Simulated Plant-Record Method of Life Analysis of Utility Plant for Depreciation-Accounting Purposes

Author(s): Alex. E. Bauhan

Source: *Land Economics*, Vol. 24, No. 2 (May, 1948), pp. 129-136
Published by: University of Wisconsin Press
Stable URL: http://www.jstor.org/stable/3159428
Accessed: 04-01-2018 16:39 UTC

# Simulated Plant-Record Method of Life Analysis of Utility Plant for Depreciation-Accounting Purposes

*By* ALEX. E. BAUHAN*

PRESENT-DAY requirements in the matter of depreciation accounting for utilities quite often involve estimates of the average life of various classes of utility plant but it is frequently not recognized that, if depreciation accounting for a group of utility-plant units is related to the average life, it must also be related to the estimated "mortality dispersion" of the plant. The manner in which the retirement dates of a group of related plant units, installed in a given year, distribute themselves in the years before and after the average age of retirement, i.e., mortality dispersion, has a marked effect on the theoretically required reserve under any group-depreciation-accrual plan associated with estimated average life.

Such a reserve determination is likely to be a greater misstatement due to hitherto common errors in estimating mortality dispersion than in estimating average life. A determination made in disregard of the dispersion of retirements, if it pretends to be associated with life of plant by the usual group accounting methods, regardless of whether the accrual plan be straight line, sinking fund, or other accrual plan, is without validity. The ratio between an alleged theoretical reserve requirement calculated without regard for mortality dispersion and one giving proper attention to it may be as much as two to one.

If necessary estimates of mortality dispersion as well as average life are to be drawn from past plant experience, methods of life analysis which tell us how the retirements of an installation "vintage" are distributed through the years, such as the here-described plant-record simulation method, are essential. By the application of actuarial principles as used for life-insurance purposes, information as to mortality dispersion as well as average life is usually obtainable; and this is the method commonly used.[1] But the actuarial method, which requires a knowledge of the installation date of each item of retired and surviving plant, is frequently not available because installation dates are not obtainable or because the labor of discovering them in addition to that involved in the pursuit of the method is too great. Fortunately in such cases, not to mention other reasons why the method might be preferred, the desired results can be generally obtained, if at all obtainable, by what has been designated as the "simulated plant-record method."

With some background mention of the phenomenon of utility-plant-mortality dispersion, this article undertakes to explain the principles of that method, as developed in connection with its application to actual extensive analyses of electric-and gas-utility plant.[2]

## *Mortality Dispersion*

The underlying theory of the simulated plant-record method depends on a concept of each year's additions, followed by the characteristic year-by-year retirement

* Public Service Electric & Gas Co., Newark, N. J.

[1] See, "An Appraisal of Methods for Estimating Service Lives of Utility Properties," prepared by cooperating committees on depreciation, American Gas Association, Edison Electric Institute 1942; also, *Report of Committee on Depreciation*, National Association of Railroad and Utility Commissioners, 1943.

[2] Additional details and observations on the practical application of the method may be had by reference to a paper by the author presented at the National Accounting Conference of American Gas Association and Edison Electric Institute at Buffalo, N. Y., April 8, 1947.

of those additions. Records in either monetary units or physical units may be thought of, but ordinarily only monetary records are adequately available in practice. The year-by-year retirements of the plant additions made in a particular year have been found to be distributed usually in some such manner as is illustrated by the bar diagram marked "Annual Retirements" in Figure 1.[3] A smooth curve

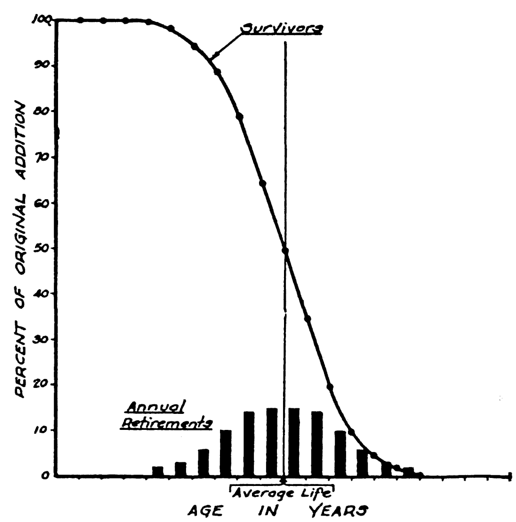


Figure 1—*Mortality Dispersion* is illustrated by bar diagram marked "Annual Retirements." It shows how retirements of a single installation of a multiplicity of related plant units typically occur at ages earlier than and later than average life. If the annual retirements are successively subtracted from the original installation the upper curve of "Survivors" is obtained.

connecting the ends of the bars would be the retirements-frequency-distribution curve. This diagram represents the phenomenon of mortality dispersion, recognition of which is so essential to any proper consideration of group-plant depreciation.

The upper curve marked "Survivors" is obtained by subtracting from the original additions the accumulated annual retirements as obtained by adding the year-by-year values of the "Annual Retirements" curve. For any year it shows how much of those original additions remain. In generalized form the annual retirements and survivors are expressed in percent of the original additions as a function of various percentages of average life.

Several families of standard generalized mortality dispersions have been developed. The most generally known and used are those published by the Iowa Engineering Experiment Station, freqently called the Iowa type curves.[4] Specimens of these are reproduced in Figure 2. Individual companies, consultants and other authorities have also developed dispersion types based on their own experience. Such standardized mortality-dispersion types serve to conveniently represent and designate the

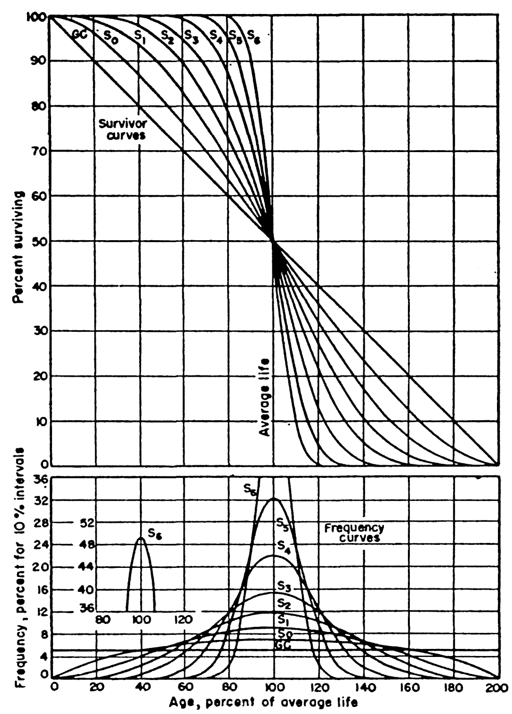


Figure 2—*Curves for Symmetrical Mortality Dispersion.* (Adapted from Iowa Engineering Experiment Station Bulletin 155, Fig. 29, by Robley Winfrey, Type GC added)

[3] Edwin B. Kurtz, *Life Expectancy of Physical Property Based on Mortality Laws* (New York: Ronald Press, 1930); Edwin B. Kurtz, *The Science of Valuation and Depreciation* (New York: Ronald Press, 1937).

[4] Robley Winfrey, *Depreciation of Group Properties.* Iowa Engineering Exp. Sta. Bul. 155, 1942.

experienced mortality dispersion, to conveniently designate the estimates of future dispersion, and to minimize the work of computing theoretical reserve requirements.

### *Principle of the Simulation Method*

The simulated plant-record method of life analysis consists of applying such standard mortality dispersions to the record of plant additions and discovering by trial and error which particular combination of average life and mortality dispersion (sometimes hereinafter called a mortality pattern or a mortality characteristic) best simulates in calculated results the record of actual balances or actual retirements. The method serves equally whether applied to records of balances or retirements, but this article describes the method in reference only to balances. The description of the method as to retirements would follow along the same lines.[5]

It can be illustrated by considering first only a single year's additions, as shown in Figure 3, of which the survivors or balances in succeeding years diminish in accordance with the mortality characteristic of the plant. Either graphically or numerically it is an ordinary task to determine which one of a set of standard mortality patterns, when applied to the additions, gives the same, or as nearly the same, survivors or balances at various time points in the actual plant record. In the process of fitting, many patterns would be tried, among them probably being such as those shown by dotted lines in the diagram which obviously do not reproduce the actual balances because, in the case of trial (1) average life is too long, in (2) average life is too short, in (3) mortality dispersion is too narrow, and in (4) mortality dispersion is too wide. This essentially is the procedure of the actuarial method for typing the mortality pattern, and the simulattion method for this simple case is the identical procedure.

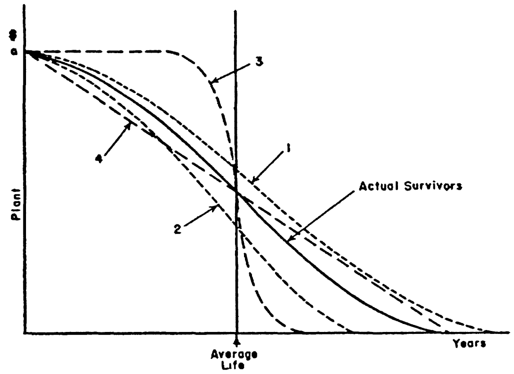


Figure 3—*Fitting a Single Year's Additions.* The solid line represents actually recorded survivors (balances) of an original addition *a*. The dotted lines illustrate several possible attempts to type or "fit" the actual balances with balances calculated from the original additions by the application of standard survivorship ratios. These particular trials fail because, in the case of (1), average life is too long, (2), average life is too short, (3), mortality dispersion is too narrow, (4) mortality dispersion is too wide.

If the plant history is a composite of a number of year's additions, each with its characteristic mortality pattern, and if the record of retirements or survivors of each particular year's addition is known, the actuarial approach will serve.[6] If the

[5] The basic principle of the method is described in the 1943 Report of the Committee on Depreciation of the National Association of Railroad and Utility Commissioners, p. 104. Stages in the development of the method can be traced in: Cyrus G. Hill, "Depreciation of Telephone Plants," *Telephony*, March 18 and 25, 1922; Walter J. Lyman, "Fundamental Considerations in the Preparation of a Power System Master Plan," *Edison Electric Bulletin*, October 1933, p. 218; Testimony by Company Witness in New York State Public Service Commission Case 8230 re: New York Telephone Co., 1935; testimony by C. Beverley Benson in New York State Public Service Commission Case 8490 re: Syracuse Lighting Co. and Case 8403 re: Queens Borough Gas and Electric Co., 1937; testimony by C. Beverley Benson in State of Ohio Public Service Commission Cases 1100, 11218, and 11442 re: East Ohio Gas Co., City of Cleveland, p. 38; also in papers presented at National Accounting Conference of American Gas Association and Edison Electric Institute at Buffalo, April 8, 1947: H. R. Whiton, "The Indicated Retirement Approach to the Simulated Plant Record Method of Estimating Lives of Mass Accounts of Utility Property for Depreciation Accounting Purposes;" P. H. Jeynes, "Indicated Renewals;" Alex. E. Bauhan, "Life Analysis of Utility Plant for Depreciation Accounting Purposes by the Simulated Plant-Record Method."

[6] The actuarial method merges the records of all the vintages as a function of age (not time). Thus merged, the

*(Footnote 6 continued on page 132)*

retirements or survivors of each individual year's additions are not identifiable and recorded, as is frequently the case, the actuarial method is not available; but we can look to the total survivors or balances resulting from all the years' additions and get the mortality characteristic of the account by application of the simulation method.

In elementary fashion this is illustrated in Figure 4. If the plant additions from

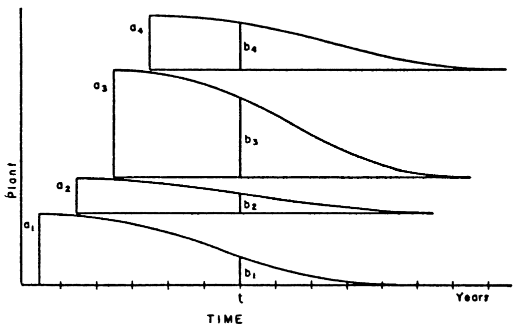


Figure 4—*A Plant History.* Showing actual survivors elements $b_1$, $b_2$, $b_3$, $b_4$, etc. resulting from annual additions $a_1$, $a_2$, $a_3$, $a_4$, etc. Their sum is the book balance at time *t*. The simulation method calculates these elements from recorded additions and assumed survivors curves and judges the reasonableness of the assumption by comparing the sum of the calculated survivorship elements with the book balance.

year to year are represented by the dollars shown as $a_1$, $a_2$, $a_3$, $a_4$, etc., then in the course of time retirements will be made from these additions leaving survivors tapering off to zero in accordance with the mortality characteristic. It is this experienced but unknown mortality characteristic which we aim to discover by trial and error. The combined plant balance in any year will consist of the survivors of these successive additions. Thus the balance at time *t* is the sum of the survivors $b_1$, $b_2$, $b_3$, $b_4$, etc. The simulation procedure consists of experimentally reproducing these survivorship elements from the additions record.

Using an assumed mortality pattern it calculates what the survivors would be at time *t* for each annual addition. These calculated survivors are then added to give a simulated balance which is compared with the actual balance. Such comparison of simulated and actual balances would be made at a number of time points in the plant's history. If the mortality pattern was well selected the difference between the simulated and actual balances would be small. If a poor selection was made, it would show up in a large deviation between the calculated figure and the actual. Thus trials would be repeatedly made until that particular one is found which best simulates the actual plant-balance record.

Stated in other words, the essence of the simulated plant-record method is that an effort is made by trial and error to duplicate the year-by-year balances of the account by a series of corresponding calculated, or "simulated," balances arising from the assumption that each year's actual additions were retired in accordance with a selected pattern of average life and mortality dispersion. Successive pattern selections are tried until a pattern is found which results in a series of year-by-year calculated balances simulating the progression of actual balances as closely as possible. That best fitting pattern is deemed to represent the experienced average life and mortality dispersion of the account.

*Fitting Process*

This comparison can be roughly made graphically; i.e., the curve of the actual balances can be drawn on coordinate paper and the calculated results for each trial plotted, somewhat as shown in Figure 5. When the plotted points for a particular trial fall closer to the actual line than for any other trial, that trial is said to represent the average life and mortality dispersion of the plant. However, this method is rather crude in

(*Footnote 6 continued from page 131*)
ratio of survivors to additions or the ratio of yearly retirements to additions as a function of age may be typed by fitting standard mortality patterns.

that the distinction between the best fit and several inferior fits is frequently not discernible, and, of course, the judgment of the observer enters into such a determination. Deciding between two close fits is not, as might at first be supposed, a matter of choosing between two average lives which are close to each other. The average lives of two close fits may be quite far apart.

A more precise and more objective comparison is by the use of the least squares method, which is commonly used for curve-fitting purposes. By this method the year-by-year differences between the calculated and actual balances are observed; then, to accentuate the larger discrepancies, the differences are squared. The trial which shows the smallest sum of squared differences is deemed to be the best fit and to be indicative of the average life and mortality dispersion of the account.

### *Required Data and Survivors' Tables*

In practice the procedure requires a tabulation of the additions and the balances for the account under consideration going back as far as they may be available. If small early additions are not available, they may be roughly estimated. The operation of the method is such that the small early additions, and in the utility business the early additions were ordinarily small, have little influence on the final answer, and precision in estimating them is of no importance.

Before the simulated plant-record procedure is started there should be available not only a suitable statement of annual additions and balances for the plant under consideration, but also a large assortment of precalculated survivors tables based on the generalized tables or curves of some family of standardized dispersion types, such as the Iowa types. For a given average life and for a given type of mortality dispersion, these tables show the percent of a year's additions which survive in each succeeding age-year. In one application some 2,000 survivors' tables based on the Iowa types are in regular use. They show percentage of survivors to one decimal place for ages 0.5 to 59.5 years, for twenty-six different types of Iowa dispersions and for average lives running from 5 years to 150 and more years.

The physical arrangement of the tables is important. In any extensive study it is out of the question, because of the labor involved, to rewrite the table on a computation form every time a computation is made. The tables should be written, photographed, or printed on stiff durable paper, or on plastic coated paper, and then cut into strips so that each strip will show the survivors' percentages corresponding to each age-year for a particular pattern of average life and mortality dispersion. Survivors' percentages need not be shown for more than 55 or 60 years, if the pattern extends beyond such an age, unless it is expected to work with plant histories which include a greater span of years. Assuming that the work sheets will show additions chronologically downward, and this is believed to be the best arrangement, the survivors-table strips should run upwards by ages and the line spacing should be identical with that on the work sheets. Thus, the survivors' percentages can be used as multipliers of annual additions by simply laying the strip alongside of the additions column without the necessity of rewriting the survivors' percentages.

The tables should show percent survivors at mid-year intervals. This convention is desirable because, in order to facilitate calculation, it can be assumed that all the additions made at various times during a calendar year are equiva-

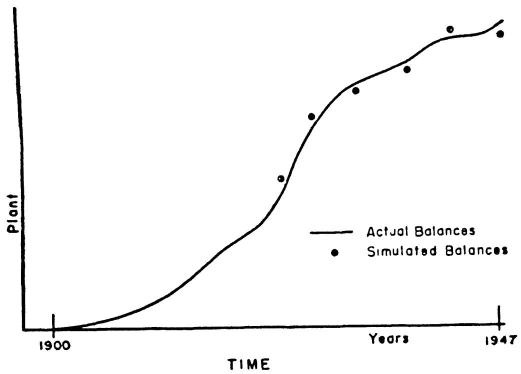


**Figure 5**—*Comparison of Balances.* Balances calculated from assumed patterns of average life and mortality dispersion can be recorded and compared graphically (or numerically) with actual balances over a range of years. That pattern whose balances most nearly simulates the actual balances is the sought for average life and dispersion of the plant history.

lently represented by a single installation on July 1. The survivors of these additions may therefore be considered to be one-half year old at the end of the 1st year, 1 ½ years old at the end of the 2nd year, etc. It follows that the survivors tables are properly set up at the half-year ages.

Orderly filing of the survivors-table strips facilitates their use. A visible index cabinet, using a file pocket deep enough to carry the length of the strip (10 or 11 inches) and wide enough for 10 strips, with celluloid-holding strips at the top and bottom of the pocket, has been successfully used. Alternatively, the survivors tables may be on pages and the list of additions may be written on a movable strip so that the additions strip can be moved from page to page and column to column of survivors tables for the cross multiplication.

*Computation*

The computing process consists of putting the column of survivors' percentages in juxtaposition to the column of annual additions. The bottom of the survivors table, corresponding to age 0.5 years, is placed opposite the year in the additions column for which it is desired to obtain a calculated or simulated balance for comparison with the actual balance. The figures in the additions column are then cross multiplied by the figures appearing on the same line in the survivors table. The summation of these cross products is the desired simulated balance for comparison with the actual balance. To get the simulated balance for any other year the beginning of the survivors table (age 0.5) is aligned with the addition of the selected year and the cross multiplication and summation process is repeated. Thus, the simulated balance and the actual balance can be compared at as many points in the life history of the account as desired.

A form has been developed for conveniently recording these simulated balances as well as their squared deviations from the actual balances. Another form records the mean squared deviations in a manner which economically guides the succession of mortality pattern trials.

The number of trials per account varies between 50 and 100. Short cuts are available which can frequently be used to limit the number of trials. For instance, the number of trials for a given type of dispersion can often be limited to three, two in the approximate best fitting average life region and the third located precisely at the best fitting average life by means of a rapidly performed solution of the equation for least mean squared deviation on the tolerable assumption that over a limited range the simulated balance for any year is a straight line function of the average life assumption.

The work can be speeded considerably by using lumped additions instead of annual additions. That is, the additions of each five-year period may be taken as if made in the middle year of the period or, more accurately, in that year in which the weighted mean time of installation for the 5-year period occurs. In this case, years selected for comparison of actual and simulated balances must fall on only the terminal years of the lumped periods. The lumping of additions need not be by uniform periods, but the special care required in handling such an operation may not be compatible with production methods. Such rough computations, if handled understandingly, can reduce the time required to discover the area in which the desired fit falls, and can be finished off with the more refined computation using each year's additions in only that area.

### *Term of Balance Comparisons*

A decision which must be made before survivors calculations are started is the extent of and the intervals at which points of comparison between actual and calculated balances will be made. That is, shall the comparison be of annual balances throughout the entire history of the account, as may have been inferred from the previous discussion, or merely between 1940 and 1945 or between 1905 and 1945, or over some intermediate span. It is essential to the process that the analysis include comparisons over a fairly extended period. If the term of comparison is too short, the results are indeterminate. It is, for instance, theoretically impossible to make a determination from a single year by the simulated plant-record method as, by the use of intermediate lives and dispersions, an infinite number of patterns can be found which will yield a calculated balance equal exactly to the actual balance. This condition is probably not much improved by using a span of only four or five years. Practically, in dealing with the wider dispersions typical of utility-plant accounts, it is believed that indeterminateness will be avoided if the comparison term is made not less than 15 years.

As to extending the term of comparison beyond that required for determinateness, the choice lies in the statistical philosophy which is to be followed. If one wishes to recognize more fully the influence of earlier experience on the shape of the overall survivorship pattern, it is well to make the term quite extended. In the comparisons made in recent years is included the late history of old plant, but in the comparisons of earlier years this same plant is included in its younger days. By the more extended comparison term we give added weight to the experience of earlier years. Thus, in the case of short lived accounts, is introduced life and dispersion indications of vintages which have no present-day survivors. One reason for doing this, assuming that necessary future redeterminations will be similarly made, would be to avoid the undue fluctuations of life and dispersion estimates which would result if attempt were made to follow the vicissitudes of short-time-life and dispersion indications. The point, however, is not as important as may seem for the reason that with any plant which has had the growth characteristics exhibited by most utility accounts, the additions of recent decades so far outweigh the additions of earlier decades as to make balance comparisons of the recent periods controlling in the findings of the simulated plant-record process as here outlined. In such cases the result will not be materially changed by making balance comparisons prior to, say 1920, although it may be desirable to do so if it is thought that the acceptability of the conclusions is thereby improved.

It is, however, not necessary for the observations to be made in each year in the selected comparison term. It appears that, ordinarily, balance comparisons made for every fourth or fifth year will give a result not importantly different than comparisons made on the basis of every year. This reduces the labor of the computations considerably.

*Conclusion*

In any application of this method it goes without saying that the first requirement is a good record of the year-by-year additions and balances classified according to the present system of accounts. Carefully planned production methods are essential. The use of conveniently set up survivors-tables strips, instead of writing and rewriting the figures, and the use of a convenient computation form are steps to that end. The adoption of the mean-square-of-differences-tally sheet, which economically guides the succession of trial and error calculations of simulated balances until the least mean square and thus the best fitting pattern of average life and mortality dispersion is found, is an important feature of the procedure. Time and economy considerations will recommend the use of skilled calculators with key-operated machines or automatic multiplication from punched cards.

Basically, operating on corresponding data and fitting the same family of generalized mortality dispersions, the results of the simulation method will be the same as those of the actuarial method. The method is entirely independent of irregularities in the amount or rate of growth, and functions equally well on declining plant balances as on increasing balances. Only in the rare case of the plant's being perfectly static does the method become indeterminate as to dispersion type, although not as to average life indication.

Where a fairly stable life and dispersion characteristic has been experienced, the plant-record-simulation method will discover it. Where the life and dispersion have been moderately fluctuating, the method will give a desirably weighted average indication. In either case the result should be helpful in selecting a suitable average life and dispersion for the determination of accrual rate and theoretical reserve requirement for future depreciation accounting associated with life. If the life and mortality dispersion characteristics have fluctuated wildly, or if the plant is immature in relation to the best fitting pattern, neither this method nor any other statistical procedure will give an answer of any prophetic merit.