M	1466M	1998	8.11	0.0	12.32	14.1	2009
	M	24.7BYR		1645M	1999	10.84		9.24	8.7	2012
	U	31.3BYR		1717M	2000	13.69		7.30	5.3	2017
MIC BELL	L	10.9BYR	1251M	1042M	1996	8.74	22.6	8.85	6.1	2003
	M	14.2BYR		1218M	1997	11.38		6.80	3.5	2006
	U	17.4BYR		1228M	1997	13.90		5.56	1.9	2010
OH BELL	L	7.6BYR	864M	663M	1994	8.82	0.0	11.34	5.7	2004
	M	9.5BYR		751M	1995	11.03		9.07	3.4	2006
	U	11.5BUR		784M	1996	13.34		7.50	1.7	2009
CIN BELL OH	L	1.8BYR	171M	127M	1997	10.27	0.0	8.83	5.7	2004
	M	2.2BYR		138M	1997	12.86		6.68	3.4	2006
	U	2.8BYR		149M	1997	15.92		5.36	1.7	2010
PAC BELL	L	22.1BYR	2383M	1809M	1996	9.29	0.0	10.77	7.5	2004
	M	27.9BYR		2150M	1997	11.71		8.54	4.3	2006
	U	32.2BYR		2158M	1998	13.53		7.39	2.7	2008

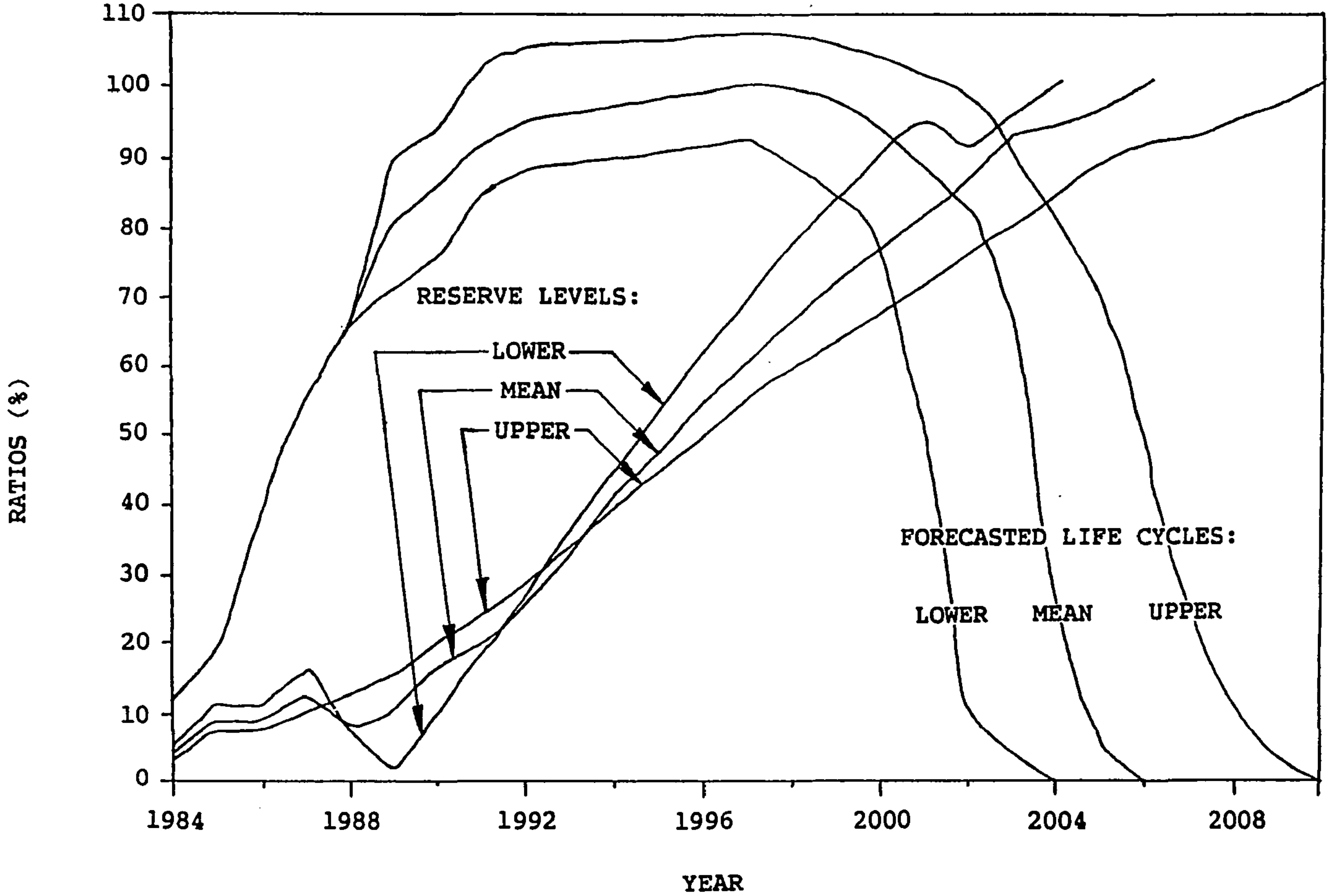

FIGURE 12. Sensitivity analysis of calculated reserve requirements for Cincinnati Bell digital-ESS account - IRL method

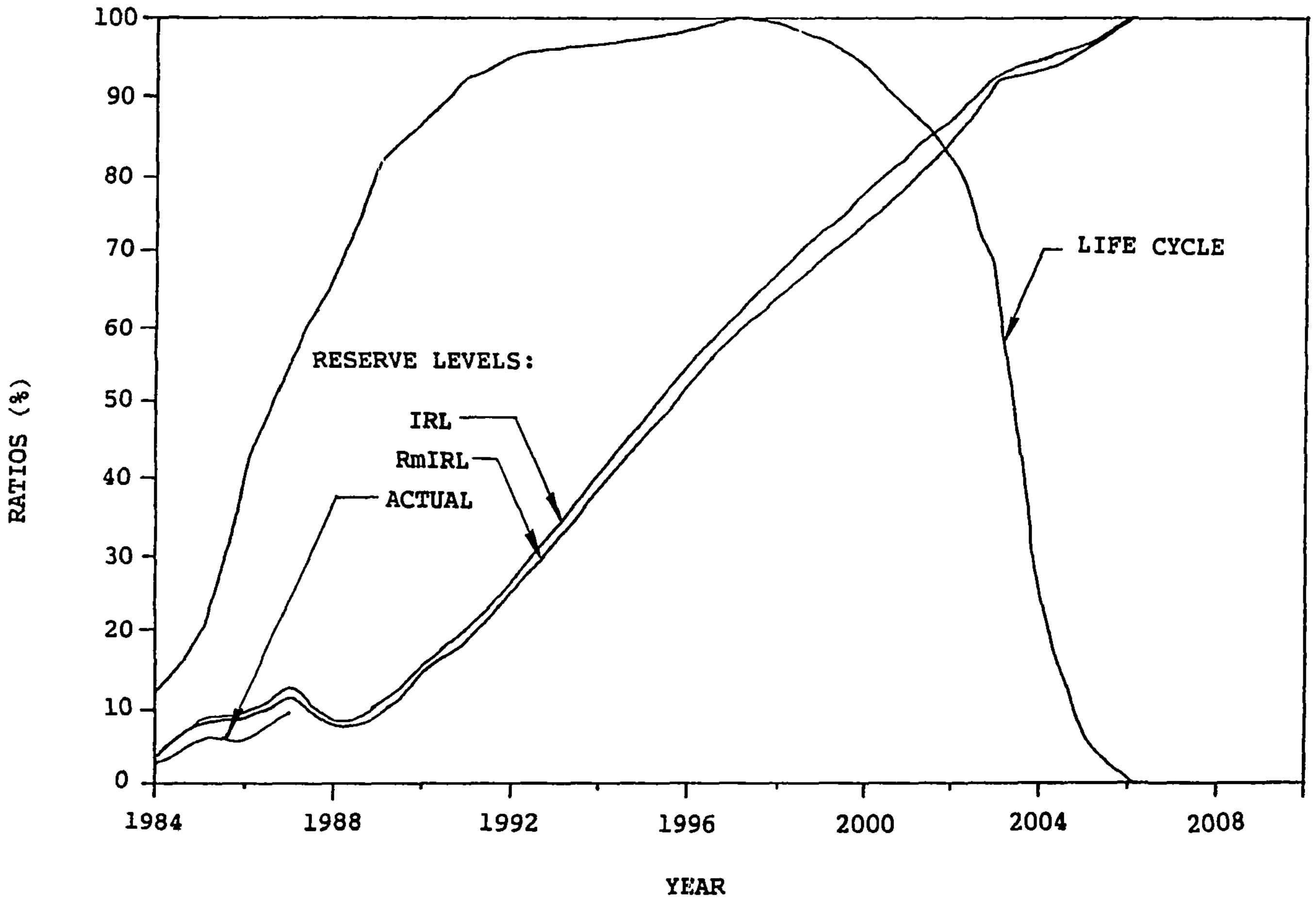

FIGURE 13. Calculated reserve requirements for Cincinnati Bell digital-ESS account

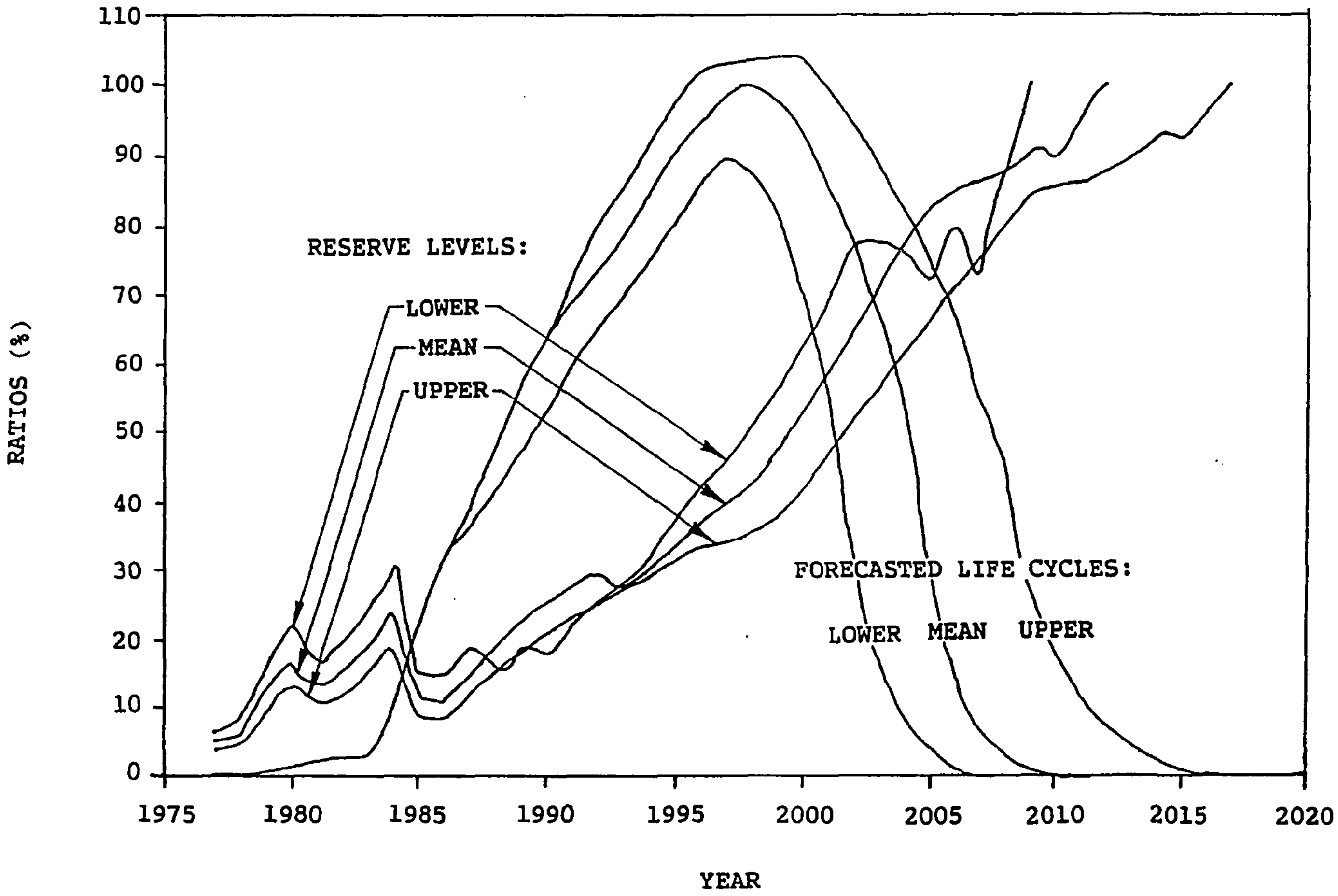

FIGURE 14. Sensitivity analysis of calculated reserve requirements for Illinois Bell digital-ESS account - RmIRL method

Table 8. Sensitivity analysis of digital-ESS reserve requirements

				YEAR			ENDING
		1985	1888	1991	1994	1997	YEAR
ILL BEL	L	18.7	20.4	28.8	40.1	54.3	2009
	U	10.2	16.7	25.7	33.4	38.4	2017
	R	8.5	3.7	3.1	6.7	15.9	8
MIC BEL	L	10.4	13.2	23.1	34.1	54.2	2003
	U	6.5	11.1	19.1	27.1	40.6	2010
	R	3.9	2.1	4.0	7.0	13.6	7
OH BELL	L	8.0	11.7	25.3	43.9	67.8	2004
	U	5.2	14.7	26.2	37.3	54.3	2009
	R	2.8	-3.0	-0.9	6.6	13.5	5
CIN BEL	L	11.2	7.3	18.2	45.1	70.7	2004
	U	7.2	12.8	23.7	39.4	55.0	2010
	R	4.0	-5.5	-5.5	5.7	15.7	6
PAC BEL	L	17.1	24.5	37.5	49.4	73.2	2004
	U	10.6	17.5	30.4	42.0	57.9	2008
	R	6.5	7.0	7.1	7.4	15.3	4

2. The life cycle forecasting is only an approximation process. Judgement should be employed to adjust the predicted life cycle from the forecasting model in order to increase the accuracy of forecasting. However, the life cycles used in this study were not adjusted but were used as forecasted by the PLC model.
3. The estimation of future additions is very important since it affects the depreciation rate calculated from the investment recovery life (IRL). If the estimation is made correctly, it will result in good estimates of the mortality pattern of property and hence, increase the accuracy of life estimation. In this study, part of the future additions and retirements were estimated by the industry. Others were estimated on the basis of addition patterns assumed.
4. The average net salvage needs to be the weighted average of the past actual and future estimated net salvage provided.
5. In practice, adjustments in and out of property account were not accounted for in the calculation of depreciation rates and reserve accumulation. Thus, the IRL rate calculated included the amount of adjustments which changed the amount of total original investment. Adjustments are made for several reasons, for example, transfers in & out, sales, acquisitions, reclassification, reuse, scrap, or error corrections of previous records. Many of these are

obviously not considered as investments in the services provided. However, some may be considered as new investments to provide regular service to the customer. If so, they should be accounted for as additions or retirements to be recovered by the rates calculated.

VIII. CONCLUSIONS

This study has presented a potential depreciation tool for utility companies, especially for those with property subject to rapid technology advancement. The life cycle depreciation (LCD) model was presented and compared with the conventional depreciation models. A validation of the model was accomplished by the simulation of life cycles using Iowa curves. Finally, the effects of life estimation on reserve requirements were demonstrated by applying the life cycle depreciation model to the actual data from the telecommunication industry.

A. The LCD Model

The life cycle depreciation model is a modified form of the traditional depreciation concept in which life forecasts are based primarily on technological forecasting techniques. Four steps are required for the model: Data Compilation, life cycle forecasts, life estimation, and depreciation calculation. Among the four steps, the forecast of the life cycle is the key to the adequacy of capital recovery. A depreciation rate can be computed either by using the investment recovery life (IRL) or the remaining investment recovery life (RmIRL). These lives are developed from the forecasts of the life cycle. The IRL is comparable to the whole life used in conventional broad group whole life depreciation. Similarly, the RmIRL is comparable to the direct weighted average remaining life used in broad group, remaining life depreciation.

B. The Comparisons and Simulation

It was shown by a comparison with the conventional depreciation models that the life cycle model gives the same results as the broad group depreciation approach and is close to those of vintage group depreciation. Because of the likely better life forecasts coming from life cycle analyses, the LCD is better than the conventional broad group approach and perhaps better than the vintage procedure as used. It was illustrated that there is not much difference in the life estimation concept between the life cycle depreciation model and the conventional model except that the approach is different: The LCD uses forecasting techniques while the conventional uses historical curve matching and extrapolation and subjective incorporation of possible future retirement activity. The life cycle depreciation model is a mortality analysis concept but incorporates forecasting techniques in the life estimation process.

The simulation results also show that the IRL depreciation model is approximately equivalent to the conventional whole life model if both have the same forecasting capability. In the case of IRL and vintage accounting it was found that the account reserve levels were the same no matter what mortality patterns were assumed for each vintage as long as the average service lives were the same throughout.

C. The Application

The applications of the LCD model to the actual property data collected from industry demonstrated that the life cycle depreciation is reliable if the forecasts are adequate. The results indicated that the prescribed depreciation rates for telephone companies were too low to properly recover the investments. All the companies experienced reserve deficiencies for their actually reported reserve levels even when the longest (more conservative) life cycles forecasted were applied to the model. This concludes that remedial procedure should be taken in order to correct the problem of reserve deficiency. The lives of utility properties, especially those associated with rapid technology change, should be re-studied carefully to ensure their adequacy. This study suggests that the LCD is a potential model to use.

D. Recommendations for Use of the LCD Model

The presentation of the life cycle depreciation model has shown this model to be not only theoretically sound but also practically applicable. However, how to forecast the future precisely remains challenge to the utility depreciation practitioners. Several recommendations are made as follows:

1. A data querying step is necessary for the LCD model in order to keep the data consistency and adequacy. Balances, additions, and retirements should be in agreement over time according to their relationships in the life cycle.

2. Since the life cycle forecasts (balances, additions, and retirements) are crucial to the LCD application, forecasting techniques should be employed prudently.
3. A sensitivity analysis, such as the lower and upper limit range described in this study, is suggested to secure a possible range of depreciation results.
4. The life cycle forecasts should be evaluated from time to time to adjust depreciation deviation resulting from forecasting errors.

The life cycle depreciation model relies heavily on forecasts of future. Thus, future researches are recommended to test the existing forecasting models and to explore more reliable forecasting techniques.

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X. ACKNOWLEDGMENT

Thanks to my parents, wife, professors, friends, sponsors, and all walks of life.

XI. APPENDIX. ACTUAL AND FORECASTED DATA ACCOUNTS USED IN THIS STUDY

COMPANY : iLLINOIS bELL
STATE : iLLINOIS
ACCOUNT : 221-47C
CATEGORY : COE-CROSSBAR

Modal Year: 1975
Modal BAL : 710000000

Total Plant Service = 14340474038
Total Plant Invstmnts = 946501991
Invstmnt Recovry Life = 15.151

	Past	Future
Gross Salv=	0.0426	0.0250
C.O.R =	0.0823	0.0950

Average net salvage = -0.0448
Depreciation rate = 0.0690

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciation Expenses	Depreciation Reserve	Reserve Ratios(%)
1942	15101806	15145813	44007		1840	3559	520680	474954	3.145
1943	15548522	472729	26013		1087	2140	1056761	1504649	9.677
1944	15633639	111937	26820		1121	2169	1075098	2551879	16.323
1945	15793517	182133	22255		930	1800	1083545	3612298	22.872
1946	17063600	1278944	8861		2727	2407	1132847	4736604	27.759
1947	22330020	5330706	64286		46372	16229	1358212	6060674	27.141
1948	43952891	21814084	191213		119734	20946	2285301	8253549	18.778
1949	66068779	22273621	157733		91555	27934	3793324	11952761	18.091
1950	82907200	17043321	204900		77022	28741	5136390	16932533	20.423
1951	89756784	7119048	291042	21578	134722	45238	5953105	22705657	25.297
1952	102133210	13825379	496688	-952265	257470	70108	6615978	28060044	27.474
1953	112030640	10573735	435543	-240762	194350	74863	7383936	34887162	31.141
1954	126084672	14508269	459974	5737	190578	63154	8209734	42770083	33.922
1955	142793908	17375961	500524	-166201	144896	88594	9270389	51430049	36.017
1956	158734991	17397756	502376	-954297	153775	77875	10396106	60445382	38.079
1957	176686306	19420908	775954	-693639	153332	79014	11564647	70614754	39.966
1958	195843363	21823129	1704563	-961509	122447	141921	12844069	80773277	41.244
1959	210988589	24698776	8801089	-752461	192362	100246	14026742	85338585	40.447
1960	232923746	24075154	1141254	-998743	189924	139029	15305198	98554681	42.312
1961	258877170	28101892	903068	-1245400	284363	147341	16956300	113499535	43.843
1962	289892424	32354884	527178	-812452	53597	145743	18920464	130988223	45.185
1963	312285344	24608595	925842	-1289833	108901	163707	20761870	149479612	47.866
1964	334976743	24341438	853894	-796145	96892	177419	22316286	170065332	50.769
1965	353125973	20317357	1431763	-736364	119910	302763	23724388	191438740	54.213
1966	375899288	24812227	2213023	174111	293289	387668	25135315	214440764	57.047
1967	408531391	35122585	1461936	-1028546	121620	295018	27045581	238822465	58.459
1968	431782987	24727805	1694981	218772	118351	225565	28972338	266211381	61.654
1969	467532836	37879827	1841463	-288515	127347	384950	31006588	294830388	63.061
1970	496563057	30608424	2165888	587685	231661	386580	33240074	326337340	65.719
1971	526258225	32978385	2656030	-627187	322640	523030	35264807	358118540	68.050
1972	577981814	56234622	3209860	-1301173	643436	897588	38071960	391425315	67.723
1973	618818480	47771904	6129506	-805732	773766	1178668	41263251	425348426	68.736
1974	658115384	45985042	5178813	-1509325	447356	1223802	44026094	461909936	70.187
1975	709344965	38985406	5033941	17278116	469106	933362	47147264	520837118	73.425

iLLINOIS bELL COE-CROSSBAR (continued)

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciation Expenses	Depreciation Reserve	Reserve Ratios(%)
1976	705817960	31171381	22388712	-12309674	971564	1680424	48791952	534221824	75.688
1977	705117990	20143915	19793041	-1050844	1271382	2181266	48646214	561114270	79.577
1978	682654363	21202808	42343409	-1323026	4064905	4972719	47847581	564387601	82.675
1979	656905384	23311832	48426311	-634500	3725951	4081089	46185307	561156960	85.424
1980	619867116	27750487	60028485	-4760270	5733766	4711186	44020530	541411315	87.343
1981	567206045	26448423	69955720	-9153774	1941500	5528682	40927879	499642518	88.088
1982	526840893	15667770	51143283	-4889639	3254239	5833010	37720523	478751348	90.872
1983	405958624	9297957	92593274	-37586952	591336	4776268	32161038	376547228	92.755
1984	324799528	4104776	77715961	-7547911	2924242	9623229	25195061	309779431	95.376
1985	249848849	4071750	72001493	-7020936	2897890	7775473	19812712	245692131	98.336
1986	155908275	4029096	89864589	-8105081	-19413	5568765	13989684	156123967	100.138
1987	54637216		101271059		2531776	9620751	7259182	55023116	100.706
1988	17084337		37552879		938822	3567524	2472814	17314350	101.346
1989	4372791		12711546		317789	1207597	739798	4452794	101.830
1990	928859		3443932		86098	327174	182790	950577	102.338
1991	163544		765315		19133	72705	37664	169353	103.552
1992	0		163544		4089	15537	5639	0	99.999

COMPANY : mICHIGAN bELL
STATE : mICHIGAN
ACCOUNT : 221-47C
CATEGORY : COE-CROSSBAR

Modal Year: 1979
Modal BAL : 441500000

Total Plant Service = 8214111513
Total Plant Invstmnts = 603854410
Invstmnt Recovry Life = 13.603

	Past	Future
Gross Salv=	0.0204	0.0600
C.O.R =	0.0395	0.1400

Average net salvage = -0.0320
Depreciation rate = 0.0759

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciation Expenses	Depreciation Reserve	Reserve Ratios(%)
1945	5830822	5829681	533	1674	79	138	221173	222255	3.812
1946	9291057	3462681	2446	0	46	1102	573598	792351	8.528
1947	14077880	4806482	4133	-15526	899	300	886423	1659714	11.790
1948	20784522	6734168	10401	-17125	5391	509	1322389	2959459	14.239
1949	26080153	5256107	75933	115457	23815	4946	1777656	4795508	18.388
1950	33548503	7522213	20868	-32995	24247	3981	2261815	7023726	20.936
1951	37046064	3550794	15763	-37470	7929	4696	2677770	9651496	26.053
1952	42102868	5130758	40070	-33884	14470	8086	3002252	12586177	29.894
1953	47321653	3768184	148509	1599110	8858	23179	3392022	17414479	36.800
1954	53302890	6117704	60274	-76193	23437	19108	3816857	21099199	39.584
1955	57620251	6827064	95125	-2414578	18813	21575	4207501	22794234	39.559
1956	66990897	7401274	88249	2057621	58909	50444	4726710	29498781	44.034
1957	77978829	10647272	291853	632513	168944	68115	5498945	35439214	45.447
1958	88924511	11788097	353605	-488810	126095	45936	6330923	41007882	46.115
1959	90549961	5955138	207359	-4122329	132259	38932	6807767	43579288	48.127
1960	99173126	9519634	98082	-798387	28470	34393	7196514	49873411	50.289
1961	109276528	10736366	365950	-267014	-486	60671	7906845	57086134	52.240
1962	120774406	12871740	358586	-1015276	104569	15415	8726217	64527643	53.428
1963	127851445	7846549	272131	-497379	29930	106215	9430795	73112643	57.186
1964	143633223	16868792	516728	-570286	64352	112073	10297868	82275777	57.282
1965	157343078	14546235	748353	-88027	78440	199664	11416535	92734708	58.938
1966	174350714	18118915	607110	-504169	91670	218755	12581701	104078045	59.695
1967	201247353	28556735	681602	-978494	17289	277343	14247064	116404959	57.842
1968	220006053	19768014	629833	-379481	57893	180676	15978847	131251709	59.658
1969	249969382	31764895	933496	-868070	92227	344949	17826955	147024377	58.817
1970	270331871	22052581	1109376	-580716	258322	288528	19735898	165039977	61.051
1971	292453946	26274916	1789086	-2363755	130209	458507	21347409	181906246	62.200
1972	322211350	33420396	2553807	-1109185	139097	558192	23315284	201139444	62.425
1973	348583169	29396214	2701781	-322614	-22910	593201	25444360	222943297	63.957
1974	379807785	33549100	4186662	1862178	54397	674995	27629089	247627304	65.198
1975	404931571	29735190	5056698	445294	215491	981232	29766478	272016637	67.176
1976	417676333	29735190	10755452	-6234976	379474	1244755	31202896	285363824	68.322
1977	430059974	21832089	10742055	1293607	323591	1281925	32156058	307113100	71.412
1978	441315137	20056743	6940900	-1860680	85004	1007314	33052718	330441928	74.877
1979	441444913	22028013	20705930	-1192307	258552	1009976	33484567	341276834	77.309

mICHIGAN bELL COE-CROSSBAR (continued)

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciation Expenses	Depreciation Reserve	Reserve Ratios(%)
1980	436075298	20568036	27456373	1518722	488913	1197681	33285811	347916227	79.784
1981	405946114	21365138	52920813	1426491	119530	1079870	31939283	327400847	80.651
1982	362849679	11961773	41984273	-13073935	298538	1529137	29161712	300273752	82.754
1983	316023352	3380502	46593310	-3613519	8632	1233966	25750791	274592381	86.890
1984	227500790	3615692	28238101	-63900153	381897	666451	20616781	202786354	89.137
1985	186172490	3139216	42241726	-2225790	3333349	2330957	15691320	175012550	94.006
1986	124663542	2848129	59639721	-4717356	2095987	791254	11790531	123750738	99.268
1987	89640791	2000000	37022751		2221365	5183185	8128922	91895089	102.515
1988	31199153	1000000	59441638		3566498	8321829	4583661	32281781	103.470
1989	8178151	500000	23521002		1411260	3292940	1493647	8372746	102.379
1990	1690159	0	6487992		389280	908319	374322	1740036	102.951
1991	279776		1410383		84623	197454	74723	291546	104.207
1992	0		279776		16787	39169	10612	0	99.999

COMPANY : oHIO bELL
STATE : oHIO
ACCOUNT : 221-47C
CATEGORY : COE-CROSSBAR

Modal Year: 1979
Modal BAL : 300000000

Total Plant Service =5415177176
Total Plant Invstmnts = 419493243
Invstmnt Recovry Life = 12.909

	Past	Future
Gross Salv=	0.0565	0.0700
C.O.R =	0.0815	0.0900

Average net salvage = -0.0238
Depreciation rate = 0.0793

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciatio Expenses	epreciation Reserve	Reserve n Ratios(%)
1945	4991705	4998705	7000		2460	1085	197946	192321	3.853
1946	6331282	1343871	4294		37	1048	449012	636028	10.046
1947	7869186	1542673	4769		264	2049	563118	1192592	15.155
1948	12396159	4536885	9912		503	5711	803621	1981093	15.982
1949	17196476	4808876	8559		1037	3278	1173494	3143786	18.282
1950	20025551	2867674	38599		13051	7585	1476036	4586690	22.904
1951	21543139	1547748	30160		5357	12491	1648403	6197799	28.769
1952	22795272	1510443	258310		43088	19713	1758236	7721100	33.871
1953	24782793	2051795	64274		14008	24615	1886704	9532923	38.466
1954	26647076	1949217	84934		7190	15569	2039447	11479058	43.078
1955	29355188	3160070	451958		18882	40735	2220765	13226012	45.055
1956	35956805	6736420	134803		35239	8804	2589942	15707586	43.685
1957	43279894	7392354	69265		3795	15606	3142125	18768635	43.366
1958	53128622	10064036	215308		45291	54444	3823072	22367246	42.100
1959	59084559	6198995	243058		64779	42302	4449805	26596469	45.014
1960	62297876	3413597	200280		12645	37412	4813411	31184833	50.058
1961	67905430	6220789	613235		76667	94233	5163202	35717234	52.598
1962	76949785	10422303	1423323	45375	45806	58627	5744222	40070687	52.074
1963	87454735	10831508	545914	219356	118641	61704	6519448	46320514	52.965
1964	99807965	12725558	352232	-20096	90295	72985	7425887	53391383	53.494
1965	113440907	14162456	531715	2201	176772	93643	8456367	61401365	54.126
1966	127113952	14080525	408198	718	70622	90028	9539184	70513662	55.473
1967	135198722	8908997	464715	-359512	73643	125815	10401988	80039251	59.201
1968	142098722	7235214	335533	319	25973	65554	10996208	90660664	63.801
1969	157379122	16038726	759064	738	-44621	148889	11875770	101584598	64.548
1970	168921498	12388259	847419	1536	103233	173108	12939425	113608265	67.255
1971	185998642	18799485	1407243	-315098	18018	269205	14074330	125709066	67.586
1972	199779804	15233941	1447497	-5282	234697	394964	15298013	139394034	69.774
1973	217399168	18326490	1535583	828457	204165	383958	16543199	155050313	71.321
1974	235667452	17891632	1483600	1860252	2580	418341	17966320	172977525	73.399
1975	250173204	18231283	4476185	750654	159731	519752	19265972	188157945	75.211
1976	265959954	16196988	3480033	3069795	129782	515284	20467219	207829424	78.143
1977	280629472	19804909	5455067	319676	100808	652748	21674960	223817052	79.755
1978	293757784	37708724	24630278	49866	1027834	2452034	22777280	220589721	75.092
1979	299568909	16585604	11106499	332020	6449784	2579105	23528322	237214243	79.185

oHIO bELL COE-CROSSBAR (continued)

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciation Expenses	Depreciation Reserve	Reserve Ratios(%)
1980	280442595	18809108	36231493	-1703929	1826297	1791800	23000310	222313628	79.272
1981	276518373	15930845	18503903	-1351164	3217286	2663254	22086242	225098835	81.405
1982	257121724	9306537	26844922	-1858264	5866265	3342163	21161455	220081206	85.594
1983	242566982	7433198	19169187	-2818753	-1831877	1860002	19815115	214216503	88.312
1984	177834458	5405020	35559701	-34577843	108885	2650169	16670985	158208660	88.964
1985	145097763	3163490	33602853	-2297332	-1166146	2037692	12805851	131910488	90.911
1986	100922991	2015706	42322958	-3867520	565049	2045187	9755933	93995805	93.136
1987	56465990	1000000	45457001		3181990	4091130	6241247	53870912	95.404
1988	17878835	500000	39087155		2736101	3517844	2948138	16950152	94.806
1989	6361407	12589	11530017		807101	1037702	961245	6150779	96.689
1990	972890	0	5388517		377196	484967	290841	945333	97.167
1991	106358		866532		60657	77988	42797	104268	98.035
1992	0		106358		7445	9572	4218	0	99.999

COMPANY : wISCONSIN bELL
STATE : wISCONSIN
ACCOUNT : 221-47C
CATEGORY : COE-CROSSBAR

Modal Year: 1977
Modal BAL : 137800000

Total Plant Service = 2329314656
Total Plant Invstmnts = 179095571
Invstmnt Recovry Life = 13.006

	Past	Future
Gross Salv=	0.0662	0.0250
C.O.R =	0.0722	0.0950

Average net salvage = -0.0093
Depreciation rate = 0.0776

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciation Expenses	Depreciation Reserve	Reserve Ratios(%)
1947	2944075	2944497	422	0	13	43	114233	113781	3.865
1948	7476930	4532888	33	0	160	175	404346	518079	6.929
1949	11478697	4004967	3200	0	2128	1090	735499	1251416	10.902
1950	13958810	2492318	12205	0	4814	1155	987003	2229873	15.975
1951	14285148	336568	10230	0	3447	4008	1095896	3314978	23.206
1952	14420944	164062	28266	0	-702	6507	1113827	4393330	30.465
1953	16482146	2098809	37607	0	4704	8290	1199073	5551210	33.680
1954	18660096	2185554	7604	0	418	1126	1363557	6906454	37.012
1955	21196717	2606263	69642	0	9152	7448	1546487	8385004	39.558
1956	23521400	2410030	85347	0	4796	9629	1735111	10029934	42.642
1957	27073417	3619056	67039	0	15798	9971	1963133	11931856	44.072
1958	30563653	3595725	105489	0	7511	14596	2236380	14055662	45.988
1959	32029318	1499917	34252	0	6867	8358	2428674	16448593	51.355
1960	34354528	2364406	39196	0	1861	16327	2575764	18970696	55.220
1961	38239826	3993043	107745	0	10297	22128	2816739	21667859	56.663
1962	43810169	5778651	208308	0	10700	44177	3183628	24609701	56.173
1963	48551474	4863569	122264	0	32993	32512	3583731	28071649	57.818
1964	52759642	4398696	190528	0	21615	50612	3930980	31783104	60.241
1965	58388101	6015302	386843	0	101999	44069	4312652	35766843	61.257
1966	60539710	2465631	314022	0	101222	41903	4614527	40126667	66.282
1967	65259439	4889497	169768	0	13512	22413	4881142	44829139	68.694
1968	69054797	4237810	442452	0	24195	48889	5211536	49573530	71.789
1969	74963586	6557741	648952	0	43213	39623	5588068	54516236	72.724
1970	79758307	5718102	923381	0	165451	73599	6003375	59688082	74.836
1971	87555256	8819989	1023040	0	84963	43229	6491946	65198722	74.466
1972	95198270	8162351	519337	0	8398	119476	7091033	71659340	75.274
1973	104693679	11513192	2017783	0	80480	348085	7756022	77129974	73.672
1974	111283214	8548958	1959423	0	150153	229210	8380135	83471629	75.008
1975	118866495	11102423	3519142	0	98447	212573	8930056	88768417	74.679
1976	130345003	12372747	894239	0	73102	369201	9669674	97247752	74.608
1977	137748938	9259705	1855770	0	285068	388373	10402333	105691010	76.727
1978	134453676	4636036	7931298	0	296487	428288	10561753	108189664	80.466
1979	124697837	4467132	12565561	-1657410	3261334	1132870	10055357	106150514	85.126
1980	122404208	6834550	8264000	-864179	1123800	960172	9587824	106773787	87.230
1981	97107219	4613969	27942939	-1968019	1812666	1071516	8517279	86121258	88.687

WISCONSIN BELL COE-CROSSBAR (continued)

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciation Expenses	Depreciation Reserve	Reserve Ratios(%)
1982	83178416	1485136	14004558	-1409381	842354	1720630	6995276	76824319	92.361
1983	59854713	2165379	25202927	-286155	619949	1575697	5549839	55929328	93.442
1984	28686159	621431	19247758	-12542227	888401	1629804	3435481	26833421	93.541
1985	20437630	248891	7350583	-1146837	755682	1181643	1906056	19816096	96.959
1986	9112465	190580	10636203	-879542	273357	328162	1146575	9392121	103.069
1987	3022798	140000	6229667		155742	591818	470861	3197239	105.771
1988	732076	90000	2380722		59518	226169	145693	795559	108.672
1989	143175	50000	638901		15973	60696	33961	145896	101.900
1990	22499	0	120676		3017	11464	6428	23201	103.120
1991	0		22499		562	2137	873	0	99.999

COMPANY : iNDIANA bELL
STATE : iNDIANA
ACCOUNT : 221-47C
CATEGORY : COE-CROSSBAR

Modal Year: 1979
Modal BAL : 111300000

Total Plant Service =		1483814644
Total Plant Invstmnts =		119104569
Invstmnt Recovry Life =		12.458
	Past	Future
Gross Salv=	0.0451	0.0300
C.O.R =	0.0687	0.0700
Average net salvage =		-0.0236
Depreciation rate =		0.0822

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciation Expenses	Depreciation Reserve	Reserve Ratios(%)
1950	582223	582223	0	0	0	0	23918	23918	4.108
1951	778460	198488	2251	0	79	15	55898	77629	9.972
1952	939623	165241	858	-3220	5	324	70580	143811	15.305
1953	968695	28646	68	494	0	0	78395	222632	22.983
1954	1201065	232370	0	0	0	0	89135	311767	25.958
1955	1246131	28912	297	16451	0	0	100532	428453	34.383
1956	1926397	682321	297	-1758	18	81	130329	556664	28.897
1957	3298536	1401163	106892	77868	184	4461	214643	738006	22.374
1958	5074106	1818391	7844	-34977	5169	529	343952	1043777	20.571
1959	7574372	2695894	31735	-163893	-40	882	519606	1366834	18.046
1960	8724085	1925687	3675	-772299	5728	993	669549	1265144	14.502
1961	12481796	4295971	85966	-452294	1921	7092	871149	1592861	12.761
1962	14779764	2467878	75860	-94050	20538	18787	1119919	2544621	17.217
1963	18274953	3823363	108672	-219502	34648	27917	1357905	3581083	19.596
1964	20021206	1912849	44835	-121761	21569	15130	1573226	4994152	24.944
1965	24456939	4795305	94537	-265035	-15772	40167	1827185	6405826	26.192
1966	26432419	2081440	43747	-62213	-1972	27588	2090561	8360868	31.631
1967	27655186	1326414	40513	-63134	3905	20268	2221947	10462804	37.833
1968	30141064	2774043	42224	-245941	5403	7031	2374300	12547311	41.629
1969	32238058	2363583	78774	-187815	26924	29545	2562567	14840668	46.035
1970	41923614	10250252	116380	-448316	18705	26654	3046600	17314623	41.300
1971	44250192	2695338	254436	-114324	53698	22396	3540065	20517230	46.366
1972	50198931	5961028	350476	338187	130705	66765	3880019	24448899	48.704
1973	54194939	5051780	921887	-133885	31717	127379	4288554	27586020	50.901
1974	57582267	3842060	376344	-78388	-5801	93119	4591866	31624233	54.920
1975	60510636	3705285	674912	-102004	52881	118750	4851318	35632766	58.887
1976	88632049	4446449	397212	24072176	1419	119007	6126859	65317001	73.695
1977	95174107	6515672	1067780	1094166	113110	340082	7550852	72667267	76.352
1978	101399427	9586924	1129734	-2231870	-125319	298083	8075343	76957603	75.896
1979	111261819	11148879	1060353	-226134	96628	266470	8736234	84237509	75.711
1980	98616208	8471609	20732225	-384995	1711515	668444	8621898	72785258	73.807
1981	98509448	5321529	4115597	-1312692	459793	814518	8098024	75100268	76.237
1982	98590678	1912028	920023	-910775	62274	875529	8096975	80553190	81.705
1983	81579734	2099704	18638348	-472300	510615	668107	7401494	68686544	84.196

iNDIANA bELL COE-CROSSBAR (continued)

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciation Expenses	Depreciation Reserve	Reserve Ratios(%)
1984	61730136	662963	3851349	-16661212	331464	315669	5887244	54077022	87.602
1985	46968039	582625	14345009	-999713	416412	533620	4465377	43080469	91.723
1986	30391152	700262	16018357	-1258792	480641	462896	3177956	28999021	95.419
1987	16508120	400000	14283032		428491	999812	1926646	16071314	97.354
1988	5391997	150000	11266123		337984	788629	899668	5254214	97.445
1989	1320376	0	4071621		122149	285013	275748	1295476	98.114
1990	249306		1071070		32132	74975	64483	246047	98.693
1991	36391		212915		6387	14904	11737	36352	99.892
1992	0		36391		1092	2547	1495	0	99.999

COMPANY : iLLINOIS bELL
STATE : iLLINOIS
ACCOUNT : 221-77C
CATEGORY : COE-ESS-ANALOG

Modal Year: 1985
Modal BAL : 1000000000

Area under life cycle = 18438626477
Total Plant additions = 1319578748
Invstmnt Recovry Life = 13.973

	Past	Future
Gross Salv=	0.3199	0.1000
C.O.R =	0.0613	0.1200
Average net salvage =		0.0135
Depreciation rate =		0.0706

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciation Expenses	Depreciation Reserve	Reserve Ratios(%)
1968	13461254	13461254	0	0	77	1336	475166	473907	3.521
1969	25728898	13320390	12999	-1039747	6629	6162	1383366	1844742	7.170
1970	43406263	17495866	69138	250637	41152	14476	2440390	4242670	9.774
1971	78711185	33992270	137672	1450324	43887	15125	4310603	8444363	10.728
1972	105175724	26278766	127473	313246	56704	16459	6490992	14848127	14.117
1973	161607391	59071618	493305	-2146646	279740	16248	9417131	24035445	14.873
1974	215360967	54618833	389410	-475847	182643	78584	13306541	37056635	17.207
1975	273270217	56603989	694283	1999544	249945	129757	17248108	53730647	19.662
1976	311111114	57868547	2120924	-17906726	751795	267133	20627975	72722361	23.375
1977	378890796	66266075	802796	2316403	422633	204501	24356258	96493955	25.467
1978	452579033	79976973	8123706	1834970	1245168	599002	29349910	118366324	26.154
1979	552634857	120626106	19076608	-1493674	8930198	761026	35482871	142941759	25.865
1980	648252326	102353707	11377650	4641412	8984911	771438	42389909	182167491	28.101
1981	752790096	115688727	15996322	4845365	3444836	1057417	49455154	218013742	28.961
1982	806673008	72381504	19550385	1051793	2854750	1113538	55047218	255251787	31.643
1983	880837606	140681310	15434953	-51081759	8910791	1271740	59567145	307023030	34.856
1984	962717677	86288979	6543788	2134880	1423411	947901	65075339	366030091	38.021
1985	996455334	46400585	12406932	-255996	5348677	650762	69156509	427477583	42.900
1986	976285102	30034601	45435302	-4769531	7622128	1806789	69635423	457493043	46.861
1987	983021034	19291000	23264068		2326407	2791688	69161208	502924902	51.161
1988	990730381	12601000	22290653		2229065	2674878	69671110	549859546	55.500
1989	993790845	8504000	24939536		2493954	2992744	70051271	594472490	59.819
1990	990399721	4000000	28391124		2839112	3406935	70039599	635553143	64.171
1991	989456294	950000	20943427		2094343	2513211	69886595	684077442	69.137
1992	985964802	50000	21491492		2149149	2578979	69730047	731886168	74.230
1993	979839525	0	21125277		2112528	2535033	69390587	779728972	79.577
1994	933999892		55839633		5583963	6700756	67556286	790328833	84.618
1995	885468246		55531646		5553165	6663798	64225091	797911645	90.112
1996	655824618		230643628		23064363	27677235	54405830	617060974	94.089
1997	261587456		394737162		39473716	47368459	32383570	246812639	94.352
1998	89568452		172019004		17201900	20642280	12395392	83748646	93.502
1999	45869572		43698880		4369888	5243866	4780803	43956592	95.830
2000	12545685		33323887		3332389	3998866	2061990	12028217	95.875
2001	4376543		8169142		816914	980297	597335	4293027	98.092
2002	234563		4141980		414198	497038	162767	230974	98.470
2003	0		234563		23456	28148	8280	0	99.999

COMPANY : Michigan Bell
STATE : Michigan
ACCOUNT : 221-77C
CATEGORY : COE-ESS-ANALOG

Modal Year: 1986
Modal BAL : 740000000

Area under life cycle = 13948618547
Total Plant additions = 974349547
Invstmnt Recovry Life = 14.316

	Past	Future
Gross Salv=	47.10%	10.00%
C.O.R =	6.82%	10.00%

Average net salvage = 4.41%
Depreciation rate = 6.68%

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciation Expenses	Depreciation Reserve	Reserve Ratios(%)
1967	186936	260099	240	-72923	127	166	6241	5962	3.189
1968	14251293	14082139	1833	-15949	-102	638	482020	485409	3.406
1969	21627205	7574601	14281	-184408	2024	2688	1197803	1668267	7.714
1970	34297038	13333264	28547	-634884	307	5732	1867030	3501324	10.209
1971	54350452	19271641	33722	815495	21882	12804	2959494	6436175	11.842
1972	75167954	21869112	272279	-779331	100523	58620	4323969	10529768	14.008
1973	99153596	23064787	182787	1103642	51073	98242	5819721	16119533	16.257
1974	147725957	49592509	380326	-639822	24881	47236	8242068	23958920	16.218
1975	206402117	57504430	149035	1320765	92596	66273	11822558	35658766	17.276
1976	294708327	90064425	1307046	-451169	109970	218237	16729561	50973014	17.296
1977	357853852	69622469	1029840	-5447104	333016	108127	21785774	71953837	20.107
1978	388416031	33924407	1484174	-1878054	46133	360809	24914203	95069190	24.476
1979	442473584	63858598	5813720	-3987325	2854189	317950	27739231	119530940	27.014
1980	502079783	73781280	18666195	4491114	12453045	858959	31533893	143992724	28.679
1981	576441081	86494654	10860899	-1272457	5798208	392770	36006395	174543658	30.280
1982	643701296	73980126	10916146	4196235	4888262	870755	40734426	208379445	32.372
1983	690600594	62723087	14445765	-1378024	6636888	869430	44545639	244246777	35.367
1984	696067796	55481131	16265474	-33748455	4382150	1085657	46293893	277571689	39.877
1985	726606108	46300000	21483947	5722259	6946453	1272732	47495936	309257399	42.562
1986	737251284	35268106	3420525	-21202405	5540345	633234	48870846	359614832	48.778
1987	759743981	30945822	8453125	0	845313	845313	49977153	401138860	52.799
1988	769889104	28100000	17954877	0	1795488	1795488	51066766	434250749	56.404
1989	759960736	24500000	34428368	0	3442837	3442837	51074003	450896384	59.332
1990	751988573	20400000	28372163	0	2837216	2837216	50476394	473000615	62.900
1991	743997207	11495660	19487026	0	1948703	1948703	49943452	503457041	67.669
1992	728749415	7900000	23147792	0	2314779	2314779	49167613	529476862	72.656
1993	690399893	5000000	43349522	0	4334952	4334952	47378268	533505608	77.275
1994	653582469	1400000	38217424	0	3821742	3821742	44868821	540157005	82.646
1995	570876248	500000	83206221	0	8320622	8320622	40878527	497829311	87.204
1996	400365848	100000	170610400	0	17061040	17061040	32424896	359643806	89.829
1997	236458524	0	163907324		16390732	16390732	21260367	216996850	91.770
1998	111736583		124721941		12472194	12472194	11624486	103899395	92.986
1999	53438466		58298117		5829812	5829812	5514365	51115643	95.653
2000	7586487		45851979		4585198	4585198	2037317	7300981	96.237
2001	482729		7103758		710376	710376	269391	466613	96.662
2002	0		482729		48273	48273	16116	0	99.999

COMPANY : OHIO BELL
STATE : OHIO
ACCOUNT : 221-77C
CATEGORY : COE-ESS-ANALOG

Modal Year: 1990
Modal BAL : 570000000

Area under life cycle = 12198565890
Total Plant additions = 782296365
Invstmnt Recovry Life = 15.593

	Past	Future
Gross Salv=	23.91%	9.00%
C.O.R =	6.32%	6.00%

Average net salvage = 4.59%
Depreciation rate = 6.12%

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciation Expenses	Depreciation Reserve	Reserve Ratios(%)
1964	1778	1778	0	0	0	0	54	54	3.059
1965	181185	179407	0	0	0	0	5597	5652	3.119
1966	182975	1790	0	0	0	0	11141	16793	9.178
1967	3295437	3112451	0	11	0	502	106416	122707	3.724
1968	9266533	5986259	15163	0	1097	1137	384313	491817	5.307
1969	9636598	413135	43070	0	17751	7826	578311	1036983	10.761
1970	16997075	19533117	187847	-11984793	40977	11139	814814	1693788	9.965
1971	31662035	9470966	111953	5305947	30788	6345	1488647	3094925	9.775
1972	57211786	23060521	440319	2929549	90333	21685	2718951	5442204	9.512
1973	86246338	29795394	128183	-632659	227779	48565	4388869	9882104	11.458
1974	126166316	40813696	367372	-526346	60496	65337	6498421	16008312	12.688
1975	154614368	28136064	724806	1036794	184203	102034	8590030	23955706	15.494
1976	197771430	42873192	1481979	1765849	351234	177368	10780673	33428266	16.902
1977	228175532	32414215	2311112	300999	303489	324839	13031158	44126961	19.339
1978	276244496	50632041	3260863	697786	575202	253587	15431914	56619627	20.496
1979	312485521	42929740	6828550	139835	4987296	209925	18011241	72579690	23.227
1980	382088825	75028390	1822993	-3602093	684221	204831	21249377	92485464	24.205
1981	429749021	56196101	9426690	890785	2929782	478606	24836864	110346814	25.677
1982	485315331	58351432	5813504	3028382	2758707	682913	27994912	134604016	27.735
1983	525458401	51428411	9742518	-1542823	5228280	799872	30922985	160212892	30.490
1984	558005485	96505269	18559767	-45398418	44813	1090988	33146823	173753773	31.138
1985	560223007	36041168	11320878	-22502768	3161824	592368	34210390	199212741	35.560
1986	565882934	19743176	12646080	-1437169	-1298971	305689	34451388	219413388	38.774
1987	576938502	18730056	7674488	0	690704	460469	34962771	246931906	42.800
1988	582958688	23809357	17789171	0	1601025	1067350	35485176	265161586	45.485
1989	590973961	34640371	26625098	0	2396259	1597506	35914568	275249810	46.576
1990	594984098	20000000	15989863	0	1439088	959392	36282466	296022109	49.753
1991	596990237	18000000	15993861	0	1439447	959632	36466525	316974588	53.095
1992	595820493	10000000	11169744	0	1005277	670185	36492113	342632049	57.506
1993	587995712	5000000	12824781	0	1154230	769487	36216940	366408951	62.315
1994	576986741	1000000	12008971	0	1080807	720538	35640752	390401001	67.662
1995	542495753	0	34490988	0	3104189	2069459	34248754	391193497	72.110

OHIO BELL COE-ANALOG-ESS (continued)

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciation Expenses	Depreciation Reserve	Reserve Ratios(%)
1996	499947877		42547876	0	3829309	2552873	31891875	381813932	76.371
1997	443893777		56054100	0	5044869	3363246	28875307	356316762	80.271
1998	378934945		64958832	0	5846295	3897530	25173112	318479807	84.046
1999	289498842		89436103	0	8049249	5366166	20449649	252176436	87.108
2000	178294200		111204642	0	10008418	6672279	14311371	158619304	88.965
2001	98039284		80254916	0	7222942	4815295	8453975	89226011	91.010
2002	38281933		59757351	0	5378162	3585441	4170527	35431907	92.555
2003	7829049		30452884	0	2740760	1827173	1410691	7303301	93.285
2004	839391		6989658	0	629069	419379	265197	788529	93.941
2005	0		839391	0	75545	50363	25680	0	99.999

COMPANY : WISCONSIN BELL
STATE : WISCONSIN
ACCOUNT : 221-77C
CATEGORY : COE-ESS-ANALOG

Modal Year: 1988
Modal BAL : 308000000

Area under life cycle = 6508460072
Total Plant additions = 375338577
Invstmnt Recovry Life = 17.340

	Past	Future
Gross Salv=	32.32%	6.00%
C.O.R =	4.47%	2.00%
Average net salvage =		7.11%
Depreciation rate =		5.36%

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciation Expenses	Depreciation Reserve	Reserve Ratios(%)
1969	6295803	6298014	2211	0	1702	29	168629	168091	2.670
1970	9215615	2922107	2295	0	-109	93	415464	581058	6.305
1971	21129630	12021188	107173	0	2589	291	812779	1288961	6.100
1972	33339478	12412702	202854	0	39394	4621	1458921	2579802	7.738
1973	42683716	9406255	62017	0	100748	-670	2036234	4655437	10.907
1974	53474579	11106196	315333	0	28175	25190	2575540	6918629	12.938
1975	70348731	17086323	212171	0	17194	32529	3316530	10007653	14.226
1976	95398472	25468817	419076	0	142368	54459	4439436	14115922	14.797
1977	124945215	30015251	468508	0	165492	64823	5901769	19649852	15.727
1978	163150992	39376150	1170373	0	170650	117745	7716478	26248862	16.089
1979	188624996	25955975	964065	482094	342000	167059	9422101	34881840	18.493
1980	201512977	19465285	6449479	-127825	2825678	269143	10449603	41438499	20.564
1981	232004581	43999257	13176545	-331108	1198197	473195	11611499	40598454	17.499
1982	259239791	32581617	5458690	112283	3915952	156612	13157675	52056780	20.081
1983	274880196	40334786	5085904	-19608477	2859092	282983	14306072	63853057	23.229
1984	296476582	24251400	6331869	3676855	2290760	387208	15303437	74728177	25.205
1985	307661188	15278514	3900854	-193054	1455010	61063	16181455	88402725	28.734
1986	307241000	5773608	4609160	-1584636	263288	89353	16469773	100437273	32.690
1987	310748915	5695000	2187085	0	131225	43742	16552476	114890147	36.972
1988	312039449	3864000	2573466	0	154408	51469	16681000	129100620	41.373
1989	314957743	3300000	381706	0	22902	7634	16793730	145527912	46.206
1990	316848224	2800000	909519	0	54571	18190	16922530	161577305	50.995
1991	316839588	2000000	2008636	0	120518	40173	16972935	176621949	55.745
1992	314828844	1000000	3010744	0	180645	60215	16918847	190650481	60.557
1993	312475322	500000	2853522	0	171211	57070	16801953	204713052	65.513
1994	309388422	0	3086900	0	185214	61738	16656234	218405863	70.593
1995	298274621	0	11113801	0	666828	222276	16275877	224012491	75.103
1996	289792787	0	8481834	0	508910	169637	15751020	231620951	79.926
1997	258959300	0	30833487	0	1850009	616670	14697984	216718787	83.688
1998	208482922	0	50476378	0	3028583	1009528	12520150	180781614	86.713
1999	149399783		59083139		3544988	1181663	9585666	133647466	89.456
2000	78299466		71100317		4266019	1422006	6098783	71489945	91.303
2001	22773662		55525804		3331548	1110516	2707181	20892354	91.739
2002	6727482		16046180		962771	320924	790170	6278191	93.322
2003	0		6727482		403649	134550	180191	0	99.999

COMPANY : INDIANA BELL
STATE : INDIANA
ACCOUNT : 221-77C
CATEGORY : COE-ESS-ANALOG

Modal Year: 1983
Modal BAL : 335000000

Area under life cycle = 5261919604
Total Plant additions = 409289362
Invstmnt Recovry Life = 12.856

	Past	Future
Gross Salv=	20.69%	4.00%
C.O.R =	4.96%	6.00%

Average net salvage = 0.31%
Depreciation rate = 7.75%

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciation Expenses	Depreciation Reserve	Reserve Ratios(%)
1968	240958	240958	0	0	0	0	9342	9342	3.877
1969	1454928	1213970	0	0	0	0	65749	75091	5.161
1970	4163262	2708334	0	0	0	0	217816	292907	7.036
1971	11289136	7125874	0	0	0	20	599086	891973	7.901
1972	28193894	16922599	17841	0	0	668	1530747	2404211	8.527
1973	35747301	7660244	106837	0	37461	11212	2478985	4802607	13.435
1974	43566255	8255479	436525	0	179501	5997	3074967	7614554	17.478
1975	45891525	2716005	390735	0	-57436	43192	3468256	10591447	23.079
1976	81462266	36281110	710369	0	80151	33685	4937475	14865019	18.248
1977	123322322	42689504	829448	0	445004	33282	7939448	22386742	18.153
1978	161048539	39052070	680558	-645295	134417	96730	11024989	32768860	20.347
1979	194574321	33941979	358073	-58124	-21657	105491	13787411	46071050	23.678
1980	236300263	48539955	5556141	-1257872	509194	121637	16704902	57607368	24.379
1981	266796922	40832437	10934947	599169	1072048	142071	19504955	67107354	25.153
1982	295713699	28576860	1737591	2077508	2350568	465786	21808399	89062944	30.118
1983	334101667	40299356	2466772	555384	405273	415393	24417788	111003840	33.225
1984	320557787	22353319	4017173	-31880026	1349615	466521	25380987	133250748	41.568
1985	312443064	21479913	22798753	-6795883	1589824	277379	24541288	136305728	43.626
1986	327390216	17649403	2357383	-344868	2973917	428326	24806180	161300117	49.268
1987	334433597	15500000	8456619	0	338265	507397	25658748	178333113	53.324
1988	330277689	8000000	12155908	0	486236	729354	25770694	191704781	58.044
1989	329629882	4000000	4647807	0	185912	278868	25584455	212548473	64.481
1990	320019984	1000000	10609898	0	424396	636594	25186767	226913144	70.906
1991	310096958	0	9923026	0	396921	595382	24429480	241221137	77.789
1992	297959165		12137793		485512	728268	23574187	252414776	84.715
1993	237893984		60065181		2402607	3603911	20774896	211923187	89.083
1994	171063414		66830570		2673223	4009834	15855178	159611184	93.305
1995	78260480		92802934		3712117	5568176	9666226	74618418	95.346
1996	17238366		61022114		2440885	3661327	3702467	16078328	93.271
1997	9347482		7890884		315635	473453	1030727	9060354	96.928
1998	1087914		8259568		330383	495574	404578	1040172	95.612
1999	352364		735550		29422	44133	55839	345750	98.123
2000	0		352364		14095	21142	13661	0	99.999

COMPANY : CINCINNATI BELL
STATE : KENTUCKY
ACCOUNT : 221-77C
CATEGORY : COE-ESS-ANALOG

Modal Year: 1984
Modal BAL : 24911961

Area under life cycle = 351130172
Total Plant additions = 26899143
Invstmnt Recovry Life = 13.054

	Past	Future
Gross Salv=	63.29%	5.00%
C.O.R =	2.63%	2.00%

Average net salvage = 9.49%
Depreciation rate = 6.93%

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciation Expenses	Depreciation Reserve	Reserve Ratios(%)
1971	2488927	2488927	0	0	0	46	86286	86240	3.465
1972	3398511	950226	40642	0	17992	645	204106	267052	7.858
1973	3386507	-9995	2059	50	2430	202	235224	502444	14.837
1974	4210658	825758	1472	-135	367	1243	263379	763475	18.132
1975	4274542	65311	0	-1427	0	1	294166	1057640	24.743
1976	6807472	2530466	4537	7001	352	-142	384192	1437789	21.121
1977	6839343	48723	2434	-14418	0	420	473109	1908044	27.898
1978	7290362	471897	2734	-18144	0	1578	489850	2393582	32.832
1979	8096496	833499	3070	-24295	763	-962	533433	2925670	36.135
1980	10004457	1935053	28690	1598	2353	5298	627525	3521561	35.200
1981	17191827	9848121	2814790	154039	2183889	23745	942843	3809758	22.160
1982	22483772	4926652	39344	404637	-11004	28250	1375477	5106637	22.713
1983	23539613	1291391	106088	-129462	-180473	11488	1595543	6404131	27.206
1984	24911961	503442	22867	891773	-83948	1070	1679724	7975970	32.017
1985	21604158	627087	-61088	-3995978	-3819	1625	1612625	9644239	44.641
1986	22202662	674410	20842	-55064	-12245	5152	1518699	11124698	50.105
1987	22634029	508000	76633		3832	1533	1554402	12604767	55.689
1988	23039032	485000	79997		4000	1600	1583398	14110568	61.246
1989	23507679	575000	106353		5318	2127	1613686	15621091	66.451
1990	23487349	100000	120330		6017	2407	1629228	17133599	72.948
1991	21733051	0	1754298		87715	35086	1567705	16999634	78.220
1992	18539601		3193450		159673	63869	1396176	15298164	82.516
1993	13249975		5289626		264481	105793	1102084	11269311	85.052
1994	8309983		4939992		247000	98800	747443	7224961	86.943
1995	4899867		3410116		170506	68202	457960	4375109	89.290
1996	2028768		2871099		143555	57422	240203	1830345	90.220
1997	872842		1155926		57796	23119	100593	809690	92.765
1998	96728		776114		38806	15522	33613	90473	93.533
1999	0		96728		4836	1935	3353	0	99.999

COMPANY : CINCINNATI BELL
STATE : OHIO
ACCOUNT : 221-77C
CATEGORY : COE-ESS-ANALOG

Modal Year: 1984
Modal BAL : 120532805

Area under life cycle = 1785872149
Total Plant additions = 157346037
Invstmnt Recovry Life = 11.350

	Past	Future
Gross Salv=	33.71%	5.00%
C.O.R =	4.40%	2.00%

Average net salvage = 7.29%
Depreciation rate = 8.17%

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciation Expenses	Depreciation Reserve	Reserve Ratios(%)
1968	5092073	5092073	0	0	0	0	207957	207957	4.084
1969	8440239	3348166	0	0	0	17	552652	760592	9.011
1970	15591441	7163330	9027	-3101	463	741	981440	1732727	11.113
1971	19926534	4424531	143322	53884	106465	4180	1450533	3142223	15.769
1972	29441690	9565986	120593	69763	46381	7155	2016169	5077025	17.244
1973	34563481	5090656	34628	65763	46421	4869	2613933	7697882	22.272
1974	36154373	1700516	72339	-37285	-17475	19534	2888075	10476610	28.977
1975	43010266	7089264	228889	-4482	147823	17282	3233037	13611299	31.647
1976	46451942	3509137	14394	-53067	-648	5951	3653584	17243889	37.122
1977	54647324	8127289	391656	459749	17527	26353	4128834	20972242	38.377
1978	63579159	9722682	898676	107829	173156	276173	4828300	24798849	39.005
1979	71401631	12200106	4000639	-376995	2693456	244662	5512536	28759539	40.279
1980	84927494	13718555	573551	380859	10540	112261	6384389	34468656	40.586
1981	97465493	16364004	3885972	59967	2437904	13210	7448822	40456200	41.508
1982	110120150	14690269	2142717	107105	890525	35176	8477675	47646507	43.268
1983	112754092	5350861	2819586	102667	888527	68627	9102052	54748874	48.556
1984	120532805	10499627	2083637	-637277	94686	88023	9527299	62199199	51.604
1985	107479155	7864622	4923741	-15994531	1503931	138295	9311874	67952968	63.224
1986	107660323	3849247	3342347	-325732	-382296	66578	8786169	72947916	67.757
1987	109548584	3000000	1111739		55587	22235	8870684	80740213	73.703
1988	113351072	3000000	-802488		-40124	-16050	9103090	90621717	79.948
1989	108621035	3000000	7730037		386502	154601	9065210	92188790	84.872
1990	97423383	3000000	14197652		709883	283953	8414732	86831800	89.128
1991	79077902	3000000	21345481		1067274	426910	7208208	73334892	92.738
1992	58319537	3000000	23758365		1187918	475167	5611230	55900508	95.852
1993	31682932	3000000	29636605		1481830	592732	3675648	30828649	97.304
1994	10958401	3000000	23724531		1186227	474491	1741447	9557301	87.214
1995	6782382		4176019		208801	83520	724523	6231086	91.872
1996	867256		5915126		295756	118303	312407	805820	92.916
1997	0		867256		43363	17345	35418	0	99.999

COMPANY : NEW ENGLAND BELL
STATE : RHODE ISLAND
ACCOUNT : 221-77C
CATEGORY : COE-ESS-ANALOG

Modal Year: 1984
Modal BAL : 79033860

Area under life cycle =	1530291654	
Total Plant additions =	101155063	
Invstmnt Recovry Life =	15.128	
	Past	Future
Gross Salv=	18.91%	7.70%
C.O.R =	4.00%	7.70%
Average net salvage =		1.25%
Depreciation rate =		6.53%

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciation Expenses	Depreciation Reserve	Reserve Ratios(%)
1967	1561340	1561340	0	0	0	0	50957	50957	3.264
1968	1591445	33914	3809	0	0	0	102897	150046	9.428
1969	918620	-566766	106059	0	0	67	81921	125841	13.699
1970	4524259	3605639	0	0	0	14	177639	303466	6.708
1971	9362526	4838609	342	0	0	-7515	453223	763862	8.159
1972	11024831	1666314	4009	0	-322	652	665382	1424262	12.919
1973	10547996	-475560	1275	0	34	2046	704073	2125047	20.146
1974	11187365	639369	0	0	2800	894	709377	2836330	25.353
1975	13371592	2199329	15102	0	0	3439	801531	3619320	27.067
1976	17454134	4102700	20158	0	5322	1049	1006059	4609495	26.409
1977	18637150	1299811	116795	0	-1859	26203	1177912	5642549	30.276
1978	19415192	3271197	1876	-2491279	0	2700	1241915	6879888	35.436
1979	20614987	1251342	34859	-16688	0	10376	1306465	8141118	39.491
1980	33416552	15035598	2199685	-34348	230346	27764	1763428	7907443	23.663
1981	42887193	9479924	90182	80899	1145001	39367	2490326	11413221	26.612
1982	53176834	10702689	794010	380962	2948	46141	3135242	13711260	25.784
1983	72574125	14353377	87135	5131049	115485	33200	4104135	17810545	24.541
1984	79033860	13975200	3484228	-4031237	8896	75177	4948031	19208067	24.304
1985	74435609	3594817	453286	-7739782	85161	23395	5008784	23825332	32.008
1986	77858911	4506644	1083342	0	12799	54861	4970437	27670365	35.539
1987	78947843	2000000	911068		70152	70152	5117703	31877000	40.377
1988	79610125	3700000	3037718		233904	233904	5174858	34014140	42.726
1989	79802281	2300000	2107844		162304	162304	5202744	37109040	46.501
1990	79999173	2000000	1803108		138839	138839	5215441	40521373	50.652
1991	79793712	1800000	2005461		154420	154420	5215162	43731074	54.805
1992	79019123	1500000	2274589		175143	175143	5183176	46639661	59.023
1993	78208191	1000000	1810932		139442	139442	5131429	49960158	63.881
1994	74710302	500000	3997889		307837	307837	4990802	50953071	68.201

New England Bell Rhode Island COE-ANALOG-ESS (continued)

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciation Expenses	Depreciation Reserve	Reserve Ratios(%)
1995	69726112		4984190		383783	383783	4713972	50682853	72.688
1996	64826674		4899438		377257	377257	4391400	50174816	77.398
1997	56667182		8159492		628281	628281	3965196	45980520	81.141
1998	48714551		7952631		612353	612353	3439344	41467233	85.123
1999	37181118		11533433		888074	888074	2803378	32737178	88.048
2000	25849302		11331816		872550	872550	2057124	23462486	90.766
2001	14939339		10909963		840067	840067	1331219	13883742	92.934
2002	7829282		7110057		547474	547474	743100	7516785	96.009
2003	872823		6956459		535647	535647	284011	844337	96.736
2004	0		872823		67207	67207	28486	0	99.999

COMPANY : NEW ENGLAND BELL
STATE : VERMONT
ACCOUNT : 221-77C
CATEGORY : COE-ESS-ANALOG

Modal Year: 1984
Modal BAL : 47216656

Area under life cycle = 587556467
Total Plant additions = 56371982
Invstmnt Recovry Life = 10.423

	Past	Future
Gross Salv=	12.54%	7.90%
C.O.R =	9.00%	7.90%
Average net salvage =		0.19%
Depreciation rate =		9.58%

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciation Expenses	Depreciation Reserve	Reserve Ratios(%)
1976	5587	5587	0	0	0	0	268	268	4.788
1977	250350	244763	0	0	1184	0	12254	13706	5.475
1978	10368428	10118078	0	0	0	0	508432	522138	5.036
1979	21270654	10974168	63942	-8000	0	12239	1514895	1960852	9.219
1980	28632719	7451843	97778	8000	53330	12022	2389398	4293780	14.996
1981	32092391	3852956	247656	-145628	151604	15177	2907548	7090099	22.093
1982	39143168	7770347	830631	111061	4139	22776	3410793	9651624	24.657
1983	43612918	5208670	872685	133765	180698	24442	3962402	12897597	29.573
1984	47216656	7127148	883546	-2639864	24251	165507	4348964	16221759	34.356
1985	43543637	3909635	15180	-7567474	-46924	3813	4345647	20501489	47.083
1986	45948855	2416927	11709	0	10673	15978	4284944	24769419	53.906
1987	47263829	2100000	785026		62017	62017	4463069	28447462	60.189
1988	48018372	1900000	1145457		90491	90491	4562158	31864164	66.358
1989	46391040	1900000	3527332		278659	278659	4520369	32857200	70.827
1990	42183821	1000000	5207219		411370	411370	4241008	31890989	75.600
1991	36918381	500000	5765440		455470	455470	3787452	29913001	81.025
1992	28382711	0	8535670		674318	674318	3126648	24503979	86.334
1993	17382922		10999789		868983	868983	2191281	15695471	90.292
1994	8201837		9181085		725306	725306	1225011	7739397	94.362
1995	728191		7473646		590418	590418	427574	693325	95.212
1996	0		728191		57527	57527	34866	0	99.999

COMPANY : NEW ENGLAND BELL
STATE : NEW HAMPSHIRE
ACCOUNT : 221-77C
CATEGORY : COE-ESS-ANALOG

Modal Year: 1984
Modal BAL : 70470821

Area under life cycle = 817709168
Total Plant additions = 78776829
Invstmnt Recovry Life = 10.380

	Past	Future
Gross Salv=	15.36%	7.60%
C.O.R =	2.34%	7.60%

Average net salvage = 0.79%
Depreciation rate = 9.56%

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciation Expenses	Depreciation Reserve	Reserve Ratios(%)
1972	139010	139010	0	0	0	0	6643	6643	4.779
1973	5242773	5103763	0	0	0	0	257189	263832	5.032
1974	5377132	134359	0	0	0	0	507513	771345	14.345
1975	5441845	64713	0	0	0	0	517026	1288371	23.675
1976	5678308	344629	108166	0	0	1312	531419	1710311	30.120
1977	8304481	2626173	0	0	7226	4788	668221	2380970	28.671
1978	16636714	8350864	18631	0	0	1	1191910	3554248	21.364
1979	29458529	12822604	788	-1	378	1335	2202837	5755340	19.537
1980	41294067	11945684	110146	0	468	8542	3381182	9018302	21.839
1981	46631035	4964882	27973	400059	6196	3444	4201836	13194916	28.296
1982	58457964	12148461	2271266	1949734	15096	21205	5022078	15939619	27.267
1983	68089269	9326519	1709895	2014681	128418	35344	6047541	20370339	29.917
1984	70470821	10510986	178527	-7950907	0	19449	6621621	26793984	38.021
1985	59620198	-715701	53199	-10081723	600997	7639	6216894	33551038	56.275
1986	62498604	3178040	299634	0	-24801	8778	5835912	39053736	62.487
1987	63518321	3500000	2480283		188502	188502	6022198	42595651	67.060
1988	64018372	3800000	3299949		250796	250796	6094826	45390529	70.902
1989	60001738	2700000	6716634		510464	510464	5926773	44600667	74.332
1990	53523821	1000000	7477917		568322	568322	5425251	42548001	79.494
1991	41284932	500000	12738889		968156	968156	4530797	34339909	83.178
1992	28393722	0	12891210		979732	979732	3329860	24778559	87.268
1993	16383932		12009790		912744	912744	2139871	14908639	90.995
1994	6726191		9657741		733988	733988	1104405	6355304	94.486
1995	517389		6208802		471869	471869	346162	492664	95.221
1996	0		517389		39322	39322	24725	-0	99.999

COMPANY : NEW ENGLAND BELL
STATE : MASSACHUSETTS
ACCOUNT : 221-77C
CATEGORY : COE-ESS-ANALOG

Modal Year: 1984
Modal BAL : 588554206

Area under life cycle = 9234110065
Total Plant additions = 698768393
Invstmnt Recovry Life = 13.215

	Past	Future
Gross Salv=	20.74%	8.00%
C.O.R =	7.69%	8.00%

Average net salvage = 1.30%
Depreciation rate = 7.47%

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciation Expenses	Depreciation Reserve	Reserve Ratios(%)
1967	415959	415959	0	0	0	0	15534	15534	3.735
1968	11668248	11252289	0	0	0	0	451294	466828	4.001
1969	12252279	591500	7469	0	0	860	893330	1351829	11.033
1970	29715436	17485330	22173	0	0	4063	1567315	2892908	9.735
1971	43007085	13340481	48832	0	0	-39892	2715876	5599844	13.021
1972	59704720	16771384	73745	0	2706	29787	3835848	9334863	15.635
1973	94604563	35172836	272993	0	39782	33785	5762794	14830661	15.676
1974	130963263	36467316	108616	0	26087	68480	8423997	23103649	17.641
1975	146587978	16304362	679647	0	158936	244819	10365356	32703476	22.310
1976	173291810	28327326	1623494	0	183460	206719	11946147	43002870	24.815
1977	209197024	36553429	648215	0	302418	114550	14284328	56826851	27.164
1978	245829556	37868364	743062	-492770	253548	93856	16993304	73236785	29.792
1979	306360808	62430880	778435	-1121193	353260	123808	20621957	93309760	30.457
1980	391045330	51162139	7620916	41143299	2368975	395646	26045148	113707321	29.078
1981	411392987	71408712	7756724	-43304331	3432671	2761880	29967652	136589040	33.202
1982	470012465	62585304	3633080	-332746	1368680	323682	32916738	166917696	35.513
1983	523873614	71846161	17298187	-686825	3285394	287559	37117411	189734755	36.218
1984	588554206	93469245	13039848	-15748805	1150073	229988	41544440	219159431	37.237
1985	504853201	36889394	11552544	-109037855	1352728	123083	40834108	249670640	49.454
1986	529040753	27707208	3519656	0	122577	339566	38611534	284545530	53.785
1987	553587484	31100000	6553269		524262	524262	40431552	318423813	57.520
1988	580156597	19000000	-7569113		-605529	-605529	42340511	368333437	63.489
1989	570597405	20200000	29759192		2380735	2380735	42975759	381550004	66.869
1990	562403749	15000000	23193656		1855492	1855492	42312766	400669114	71.242
1991	547569178	10000000	24834571		1986766	1986766	41452760	417287302	76.207
1992	500277671	5000000	52291507		4183321	4183321	39132615	404128411	80.781
1993	447835662	0	52442009		4195361	4195361	35407993	387094395	86.437
1994	305460726		142374936		11389995	11389995	28132411	272851870	89.325
1995	176813692		128647034		10291763	10291763	18010895	162215731	91.744
1996	87415117		89398575		7151886	7151886	9867820	82684976	94.589
1997	12877722		74537395		5962992	5962992	3745510	11893091	92.354
1998	6743777		6133945		490716	490716	732779	6491926	96.265
1999	0		6743777		539502	539502	251851	0	99.999

COMPANY : NEW ENGLAND BELL
STATE : MAINE
ACCOUNT : 221-77C
CATEGORY : COE-ESS-ANALOG

Modal Year: 1986
Modal BAL : 49000000

Area under life cycle = 610594738
Total Plant additions = 56421982
Invstmnt Recovry Life = 10.822

	Past	Future
Gross Salv=	23.72%	8.10%
C.O.R =	6.10%	8.10%
Average net salvage =		1.73%
Depreciation rate =		9.08%

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciation Expenses	Depreciation Reserve	Reserve Ratios(%)
1975	2617	2617	0	0	0	0	119	119	4.540
1976	189506	186889	0	0	0	0	8723	8842	4.666
1977	15377923	15189537	1120	0	17	342	706794	714190	4.644
1978	16270029	892107	0	-1	618	306	1436883	2151385	13,223
1979	17075088	805971	812	-100	9965	1404	1513937	3673071	21.511
1980	18357631	1308711	26168	0	2156	3570	1608719	5254208	28.621
1981	35991444	9739589	67099	7961323	3905	4906	2467561	7653669	21.265
1982	36476648	9877358	1585694	-7806460	26994	15309	3290202	9369862	25.687
1983	48926855	12408138	139487	181556	26296	11883	3877496	13122284	26.820
1984	47097273	8691638	2462308	-8058912	180715	12277	4359695	15188108	32.248
1985	46961986	4619700	68653	-4686334	657546	11692	4270485	20035795	42.664
1986	48835798	1908655	34843	0	132389	1465	4349418	24481294	50.130
1987	49399921	1000000	435877		35306	35306	4460105	28505522	57.704
1988	48691839	1200000	1908082		154555	154555	4453569	31051010	63.770
1989	46128389	1000000	3563450		288639	288639	4305035	31792595	68.922
1990	41839102	0	4289287		347432	347432	3993907	31497214	75.282
1991	35029213	0	6809889		551601	551601	3489981	28177306	80.439
1992	26792327	0	8236886		667188	667188	2806826	22747246	84.902
1993	16939225		9853102		798101	798101	1985503	14879647	87.841
1994	8772723		8166502		661487	661487	1167376	7880521	89.830
1995	3828190		4944533		400507	400507	572108	3508096	91.638
1996	1083812		2744378		222295	222295	223015	986733	91.043
1997	527199		556613		45086	45086	73143	503263	95.460
1998	0		527199		42703	42703	23936	0	99.999

COMPANY : Illinois Bell
STATE : Illinois
ACCOUNT : 2212
CATEGORY : COE-ESS-DIGITAL

Modal Year: 1999
Modal BAL : 1645064003

Area under life cycle = 24727347591
Total Plant additions = 2287613304
Invstmnt Recovry Life = 10.809

	Past	Future
Gross Salv=	31.08%	0.00%
C.O.R =	5.96%	0.00%

Average net salvage = 0.07%
Depreciation rate = 9.24%

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciation Expenses	Depreciation Reserve	Reserve Ratios(%)
1977	1439365	1439365	0	0	0	0	66532	66532	4.622
1978	7730027	6290485	0	177	0	0	423840	490372	6.344
1979	8882432	100936	2378	1053847	0	0	767884	1255878	14.139
1980	11952729	3071538	0	-1241	0	0	963071	2218949	18.564
1981	27250306	9925808	183990	5555759	34796	10681	1812096	3871170	14.206
1982	42125720	14837317	25	38122	0	0	3206793	7077937	16.802
1983	47451598	8878734	1861009	-1691847	881287	125776	4140564	10113004	21.312
1984	49901576	2887431	561914	124461	123776	82532	4499990	14092324	28.240
1985	166368722	102682803	2014648	15798991	391872	32305	9996739	22433982	13.484
1986	372116532	213734388	493463	-7493115	267193	76927	24890595	47021380	12.636
1987	524275795	157700000	1457000	-4083737	344615	63939	41434261	87279316	16.648
1988	653760067	132200000	2715728				54452770	139016358	21.264
1989	777910337	131200000	7049730				66176609	198143237	25.471
1990	911224855	142400000	9085482				78077495	267135250	29.316
1991	1031615908	142000000	21608947				89804618	335330921	32.505
1992	1138332203	142000000	35283705				100302282	400349498	35.170
1993	1206782869	181542966	113092300				108399086	395656284	32.786
1994	1285763595	107978486	28997760				115213860	481872384	37.478
1995	1388240308	132217908	29741195				123601431	575732620	41.472
1996	1491670671	142841209	39410846				133119147	669440921	44.879
1997	1559243964	161506620	93933327				141023510	716531104	45.954
1998	1627192633	103389319	35440650				147287790	828378244	50.908
1999	1645064003	88062779	70191409				151254680	909441514	55.283
2000	1608038152	77015420	114041271				150369295	945769539	58.815
2001	1539871631	16345337	84511858				145506951	1006764632	65.380
2002	1409575399	15572448	145868680				136333337	997229288	70.747
2003	1296300814	14523098	127797683				125074676	994506282	76.719
2004	1108247216	13471481	201525079				111146277	904127480	81.582
2005	881056458	12496011	239686769				91952290	756393000	85.851
2006	491202942		389853516				63430433	429969918	87.534
2007	251492794		239710148				34329889	224589658	89.303
2008	102939201		148553593				16383036	92419101	89.780
2009	49201034		53738167				7032432	45713366	92.911
2010	9203902		39997132				2699672	8415906	91.438
2011	3921833		5282069				606716	3740553	95.378
2012	0		3921833				181280	0	99.999

COMPANY : Michigan Bell
STATE : Michigan
ACCOUNT : 221-377C
CATEGORY : COE-ESS-DIGITAL

Modal Year: 1997
Modal BAL : 1218233000

Area under life cycle = 14241460222
Total Plant additions = 1251203546
Invstmnt Recovry Life = 11.382

	Past	Future
Gross Salv=	33.85%	7.00%
C.O.R =	11.20%	7.00%

Average net salvage = 22.64%
Depreciation rate = 6.80%

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciation Expenses	Depreciation Reserve	Reserve Ratios(%)
1981	5392744	5392744	0	0	0	0	183251	183251	3.398
1982	11094388	5512376	24	189292	0	0	560250	743476	6.701
1983	27110557	15779485	262	236946	0	0	1298243	2041457	7.530
1984	26101025	4366128	127588	-5248072	24624	949	1808184	3745728	14.351
1985	100773209	65039831	16535	9648888	505	2595	4311316	8038419	7.977
1986	217472956	108557353	123861	8266255	0	73230	10814329	18655656	8.578
1987	347249787	129462191	1869276	2183916	698391	162716	19189854	36511909	10.515
1988	460451000	103867525	1484000	10817688	502307	166267	27446495	62810443	13.641
1989	566197000	95199243	1854000	12400757	627545	207722	34886544	96262811	17.002
1990	674955999	95568101	2244000	15434898	759553	251417	42175642	136702588	20.254
1991	784477000	97982931	2651000	14189070	897315	297017	49593019	184244904	23.486
1992	897172001	102118647	3065000	13641354	1037446	343402	57144145	239018093	26.641
1993	1009660000	100851672	3485000	15121327	1179608	390458	64796092	301118335	29.824
1994	1123022000	99397378	3902000	17866622	1320755	437179	72470705	370570617	32.998
1995	1187311000	50990067	4107000	17405933	1390144	460147	78507467	445901080	37.556
1996	1200223000	6893963	4078000	10096037	1380328	456898	81130835	523877346	43.648
1997	1218233000	0	3963000	21973000	1341403	444013	82181596	602993331	49.497
1998	1144727822		73505178		24880151	8235498	80295814	626428620	54.723
1999	1050598872		94128950		31860918	10546179	74599435	628213844	59.796
2000	933093891		117504981		39773275	13165222	67407899	604724814	64.809
2001	664046932		269046959		91067446	30143939	54272471	450873833	67.898
2002	338041424		326005508		110346867	36525557	34051982	232741618	68.850
2003	175822224		162219200		54908215	18174990	17461610	124717253	70.934
2004	75283942		100538282		34030359	11264278	8532843	55477895	73.692
2005	2948449		72335493		24484234	8104447	2658416	2180605	73.958
2006	0		2948449		997996	330343	100191	0	99.999

COMPANY : Ohio Bell
STATE : Ohio
ACCOUNT : 221-377C
CATEGORY : COE-ESS-DIGITAL

Modal Year: 1995
Modal BAL : 750500000

Area under life cycle = 9532785659
Total Plant additions = 864494698
Invstmnt Recovry Life = 11.027

	Past	Future
Gross Salv=	5.75%	5.00%
C.O.R =	0.89%	2.00%

Average net salvage = 0.03%
Depreciation rate = 9.07%

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciation Expenses	Depreciation Reserve	Reserve Ratios(%)
1982	2533887	2506203	0	27684	0	0	114860	114860	4.533
1983	2489949	28280	2229	-69989	0	0	227728	340359	13.669
1984	17756109	15243486	26060	48734	0	0	917744	1232043	6.939
1985	107495431	83437078	84397	6386641	29	6331	5677590	6818934	6.343
1986	206407822	99033688	1774190	1652893	309462	41347	14229079	19541937	9.468
1987	305807822	102000000	3500000	900000	0	0	23218481	39260418	12.838
1988	380000000	79200000	5007822				31087328	65339924	17.195
1989	440862500	64900000	4037500				37209290	98511714	22.345
1990	530756900	95900000	6005600				44043025	136549139	25.727
1991	605862553	85200000	10094347				51522396	177977188	29.376
1992	641675500	58900000	23087053				56550281	211440416	32.951
1993	686006443	55600000	11269057				60183164	260354522	37.952
1994	732645750	67600000	20960693				64306800	303700629	41.453
1995	750500000	32000000	14145750				67230261	356785140	47.540
1996	742028372	10000000	18471628				67655570	405969082	54.711
1997	725252801	4000000	20775571				66511127	451704638	62.282
1998	687014917		38237884				64017395	477484149	69.501
1999	601828732		85186185				58422643	450720607	74.892
2000	500028392		101800340				49946637	398866904	79.769
2001	385819102		114209290				40155027	324812641	84.188
2002	268828919		116990183				29674870	237497328	88.345
2003	143728922		125099997				18701042	131098373	91.212
2004	59191023		84537899				9198260	55758734	94.201
2005	8263813		50927210				3057694	7889218	95.467
2006	0		8263813				374595	0	99.999

COMPANY : Cincinnati Bell
STATE : Ohio
ACCOUNT : 221-377C
CATEGORY : COE-ESS-DIGITAL

Modal Year: 1997
Modal BAL : 137868000

Area under life cycle = 2198689259
Total Plant additions = 170973149
Invstmnt Recovry Life = 12.860

	Past	Future
Gross Salv=	12.75%	7.00%
C.O.R =	2.21%	4.00%

Average net salvage = 0.04%
Depreciation rate = 7.77%

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciation Expenses	Depreciation Reserve	Reserve Ratios(%)
1984	16219170	0	0	16219170	0	0	630329	630329	3.886
1985	24790961	8586685	14894	0	-900	2251	1593785	2206069	8.899
1986	55925028	30029516	299255	1403806	0	1912	3136882	5041784	9.015
1987	75900000	20391000	416000	-28	94000	12000	5123143	9830927	12.952
1988	90720438	23840000	9019562				6475404	7286768	8.032
1989	111530397	25367000	4557041				7860115	10589843	9.495
1990	117668810	6620000	481587				8907415	19015671	16.160
1991	126787215	13237000	4118595				9500344	24397420	19.243
1992	131245634	4819000	360581				10027983	34064822	25.955
1993	132269590	1623000	599044				10241046	43706823	33.044
1994	133737437	1614000	146153				10337885	53898555	40.302
1995	134776000	1656000	617437				10435292	63716410	47.276
1996	136154000	2280000	902000				10529207	73343618	53.868
1997	137868000	1914000	200000				10649372	83792990	60.778
1998	137273603	2468000	3062397				10692884	91423477	66.599
1999	134612000	2476000	5137603				10566345	96852219	71.949
2000	129312000	2400000	7700000				10256932	99409151	76.875
2001	121408090	1997000	9900910				9743786	99252027	81.751
2002	113540241	2032000	9899849				9130845	98483022	86.738
2003	95506544		18033697				8124228	88573553	92.741
2004	34155720		61350824				5039091	32261820	94.455
2005	7288381		26867339				1610650	7005131	96.114
2006	0		7288381				283250	0	99.999

COMPANY : Pacific Bell
STATE : N/A
ACCOUNT : 221-377C
CATEGORY : COE-ESS-DIGITAL

Modal Year: 1997
Modal BAL : 2150207000

Area under life cycle = 32238741966
Total Plant additions = 2383480301
Invstmnt Recovry Life = 13.526

	Past	Future
Gross Salv=	0.00%	0.00%
C.O.R =	0.00%	0.00%

Average net salvage = 0.00%
Depreciation rate = 7.39%

Year	Plant in Service Dec. 31	Plant Additions	Plant Retirements	Plant Adjustments	Gross Salvage	Cost of Removal	Depreciation Expenses	Depreciation Reserve	Reserve Ratios(%)
1983	201767000	274502000	5031000	-67704000			7458537	2427537	1.203
1984	223822000	173176000	2290000	-148831000			15732360	15869897	7.090
1985	302899000	132057000	3117000	-49863000			19470814	32223711	10.638
1986	783914000	400207000	1826000	82634000			40175224	70572935	9.003
1987	1115987000	335123000	3843000	793000			70231906	136961842	12.273
1988	1218446597	111950000	9490403				86294876	213766315	17.544
1989	1294846067	86914000	10514530				92906596	296158381	22.872
1990	1409002096	125651000	11494971				99950687	384614097	27.297
1991	1595933191	197591000	10659905				111080700	485034892	30.392
1992	1788753750	208145000	15324441				125118633	594829084	33.254
1993	1947741244	169119000	10131506				138123600	722821179	37.111
1994	2045282999	109449000	11907245				147606483	858520416	41.976
1995	2098959282	81925000	28248717				153196422	983468121	46.855
1996	2146259685	65248000	17947597				156929135	1122449659	52.298
1997	2156446412	43893000	33706273				159054209	1247797596	57.864
1998	2158079451	27860000	26226961				159491140	1381061775	63.995
1999	2133830965	16912000	41160486				158655135	1498556424	70.228
2000	2020459737	6729301	120100529				153567873	1532023768	75.826
2001	1899283538		121176199				144897572	1555745141	81.912
2002	1669969528		229314010				131941320	1458372451	87.329
2003	1265872049		404097479				108526576	1162801548	91.858
2004	620555965		645316084				69733863	587219327	94.628
2005	102343179		518212786				26722753	95729294	93.538
2006	35393203		66949976				5091575	33870893	95.699
2007	2894028		32499175				1415329	2787047	96.303
2008	0		2894028				106981	0	99.999