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Chapter Author: Robert N. Grosse , Edward B. Berman

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ESTIMATING FUTURE PURCHASES OF CAPITAL EQUIPMENT FOR REPLACEMENT

Robert N. Grosse, The Rand Corporation
and
Edward B. Berman,
Council for Economic and Industry Research

This paper is concerned with the problem of predicting replacement requirements, defined as the amount of expenditure for capital goods which will maintain capacity at its exact current level. After a brief review of the literature, two approaches on which work has begun are described: the first suggests a possible method for estimating replacement requirements by industry of source alone, i.e. construction and equipment-producing industries, the second approaches the problem of securing these estimates by industry of use as well, and is concerned with partial solutions to certain additional problems, such as inadequate price deflators and changes in the technological relationships between capital requirements and capacity over time.

Interest in the measurement and prediction of replacement expenditures is not, of course, confined to economists concerned with interindustry research. It has been an annoying problem in the construction of a system of national accounts. Nor is concern with replacement limited to economists. A recent editorial in *Business Week* stated: "Backlogs left by World War II have mostly been worked off; and new capital equipment needed to take care of armament construction is available. We are fast approaching the time when the amount of new plant and equipment will be determined by the replacement market for existing plant—plus some indeterminable amount to allow for increasing standards of living."[1]

The concept and measurement of replacement demand has been of interest to economists for many years. Perhaps the largest body of literature in this field has been devoted to the problem of the optimum replacement policy for a firm. This first arose as part of

Note: Robert N. Grosse was with the Bureau of the Budget and Edward B. Berman with the Bureau of Mines at the time of writing. The views expressed in this paper are those of the authors and not necessarily those of the Bureau of the Budget or the Bureau of Mines.

[1] *Business Week*, July 18, 1953, p. 156.

the problem of proper depreciation policy since an asset cannot be depreciated properly until its useful life has first been fixed.[2] Later, economists became more concerned with the problem of optimum replacement policy as such.[3]

We had hoped that out of these contributions some light would be shed on our problem of measurement and prediction. Unfortunately for our purpose, the theories set forth by these scholars did not (nor did they pretend to) describe the actual behavior of firms, either individually or in the aggregate. They were recommendations for a rational policy. However, to quote Everett M. Hicks, manager of the grinding machine division of the Norton Co., "Until recently, however, most of the methods which have been developed have been

[2] J. S. Taylor, "A Statistical Theory of Depreciation," *Journal of the American Statistical Association*, December 1923, pp. 1,010-1,023; H. Hotelling, "A General Mathematical Theory of Depreciation," *Journal of the American Statistical Association*, September 1925, pp. 340-353; G. A. D. Preinreich, "Annual Survey of Economic Theory; The Theory of Depreciation," *Econometrica*, July 1938, pp. 219-241; G. A. D. Preinreich, "The Practice of Depreciation," *Econometrica*, July 1939, pp. 235-265; G. A. D. Preinreich, "The Economic Life of Industrial Equipment," *Econometrica*, January 1940, pp. 12-44.

Taylor concluded that a proper replacement policy would minimize the unit costs plus interest of the machinery. The proper time for replacement would be the point at which the unit cost plus interest of the old machine exceeded the minimum unit cost plus interest of the new machine.

Hotelling used a continuous function rather than the discontinuous function of Taylor. Hotelling's formula maximized the value of output minus operating costs of the machinery in terms of time, value of output, operating costs, scrap value, the useful life, and the rate of interest. The Taylor and Hotelling formulations were admitted equivalents in a static economy.

Preinreich introduced the concept of the infinite chain of revenues and costs for the new and old machines. His formulation maximized the present value of future net profits. The Preinreich formultaion was more suitable for a replacement analysis in a dynamic economy than those of his predecessors.

[3] M. O. Vorlander and F. E. Raymond, "Economic Life of Equipment," *Transactions of the American Society of Mechanical Engineers*, 1932, Vol. 54, RP-54-2, pp. 29-51; Joel Dean, *Capital Budgeting*, Columbia University Press, 1951, pp. 89-120; Armen A. Alchian, "Economic Replacement Policy," The Rand Corporation, hectographed, Report R-224, April 12, 1952; Maurice Moonitz, "The Risk of Obsolescence and the Importance of the Rate of Interest," *Journal of Political Economy*, August 1943, pp. 348-355; Eugene L. Grant, *Principles of Engineering Economy*, Ronald, 1938, pp. 182-221; F. and V. Lutz, *The Theory of Investment of the Firm*, Princeton University Press, 1951, pp. 101-114; Simon Kuznets, "Relation between Capital Goods and Finished Products in the Business Cycle," *Economic Essays in Honor of Wesley Clair Mitchell*, Columbia University Press, 1935, pp. 236-243.

Dean compared the rate of return available from an undiscounted replacement to the rate of return obtainable from alternative investments.

so technical, requiring complicated mathematical calculations, that they have not been generally used. There has long existed a seemingly unbridgeable gap between good thinking and actual practice."[4]

Hicks believed that recent suggestions of George Terborgh,[5] especially as simplified in the *MAPI Replacement Manual,*[6] had a chance of being adopted by executives. Should Terborgh's formulas be adopted generally, investigators of the future might have a far better basis for predicting the retirement and replacement practices of individual firms than is now possible.

Terborgh suggested that in making its replacement decision, the firm should compare the alternative of retaining the present machine one additional year and replacing it with an infinite succession of machines at that time, or replacing the present machine immediately with an infinite succession of machines. He noted that replacement does not usually occur instantaneously but rather occurs in the form of a continuing functional degradation in which the machine is moved gradually from main-line to standby service. By the time the machine is scrapped, it has usually been replaced many times. Terborgh is studying the first replacement: the purchase of a new machine, shunting the present machine into the second most important function it could perform. Terborgh makes two assumptions: (1) that future machines competing for the function will have the same adverse minimum (the minimum time-adjusted sum of capital cost and operating inferiority compared to the annual projected best available machine) as the present challenger (best available ma-

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Alchian's formulation was similar to his predecessors in that he optimized future profits discounted to the present. Alchian included tables for rapid easy calculation of the replacement decision. He suggested an alternative decision based on cost minimization for machines whose output cannot be valued, e.g. for machines used by the military.

Moonitz noted the effect of rapid obsolescence in reducing the importance of the interest rate in the replacement decision. Rapid obsolescence caused firms to desire a rapid return of the original cost of replacement in the form of reduced operating costs. Moonitz discovered in a survey that 97.4 per cent of firms tested wanted their original costs returned in five years or less. The interest rate became unimportant because of the comparatively more important risk factor and because the short-year payoff reduced compound interest rate as a factor more than in proportion to the reduction in useful life.

Kuznets noted that the savings in operating cost from replacement were probably tied to the volume of output so that an increase in expected output should accelerate replacement.

[4]Everett M. Hicks, "The Economics of Machine Replacement," *Proceedings of the Society for Advancement of Management,* November 1950, p. 207.

[5]George Terborgh, *Dynamic Equipment Policy,* McGraw-Hill, 1949.

[6]Machinery and Allied Products Institute, 1950.

chine currently); and (2) that the present challenger will accumulate operating inferiority at a constant rate over its service life. With these assumptions he is àble to limit his replacement analysis to a comparison of the adverse minima of the present challenger and the old machine.

Terborgh's work may introduce a greater degree of rationality into the businessman's replacement decisions. It is likely that the result would be a tendency toward shorter lives for equipment; a tendency which would be an important factor for those who would project the replacement requirements of the economy.

Investigations into the literature of actual replacement policies of firms was also of little avail. The variety of approaches, even where the problem was given rational consideration, made it difficult to formulate a device which could be used for prediction.[7]

The most common policy is the short payoff requirement, which requires that a machine pay for itself over a specified period, usually ranging from about one to three years. Another, essentially the same, stipulates that the cost saving must be at least a specified percentage of the investment involved.[8]

There is an extensive literature on the relationship between depreciation allowances and demand for these funds for replacement purposes.[9] Domar noted that depreciation allowances are greater than replacement requirements if there is a positive rate of growth in gross investment. The ratio of depreciation allowances to replacement is a function of the rate of growth and the useful life of capital. Evsey D. Domar presented a formula for estimating the

[7] See, for example, the series of articles published in *American Machinist*, 1931, Vol. 75: Roy C. Blanchard, "A Replacement Policy that Shares Responsibility," pp. 728–742; G. S. Tracy, "Replacing Equipment to Decrease Sales Resistance," pp. 743–753; R. F. Runge, "Replacement by Formula," pp. 762–766; H. K. Spencer, "Continuous Replacement at 10 percent per Year," pp. 798–802; H. P. Bailey, "Profitable Replacement in an 'Average Lot' Plant," pp. 836–853; J. H. Jackson, "Planned Replacement in a 14-Year-Old Plant," pp. 872–878; J. R. Weaver, "Progressive Replacement at a Half Million a Year," pp. 908–917; D. S. Linton, "Diversified Replacement in a Small Plant," pp. 946–953.

[8] Hicks, *op. cit.*, p. 206, and Terborgh, *op. cit.*, pp. 187–214.

[9] Evsey D. Domar, "Depreciation, Replacement and Growth," *Economic Journal*, August 1953, pp. 1–32; R. A. D. Egerton, "The Capital Coefficient and the Rate of Depreciation," *Economic Journal*, March 1953, pp. 111–117; Robert Eisner, "Depreciation Allowances, Replacement Requirements and Growth," *American Economic Review*, December 1952, pp. 820–831; George Terborgh, *The Bogey of Economic Maturity*, Machinery and Allied Products Institute, 1945, pp. 99–132; Fritz Machlup, "The Consumption of Capital in Austria," *Review of Economic Statistics*, January 1935, pp. 13–19.

percentage of gross investment total replacement requirements would be as a function of the rate of growth and the useful life of capital goods, assuming the rate of growth is constant over the useful life of the economy's capital. For use in interindustry analysis this assumption is too restrictive.

Many economists have been concerned with the relationship between the replacement of capital goods and the level of national income.[10] Johan Einarsen explored the role of replacement in the business cycle. One long-standing issue among economists was whether reinvestment surges are generated by the cycle or are factors generating and determining the cycle. Einarsen listed Marx and Robertson as subscribing to the latter theory, and Pigou, Spiethoff, Aftalion and Schønheyder as subscribing to the former theory.[11] Einarsen himself follows the theory of an independent or generating reinvestment cycle. He finds evidence to support this theory in the Norwegian shipping industry, which has shown a strong concentration of replacement in roughly twenty-year cycles, and in which most ships are replaced roughly every twenty years.[12]

Joe. S. Bain reasoned, however, that a pure or independent reinvestment cycle depends on a technologically stable useful life. If the useful life is variable for economic reasons, the cycle will be generated rather than independent. Moreover many of the variables influencing the useful life, such as interest rate, expected value of services, and replacement cost, are influenced by the cycle and will tend to concentrate replacement just after the upturn.[13]

These studies were of great interest and served to further our belief that our investigations into the measurement and prediction or replacement were worthwhile, but did not supply us with any assistance in securing answers to the problem we faced.

[10]See, for example, S. P. Dobrovolsky, "The Effect of Replacement Investment on National Income and Employment," *Journal of Political Economy,* August 1947, pp. 352–358; Benjamin Caplan, "Premature Abandonment and the Flow of Investment," *Quarterly Journal of Economics,* November 1939, pp. 152–157; Benjamin Caplan, "Reinvestment and the Rate of Interest," *American Economic Review,* September 1940, pp. 561–568; Terborgh, *The Bogey of Economic Maturity,* pp. 99–132; C. Emery Troxel, "Economic Influences of Obsolescence," *American Economic Review,* June 1936.

[11]Johan Einarsen, *Reinvestment Cycles and Their Manifestation in the Norwegian Shipping Industry,* J. Chr. Gundersens Boktrykkeri, Oslo, 1938, pp. 13–34.

[12]*Ibid.*, and Johan Einarsen, "Replacement in the Shipping Industry," *Review of Economic Statistics,* November 1946, pp. 225–230.

[13]Joe S. Bain, "The Relation of the Economic Life of Equipment to Reinvestment Cycles," *Review of Economic Statistics,* May 1939, pp. 79–88.

Economists concerned with the measurement of national income have, of course, attempted to measure capital consumption.[14] Without considering the adequacy of these measures, they are not conceptually what we are seeking to predict. In general these are estimates of the service life of capital consumed during a time period. While it is possible that these might infer replacement demand if we knew sufficient detail of the distribution of service life left in the industries of the economy, these approaches could not be used as they stand. As these measures use depreciation data uncorrected for price change (as well as for other reasons), the question has been raised as to their usefulness in measuring capital consumption itself. "The inadequacy of accounting depreciation charges as a measure of capital consumption explains in part the popularity of the gross national product concept, which does not require data for capital consumption, and is the main reason why the Department of Commerce has been reluctant to issue a net national product series."[15]

The measurement of replacement demand for capital goods was implicit in the estimates of the stock of equipment and plant in constant prices presented by the Machinery and Allied Products Institute. Retirements were calculated by assuming an average useful life of seventeen years for all producers' equipment and distributing the retirements about this average on the basis of research done in the preparation of a volume published by the Institute.[16]

The approach used by MAPI is of very limited value for interindustry purposes as it does not distinguish among types of capital equipment. It might perhaps be used by others who are interested in an aggregate estimate. While MAPI did not attempt to use it for prediction of replacement demand, their technique might be used for this purpose. The lack of distinction among types of capital goods

[14]See, for example, Solomon Fabricant, *Capital Consumption and Adjustment*, National Bureau of Economic Research, 1938; Wendell D. Hance, "Adequacy of Estimates Available for Computing Net Capital Formation," *Studies in Income and Wealth, Volume Six*, National Bureau of Economic Research, 1943, pp. 237-276; David McCord Wright, "The Interpretation of the Kuznets-Fabricant Figures for 'Net' Capital Consumption," *Journal of Political Economy*, June 1942, pp. 435-443.

[15]Edward F. Denison, "Report on Tripartite Discussions of National Income Measurement," *Studies in Income and Wealth, Volume Ten*, National Bureau of Economic Research, 1947, p. 12.

[16]*Capital Goods Review*, May 1953. An earlier attempt, but without a dispersion around the average useful life, was described in *Capital Goods Review*, November 1950.

might make it defective even for this purpose, and the dispersion around the average useful life would shift with changes in the composition of the capital stock.

McGraw-Hill conducted a survey of replacement expenditures by manufacturing companies, estimated actual 1950 experience, and predicted that of 1951. In the survey there was no distinction between plant and equipment. This survey indicated the importance of replacement as a proportion of total capital outlays. It gave the estimate that 57 per cent of 1950 capital outlays and 42 per cent of anticipated 1951 outlays were for replacement.[17]

Paul Clark, in his study of the telephone industry, tested the assumption that retirement depends, through a fixed coefficient, upon the existing stock of capital equipment.[18] His results did not indicate this to be a useful approach. The deflation problem was serious here, as all the data used on stocks of equipment and retirements were in terms of original cost.

We believe that the solution lies in attempting to get at the age distribution of the stock of capital goods. We have suggested a number of approaches.[19] In general these assumed that the *average* useful life of producers' durable goods of each type is constant over time. We used the estimates of useful life prepared by the Bureau of Internal Revenue.[20]

Our first approach to estimating replacement by industry of origin was (1) to construct an age distribution series on capital items in 1947 prices, (2) to estimate the useful life of each item in the capital series, and (3) to assume that an item would be replaced at the end of its useful life, taking some account of dispersion around the average useful life.

After our pilot test of this approach, which used many short cuts, the National Income Division of the Department of Commerce agreed to perform this analysis because of their interest in the problem.

[17] "Industry Expands," McGraw-Hill, mimeographed, 1951.

[18] Paul Clark, "The Telephone Industry: a Study in Private Investment," W. Leontief *et al.*, *Studies in the Structure of the American Economy*, Oxford, 1953, pp. 266–267 and 285–292.

[19] Robert N. Grosse, "Replacement Expenditures in the Interindustry Framework," Bureau of the Budget, November 1951; Robert N. Grosse and Edward B. Berman, "The Replacement of Producer Durables," Bureau of the Budget, April 1952, Vol I, and September 1952, Vol. II.

[20] *Income Tax Depreciation and Obsolescence, Estimated Useful Life and Depreciation Rates*, Bureau of Internal Revenue, *Bulletin "F,"* revised, January 1942.

The *Cost and Production Handbook* (L. P. Alford, editor, Ronald, 1934, pp. 1,241–1,269) tabulates estimated depreciation rates culled from many sources in addition to BIR.

In their first run they did not calculate any dispersions of retirements about the average useful life. We have appended their description of their work (Appendix A) and have listed in Table 1, in two-digit standard industrial classification, a summary of their "predictions" for the replacement of producers' durable goods for the years 1954–1956. This work was done under the sponsorship of the interindustry research program of the Department of the Air Force.[21]

TABLE 1

Replacement Requirements for Producers' Durable Equipment, 1954–1956 (*millions of 1947 dollars*)

SIC	*Supply Industry*	*1954–1956*
25	Furniture and fixtures	1,079
34	Fabricated metal products (except ordnance, machinery, and transportation equipment)	550
35	Machinery (except electrical)	10,517
36	Electrical machinery, equipment, and supplies	2,306
37	Transportation equipment, except motocycles, bicycles and parts; and transportation equipment n.e.c.	10,724
38	Professional, scientific, and controlling instruments; photographic and optical goods, watches and clocks	559
22	Textile mill products	79
24	Lumber and wood products (except furniture)	72
39	Miscellaneous manufacturing industries	338
Miscellaneous		131
Total		26,355

n.e.c. = not elsewhere classified.

Criticisms of this approach are numerous. Among others are these:

1. The explicit assumption that equipment is replaced at the end of its useful life is wrong.

2. No account is taken of technological change, either in the useful lives or in the amount of capital necessary to maintain capacity at a certain level. Conceptually replacement is defined as the amount of expenditure of capital goods which will just maintain capacity. Frequently an expenditure for replacement equal in constant dollars to the expenditure useful life years ago will more than replace the scrapped capacity. In this case the amount of expenditure related to the expanded capacity must be considered as *net*

[21]Some of the results and subsequent analysis of this OBE study were published by Raymond Nassimbene and Donald G. Wooden in *Survey of Current Business*, June 1953, pp. 12–16 and 24, and December 1954, pp. 18–26.

investment. The first approach is unable to distinguish between those replacement expenditures which merely maintain capacity and those which expand capacity.

3. Price indexes in the area of machinery and equipment are very poor.

4. Even if frequency distributions around the average are introduced, replacement may be affected by business expectations, the availability of materials, and the supply of funds.

We have attempted to attack these problems. Perry D. Teitelbaum of the Bureau of Mines took up the question of the appropriate frequency distributions to apply to the average useful lives.[22] Teitelbaum based much of his work on the frequency distributions of retirements studied by E. B. Kurtz and R. Winfrey.[23] These men had reduced the number of types of distributions that were characteristic of retirements to a small number. Teitelbaum summarized his conclusions:

1. In using the frequency distribution approach, it appears to matter little which of a large number of possible types of frequency distribution curve is used. The resultant replacement estimates do not differ significantly. Accordingly lack of information on the "correct" distribution for a particular capital good no longer need prevent us from advancing beyond the relatively primitive "average-useful-life assumption," i.e. that *all* equipment installed at any given time is retired together one average useful life later.

2. The time series of replacements based on a specific frequency distribution is affected little by wholesale lumping of the frequencies into fewer and broader class intervals. In fact a sufficiently broad one-class rectangular distribution may yield satisfactory results. This point is of practical importance since such a distribution amounts to nothing more than a moving average.

3. The two preceding points do not necessarily imply that frequency distributions are not significant or that they may be neglected. They merely mean that the *particular* distribution is unimportant. The essential contribution of any frequency distribution is that it provides a means of smoothing out the time series of re-

[22]Perry D. Teitelbaum, "Estimating Replacement Requirements for Producers' Durable Goods," Bureau of Mines, Interindustry Analysis Branch Item 30, processed, August 1953.

[23]E. B. Kurtz, *Life Expectancy of Physical Property*, Ronald, 1930, and *The Science of Valuation and Depreciation*, Ronald, 1937; R. Winfrey, *Statistical Analyses of Industrial Property Retirements*, Bull. 125, 1935, and *Depreciation of Group Properties*, Bull. 155, 1942, Iowa Engineering Experiment Station, Iowa State College.

placements.[24] Teitelbaum's work indicates that the errors arising from an improper frequency distribution are much less significant than errors arising from an improper useful-life estimate.

We directed our attention to the problems of changes in technology and prices and derived requirements by industries purchasing the capital goods as well as by source. The obvious approach of direct observation could not be followed because of the lack of such data. Very little investment data yield information of this type.[25] Replacement outlays are not distinguished from new investment and do not show sources of goods. Deflation is also a serious obstacle to good results.

Information has been developed about the capital structure of industries by the study of plant expansions and other research. We thought it possible to make use of this information for our purposes. We wish to describe an approach to the estimation of replacement requirements by use of data on the relationships between capacity expansion and capital requirements.

If for any period the capacity of an industry is multiplied by the capital coefficients of that industry, the resulting product is a description of what the capital stock of the industry would be for that capacity under the technological conditions of the period for which the coefficients were derived. This description would show the capital stock classified by industry producing the capital. If we applied useful-life estimates to these elements of the capital stock, we could determine when each of these elements of the capital stock would have to be replaced if we knew when they had been installed.

If there had been no change in the capacity of the industry over time, the solution would be relatively simple. Each year a constant proportion of the capacity of each type of capital good would need replacement. This amount is equal to the reciprocal of the useful life of the equipment. Thus if an item with a useful life of ten years is considered, then one-tenth of its capacity needs replacing every year; if its useful life is twenty years, one-twentieth of its capacity needs replacing. Note that we talk of replacing capacity. The investment required for replacing the retired capacity is de-

[24] Teitelbaum, *op. cit.*, pp. 4 and 5.

[25] "American Machinist Mid-Century Inventory of Metal Working Equipment" (*American Machinist*, November 3, 1949, pp. 129–224) presents a large amount of data on the stocks of metalworking machinery held by each of a large number of industries. Unfortunately for our purposes, these data are presented in only a few extremely broad categories and are recorded in terms of number of machines.

termined by multiplying the capacity retired by the current best-practice capital coefficient. This device permits the calculation of replacement in current technology and prices. Thus both the price deflation of capital stock and the measurement of changes in the relations between capital and capacity are avoided.

Let us give a numerical example of this. Suppose that the capacity of the electric power industry has always been 100,000 kilowatts per year, that the transformers of this industry have a useful life of twenty years, and that $30 worth of transformers are required per kilowatt of annual capacity. Then in the current year, one-twentieth of the capacity provided by transformers needs replacing, assuming that the capacity of the industry has been constant over time. It is necessary only to multiply one-twentieth of the total capacity of the electric power industry by the capital coefficient relating transformers to electric power capacity to derive the required expenditure for replacement.[26] The calculation of the replacement requirements would be

$$R_{ij} = \frac{\overline{X}_j}{u_{ij}} (b_{ij})$$

where (each in terms of this industry)

R_{ij} = cost of transformers required for replacement
$\overline{X}_j$ = annual capacity in kilowatts
u_{ij} = useful life of transformers
b_{ij} = dollars of transformers required per kilowatt of capacity

then

$$R_{ij} = \frac{100{,}000}{20} \times \$30 = \$150{,}000$$

The equal-age-distribution assumption is not too unrepresentative of an industry which has been fairly stable for a number of years, as, for example, copper. It is, however, a poor assumption for an industry such as electric power which has had a rapid rate of growth over recent years. The difficulty with this approach is in the assumption that one-twentieth of the total available capacity to transform must be replaced in the current year. We therefore suggest, as a modification of the second approach, an alternative way of estimating how much transformer capacity must be replaced.

[26]Implicit in this approach is the assumption that the industry's capital structure is always in balance, i.e. at maximum production there are no unutilized machines and capital goods aggregated by industry of source are complementary.

We may state that the capacity to transform which must be replaced in the current year, 1955, will be equal to the total capacity to transform installed twenty years ago, both for purposes of expansion and replacement. The capacity to transform installed twenty years ago for expansion purposes may be estimated as the expansion of capacity in the industry during 1935 times the current best-practice capital coefficient. The resulting estimate represents the new transformers equal in capacity to the transformers installed in 1935 for expansion only. The transformer capacity installed for replacement purposes in 1935 may be estimated by going back twenty more years to 1915 and estimating the transformer capacity installed in that year for both expansion and replacement. The new transformers equivalent in capacity to the transformers installed in 1915 for expansion is equal to the expansion in electric power capacity in 1915 multiplied by the capital coefficient for transformers. The replacement transformer capacity installed in 1915 may be estimated by going back to 1895 and noting the total installation of transformer capacity in that year. However, since there was no electric power industry in 1895 worth mentioning, the replacement of transformers in 1915 may be considered zero. The total transformer capacity which must be replaced this year then equals the expansions in electric power capacity in 1915 and 1935 multiplied by the current best-practice capital coefficient.

Implicit in the technique is the assumption that the scrapping of equipment purchased by the industry of use from the industry of origin will cause a decrease in the capacity of the industry of use which can be restored only by the purchase of new equipment from the industry of origin equivalent in capacity to the scrapped equipment. The technique also implies that equipment tends to retain its full capacity during its useful life. This latter assumption does not mean that the equipment may not tend to be relegated to a stand-by status as it approaches the end of its useful life, nor does it imply that maintenance costs may not tend to rise toward the end of the useful life. It does, however, require that the capacity to produce its particular output remain fairly constant from the time of its purchase to the time of its retirement.

We have estimated the loss in capacity in year t associated with the scrapping of a capital good as equal to the expansion in capacity plus the replacement of capacity in year t minus the useful life of the capital good. The replacement in year t minus the useful life, on the other hand, equals the expansion in capacity plus the replacement of capacity in year t minus twice the useful life. The replacement in capacity in year t minus twice the useful life equals the expansion in capacity plus the replacement of capacity in the year t minus three times the useful life and so forth.

The loss in capacity in year t is therefore estimated as equal to the sum of expansions in capacity in years separated by integral multiples of the useful life, starting from year t and working backward. In other words if the useful life of equipment purchased by the industry of use from the industry of origin is ten years, the loss in capacity this year would be estimated as the sum of the expansions in capacity ten years ago, twenty years ago, thirty years ago, and so forth to the beginning of the industry.

The following is a suggested formulation for calculating the replacement requirement of a particular type of equipment purchased by a particular industry.

$$R_{ij}^t = \left(\Delta \overline{X}_j^{t-u_{ij}} + \Delta \overline{X}_j^{t-2u_{ij}} + \Delta \overline{X}_j^{t-3u_{ij}} \ldots + \Delta \overline{X}_j^{t-nu_{ij}}\right) b_{ij}^t$$

where

$\Delta \overline{X}_j^t$ = increase in annual capacity of industry j between beginning and end of year t

u_{ij} = useful life, in years, of a capital good purchased by industry j from industry i

$\Delta \overline{X}_j^{t-u_{ij}}$ = increase in annual capacity of industry j one u_{ij} ago

R_{ij}^t = amount, in dollars, of replacement expenditures required to be purchased by industry j from industry i in order to maintain capacity of industry j in year t

b_{ij}^t = value of capital goods, in current prices and technology, required from industry i by industry j per unit increase in annual capacity of industry j in year t

The amount of capacity to be replaced in a given year is treated as a function of the installation of that capacity useful life years ago. These installations (useful life years ago) are in turn a function of the requirements at that time for expansion and for the maintenance of capacity (replacement). The first element, expansion, can be expressed as the difference between the capacity useful life years ago and the capacity useful life minus one year ago. This is the first term after the parenthesis in the equation above

$$\Delta \overline{X}_j^{t-u_{ij}}$$

The remaining installations of capacity useful life years ago are for replacement purposes and may be determined in the same fashion. Thus replacement purchases one useful life years ago would be a function of purchases for expansion two useful life years ago and purchases for maintenance of capacity two useful life years ago. The expansion of capacity two useful life years ago is represented in the second term of the equation

$$\Delta \overline{X}_j^{t-2u}{}_{ij}$$

To determine purchases for replacement two useful life years ago, we need to examine in the same way purchases for expansion and replacement three useful life years ago, etc.

A numerical example using hypothetical data may be of use in explaining how this formulation is used. Let us assume that we are concerned with capital goods purchased by industry j from industry i and that these goods have a three-year useful life. The table following hypothecates the capacity of industry j and the purchases and retirements of capital good i by industry j.

Year	*Purchases*	*Retirements*	*Capacity, Dec. 31 (tons)*	
1936	\$ 1		2	
1937	1		4	$\Delta \overline{X}_j^{t-5u}{}_{ij} = 4 - 2 = 2$
1938	1		6	
1939	1	\$1	6	$\Delta \overline{X}_j^{t-4u}{}_{ij} = 6 - 6 = 0$
1940	1	1	6	
1941	2	1	8	
1942	2	1	10	$\Delta \overline{X}_j^{t-3u}{}_{ij} = 14 - 10 = 4$
1943	3	1	14	
1944	5	2	20	
1945	5	2	26	$\Delta \overline{X}_j^{t-2u}{}_{ij} = 28 - 26 = 2$
1946	4	3	28	
1947	7	5	32	
1948	6	5	34	$\Delta \overline{X}_j^{t-u}{}_{ij} = 42 - 34 = 8$
1949	(8)	4	42	
1950	9	7	46	
1951	10	6	54	
				16

$$b_{ij}^t = \$0.50/\text{ton}$$

$$R_{ij}^t = 1952 = 0.50\,(8+2+4+0+2) = 0.50\,(16) = 8$$

In this example it is assumed that the relevant capital coefficient is \$0.50 per ton. The problem is to predict the retirements of i by j in 1952. From the purchases column, given the three-year life of the equipment, we can predict that \$8 of capital good i held by industry j will be retired. The formula suggested above is designed to arrive at the same answer without knowledge of past purchases. The data required by the formula are the capacity series, the useful life, and the capital coefficient. By calculating the capacity changes every three years (the useful life of i), we obtain 8, 2, 4, 0, 2; the sum of these is 16; multiplying by the capital coefficient of \$0.50, we arrive at the answer \$8.

Year	Purchases	Replacement Requirements	Capacity (tons)	
1936	\$1		2	
1937	1		4	$\Delta \overline{X}_j^{t-5u_{ij}} = 4 - 2 = 2$
1938	1		6	
1939	1	\$1	6	$\Delta \overline{X}_j^{t-4u_{ij}} = 6 - 6 = 0$
1940	1	1	6	
1941	2	1	8	
1942	2	1	10	$\Delta \overline{X}_j^{t-3u_{ij}} = 14 - 10 = 4$
1943	3	1	14	
1944	5	2	20	
1945	2.5	1	26	$\Delta \overline{X}_j^{t-2u_{ij}} = 28 - 26 = 2$
1946	2	1.5	28	
1947	3.5	2.5	32	
1948	3	2.5	34	$\Delta \overline{X}_j^{t-u_{ij}} = 42 - 34 = 8$
1949	(4)	2	42	
1950	4.5	3.5	46	
1951	5	3	54	
				16

$$b_{ij}^t = \$0.25/\text{ton}$$

$$R_{ij}^t = 1952 = 0.25\,(8 + 2 + 4 + 0 + 2) = 0.25\,(16) = 4$$

Let us see, in a second example, what the result would be if technological change had occurred in the relationship between capital and capacity. Suppose that an innovation introduced in 1945 caused the capital coefficient to become \$0.25 per ton instead of \$0.50, with no change in the useful life. If the capacity series remains the same, only half as much capital need be purchased in each of the years 1945–1952 as in the first example.

To predict 1952 replacement requirements, the relevant capacity changes, 8, 2, 4, 0, 2 are summed, equaling 16 as in the first example. In this case, however, as the current capital coefficient is \$0.25 per ton, we multiply 16 by this and our answer is \$4. Looking back at the purchases three years prior to 1952, we also arrive at \$4. In this case the suggested formulation can achieve an answer using the current capital coefficient and the capacity series, and historical changes in the capital coefficients need not be investigated.

This method, by eliminating the need for examining historical records of capital purchases by industry of use (which are almost nonexistent), also obviates the need to construct price indexes for capital goods over the time studied. If the capacity of an industry is available only in dollars, it would, of course, be necessary to deflate these series to the same base-year dollars as the capacity element of the capital coefficient.

This technique is limited to those industries for which capital coefficients and capacity time series are available. For experimental purposes calculations of replacement requirements using this technique were made for electric power (see Appendix B). The summary results for electric power are given in Table 2, along with comparable replacement reported to the Federal Power Commission.

Both the replacement estimates, which we have prepared, and the replacement reported to the FPC represent replacement for only steam generation, hydroelectric generation, electric power transmission, and electric power distribution. Our estimates were first prepared in the form of shipments of capital, broken down into 190-order detail, required for the years 1947, 1948, 1949, 1950, and 1954. For purposes of comparison, the I-0 replacement estimates from the 190-order detail were aggregated into a total replacement estimate for each year, and these totals were converted into current prices. The full detail in 1950 prices may be found, however, in the Appendix.

TABLE 2

Electric Public Utilities, Estimated and Reported Replacement, 1947–1950

(millions of current dollars)

Year	*Replacement Estimate*	*FPC Replacement*
1947	182	148
1948	185	201
1949	182	272
1950	190	251
Total	739	871

In cases where capacity series cannot be obtained in the distant past, the purchases for replacement for the last available year may be estimated by assuming that all capital purchased by industry j from industry i before the last available year had an even age distribution. For example let us assume that u_{ij} is ten years and that our capacity series is available only from three u_{ij}'s ago to the present. We may then assume that capital purchased from industry i by industry j between $t-3u_{ij}$ and $t-3u_{ij}-10$ had been so purchased that in year $t-3u_{ij}$, one-tenth of this capital was ten years old, one-tenth was nine years old, and so forth. We may then assume that one-tenth, or $1/u_{ij}$ of this capital would have been replaced in year $t-3u_{ij}$. We may then carry back our formula three terms and insert as a final term

$$\cdots + \frac{\overline{X}_j^{t-3u_{ij}-1}}{u_{ij}} \quad b_{ij}^t$$

For industries in which capacity has not grown substantially in recent years, for example copper mining, the equal-age-distribution assumption may be made without great bias for year t. The formula for replacement in time t then becomes

$$R_{ij}^t = \frac{\overline{X}_j^t}{u_{ij}} \quad b_{ij}^t$$

Aside from the greater computational simplicity of this equal-age-distribution formulation, the data requirements are reduced from a time series of capacity to the capacity of year t. This formulation is, however, susceptible to a large bias in the direction of overstating replacement if the industry has in fact grown at all rapidly in recent years since the age distribution is in that case biased toward the present.

Replacement estimates have been prepared for the iron, steel, and coke industries using the equal-age-distribution assumption applied after one step back. In other words for these industries the equal age distribution assumption was made for all industries of origin for the year $t-u_{ij}-1$.

No independent estimate of replacement is available for coke and iron and steel. The Bureau of the Census has, however, estimated the total capital expenditures of these industries. Using capital coefficients and capacity changes in 1947 and 1950, Table 3 compares our estimates of purchases of machinery and equipment with that of the census.

TABLE 3

Steel and Coke Expenditures for Machinery and Equipment, 1947 and 1950

(*thousands of current dollars*)

	Estimates			*Census*
	Replacement	*Expansion*	*Total*	*Total*
1947:				
Blast furnaces and steel works	75,309	111,710	187,019	218,539
Coke	8,321	8,770	17,091	24,541
1950:				
Blast furnaces and steel works	143,624	151,641	295,265	249,265
Coke	14,506	6,229	20,735	27,128

Although this method takes account of technological changes in the capital coefficients, it does not, of course, take account of changes over time in the useful life of particular types of equipment. It is possible, for example, that the useful life of a machine tool built in 1935 is considerably different from one built in 1943. We know for example that the life expectancy of automobiles is, to some extent at least, related to the year of manufacture. Information which might be used to throw light on the changes in the useful life might be obtained from examinations of BIR corporate income tax returns where useful-life data are collected. If data on changes over time in the useful life were obtained, they could easily be incorporated in the formulation. In the absence of such information, however, we have assumed that the useful-life table published by the BIR is accurate and constant.

It is also likely that the use of some frequency distribution of useful lives around the average useful life is better than a single useful life. In our calculations we attempted something of this sort by taking the spread of capacity increases over three years rather than over one. Teitelbaum's work previously discussed has indicated that better solutions to the problem of dispersion are readily available.

The estimates of replacement described in the paper may need adjustment for significant changes in the economic picture. As recent work in the interindustry problem has been most concerned with war preparation economies, the question to be raised is what validity do our figures, which might apply to a "normal" situation, have during periods of severe economic strain. It might be that the postponement of retirement during such a period and the haste to make up for such periods would render our guesses useless.

Investigations into the actual retirement policies of industries during the period 1939–1952 have been initiated in the interindustry program at the Office of Business Economics, using Securities and Exchange Commission Form 10-K data. While it is much too early at this writing to draw any conclusions, the work indicates that in some industries replacement was in fact postponed, but that in others the effect of the war period on retirements appears negligible. We hope that out of this study will come significant answers to some of our speculations.

APPENDIX A

Note on the Procedures Used in Estimating Discards of Producers' Durable Equipment in Constant (1947) Dollars (1942–1956)[1]

Discards of producers' durable equipment in constant (1947) dollars were estimated for the years 1942–1956 in three-digit standard industrial classification detail and National Income Division producers' durable equipment group detail. As will appear from later comments, these estimates are for the most part in the nature of rough average norms. From the point of view of data available for making the estimates, producers' durable equipment falls into two categories. For one of these, transportation equipment data on discards were sometimes available, and the estimating procedures used are relatively direct. Generally, however, such statistical data do not exist. Consequently for most groups an actuarial-type method, utilizing production data and estimates of useful life, was used.

The Actuarial-Type Method

For each three-digit group (or NID group), a percentage distribution of useful life was derived for each of several production years in the period 1929–1951. This was done as follows. Useful lives of many pieces of equipment have been published by the Bureau of Internal Revenue in Bulletin F. The useful lives were applied to detailed production statistics of producers' durable equipment published in the Census of Manufactures to derive for each group a percentage distribution of useful lives. Where Bulletin F did not furnish adequate information, experts of the National Production Authority, of other government agencies, and local distributors of

[1] Budget Project 2.61, Dept. of Commerce, Bureau of Foreign and Domestic Commerce, Office of Business Economics, January 15, 1953.

equipment supplied it, but Bulletin F furnished by far the largest amount of the useful-life information utilized. A percentage distribution of useful lives was prepared for each of five or more years to test the stability of the distributions over time and to permit the use of more than one distribution if it appeared that the useful-life distribution of any group changed significantly during the period.

On the assumption that the useful-life data conform to the actual rates of discard that occur in business, the group useful-life distributions were applied to the NID estimates of purchases of equipment to derive estimates of discards. The resultant estimates of discards should be regarded as rough averages or norms. They assume that the depreciation rates provided by the BIR to businessmen as a guide are also discard rates and make no allowance for cyclical variation, which might be substantial. It was assumed, except in the case of mechanical measuring and controlling instruments (SIC 382), that the equipment covered by emergency amortization from 1941 to 1945 (original cost about $3 billion, excluding railroad equipment) continued to be useful after the end of World War II, so that the normal discard rates were applied to it. For mechanical measuring and controlling instruments, the emergency amortization equipment for all years 1941–1945 (original cost about $60 million) was assumed to have been discarded during 1945.

For a few minor groups, such as ophthalmic goods (SIC 385), no entry appears in the table for some of the years 1942–1956. This is not necessarily an indication that such equipment was not being discarded in these years, but that production data for making the estimates were not available. The estimates for these minor groups should not be used by themselves.

More Direct Methods

Motor vehicles and motor vehicle equipment (SIC 371): Data on quantities of motor vehicles scrapped are published by the Automobile Manufacturers Association. The same source gives stock of vehicles by year of manufacture for selected years. These distributions of stocks by year of manufacture were smoothed by graphical methods; following this, the missing years were interpolated. Then, by differencing adjacent year stocks, estimates of discards by year of manufacture were drawn up. These discards were then used to weight average unit prices in year of manufacture to get average original unit prices of discards by year of discard. For each year of discard, the average original unit prices were multiplied by the quantities of vehicles scrapped (as published by the

AMA) to get value of discards at original cost. Estimated physical discard rates by age of vehicle in effect during 1951 were assumed to hold for the period 1952–1956. These discard rates were then applied to production data to derive estimated discards for the period 1952–1956. Discards of passenger cars (SIC 37171) were allocated to producers' durable equipment by the same percentage (30 per cent) used to estimate NID purchases of new cars.

Discards of auto heaters (a component of NID Miscellaneous) were based on the discard computation for passenger cars.

Aircraft and parts (SIC 372): After consulting with staff members of the Civil Aeronautics Board, it was decided that perhaps the best way to estimate discards was to estimate accidental losses from CAB reports and to double this estimate to cover exports of used civilian equipment and other forms of discard. (Physical scrapping of business aircraft other than that due to accidents will have been practically nonexistent during the period 1942–1956, we believe.) The 1952–1956 projection is an arbitrary continuation of 1951.

Ship and boat building and repairing (SIC 373): Discards were computed from constructed estimates of stocks which were developed as follows: For each year 1942–1952, an estimate of the value of stocks at the beginning of the year by year of construction was made. For ships constructed after 1940, the NID producers' durable equipment series on ships, after deducting accidental losses, was used as the stocks component. For ships built in earlier years, a value index of ship registrations by year of construction was developed from Bureau of Customs data and a construction cost index, and tied to the producers' durable equipment estimate for 1941. Discards for each year were computed by differencing stocks for two successive years. Estimated average discard rates by age of vessel exclusive of sales abroad in effect during 1945–1951 were assumed to hold for the period 1952–1956. These discard rates were then applied to 1951 stocks data (adjusted to include domestic purchases of government surplus ships) to derive estimated discards for the period 1952–1956.

Railroad equipment (SIC 374): Discards are based on data of the Interstate Commerce Commission which it compiles from the accounts submitted to it by Class I railroads. They were computed from "credits to investment account." The post-World War II discard trends were projected for 1952–1956.

The estimates made by the more direct methods are, except for ship and boat building and repairing, entirely independent of the

NID estimates of purchases of producers' durable equipment. The treatment of emergency amortization equipment by the more direct methods is similar to that for the actuarial-type method; the discard estimates assume a normal useful life. For railroad equipment, however, the basic data already incorporate the effect of emergency amortization as it actually affected railroad accounts.

One might suppose that the estimates based on more direct methods would be more reliable than those based on the more theoretical actuarial-type method. We feel this is not the case. Transportation equipment moves back and forth readily from the universe of domestic business use to other uses—by persons, by government, and abroad. This movement presents large problems of estimation; consequently with the exception of railroad equipment, which should be one of the best estimates, the transportation equipment estimates are believed to be less reliable than the others. (If the actuarial-type method had been used throughout, the transportation equipment estimates would have been weaker than those derived by the direct method.) The estimate of discards of aircraft is one of the weakest of all the estimates. It is useful only as an indicator of the small magnitudes involved. Of the larger estimates, the motor vehicle estimates, especially those of passenger cars, are probably the weakest. The disparate uses of motor vehicles, their sale and purchase on the used market, and the somewhat arbitrary allocation of passenger car discards to business use make these estimates less reliable than the others. The ships and boats estimates, which were among the most difficult to make, are also weak; government subsidization, which affects the valuation of ships, and the use of total registrations to extrapolate the privately owned fleet may introduce inaccuracies.

The Deflation Procedure

The usual deflation procedure was to apply price indexes to all value or price data used in making the original cost estimates and then to repeat the computations of discards to get deflated (1947 = 100) estimates. The indexes used were those that had been constructed for deflating the NID producers' durable equipment groups. In almost all cases the deflators were revised for recent years, where necessary, to conform to the new BLS wholesale price indexes.

There were some exceptions to this procedure. Discards of aircraft and parts (SIC 372) were deflated by a specially constructed price index of the original cost of active stocks. For railroad equipment (SIC 374), where the estimates result from adjustments to accounting data, special deflators for each major type of equipment were constructed from railroad construction cost indexes of the ICC. Quantities of stocks by year of construction were estimated from ICC data for the same types of equipment in service; for each type of equipment, differences between stocks for successive years were used to weight the ICC indexes to derive discard deflators.

APPENDIX B

TABLE B-1

Electric Utilities,[a] Total Capacity, 1898-1950

(millions of kilowatts)

Dec. 31	*Total Capacity*	*Dec. 31*	*Total Capacity*
1898	0.00	1925	21.47
1899	0.20	1926	23.39
1900	0.30	1927	25.08
1901	0.60	1928	27.80
1902	1.21	1929	29.84
1903	1.51	1930	32.38
1904	1.81	1931	33.70
1905	2.11	1932	34.39
1906	2.41	1933	34.59
1907	2.71	1934	34.12
1908	3.20	1935	34.44
1909	3.69	1936	35.08
1910	4.18	1937	35.62
1911	4.67	1938	37.49
1912	5.17	1939	38.86
1913	5.93	1940	39.93
1914	6.70	1941	42.41
1915	7.46	1942	45.05
1916	8.23	1943	47.95
1917	8.99	1944	49.19
1918	10.23	1945	50.11
1919	11.47	1946	50.32
1920	12.71	1947	52.32
1921	13.52	1948	56.56
1922	14.19	1949	63.10
1923	15.64	1950	68.50
1924	17.68		

[a]Includes publicly and privately owned utilities. Does not include industrial establishments.

Source: For 1920–1950: *Statistical Bulletin, 1950. The Electric Light and Power Industry in the United States*, Edison Electric Institute, July 1951, p. 14.

For 1902, 1907, 1912, and 1917: Capacity figures were obtained from *Historical Statistics of the United States, 1789–1945*, Bureau of the Census, 1949, p. 158, Table G-218.

For other years between 1898 and 1919: Capacity figures were obtained by interpolation and extrapolation.

TABLE B-2

Replacement Estimates, Electric Power, 1947–1954

(estimates in thousands of 1950 dollars)

I-O Number	Industry	Useful Life (years)	Capital Coefficient[a]	Replacement 1947
36	Logging	35	$ 9.08	$ 6,951
72	Structural clay products	35	1.55	903
73	Pottery and related products	35	4.50	2,623
76	Asbestos products	25	2.29	2,234
80	Iron foundries	45	0.37	149
83	Copper rolling and drawing	45	1.11	447
90	Secondary nonferrous metals	30	0.15	136
92	Iron and steel forgings	35	2.66	1,548
98	Heating equipment	28	0.37	457
100	Boiler shop products and pipe bending	28	15.28	18,939
101	Metal stampings	30	0.30	273
103	Lighting fixtures	22	1.40	4,185
104	Fabricated wire products	45	13.80	5,574
110	Steam engines and turbines	30	13.28	12,271
111	Internal combustion engines	15	1.55	3,195
114	Construction and mining machinery	8	1.85	10,088
116	Machine tools and metal-working machinery	25	0.15	144
119	Pumps and compressors	22	4.21	12,556
120	Elevators and conveyors	23	0.66	1,836
121	Blowers and fans	15	1.62	3,347
123	Industrial machinery n.e.c.	20	4.72	11,686
124	Commercial machines and equipment n.e.c.	25	0.22	216
125	Refrigeration equipment	20	0.07	183
126	Valves and fittings	20	0.96	2,374
129	Wiring devices and graphite products	40	6.49	2,360
130	Electrical measuring instruments	28	7.53	9,332
131	Motors and generators	30	11.22	10,363
132	Transformers	28	31.96	39,616
133	Electrical control apparatus	28	15.28	18,939
134	Electrical welding apparatus	20	1.48	3,652
135	Electrical appliances	20	0.15	365
136	Insulated wire and cable	45	22.51	9,091
139	Radio and related products	12	0.30	603
141	Communication equipment	12	0.15	302
142	Storage batteries	20	0.52	1,278
153	Instruments, etc.	17	1.85	4,869
	Total			$203,087

(continued on next page)

TABLE B-2 (continued)

(estimates in thousands of 1950 dollars)

Replacement 1948	Replacement 1949	Replacement 1950	Replacement 1954	I-O Number
$ 6,951	$ 6,951	$ 8,385	$ 8,224	36
1,045	1,187	1,187	1,921	72
3,035	3,447	3,447	5,581	73
3,174	5,552	6,363	6,256	76
149	110	110	181	80
447	331	331	544	83
160	183	162	358	90
1,791	2,035	2,035	3,294	92
404	334	360	910	98
16,726	13,841	14,915	37,674	100
319	366	323	716	101
3,878	3,380	3,436	1,718	103
5,571	4,132	4,132	6,779	104
14,370	16,469	14,544	32,237	110
2,519	2,411	2,416	6,747	111
11,424	12,061	13,162	11,643	114
205	358	411	404	116
11,633	10,139	10,308	5,155	119
1,983	1,906	1,601	1,291	120
2,639	2,525	2,532	7,068	121
12,178	13,822	11,599	3,694	123
307	537	616	605	124
190	216	181	58	125
2,474	2,808	2,356	750	126
2,775	3,190	3,190	4,973	129
8,242	6,820	7,349	18,564	130
12,135	13,907	12,282	27,222	131
34,987	28,952	31,198	78,805	132
16,726	13,841	14,915	37,674	133
3,806	4,319	3,625	1,154	134
381	432	362	115	135
9,086	6,739	6,739	11,057	136
1,095	1,361	1,445	1,777	139
548	681	723	889	141
1,332	1,512	1,269	404	142
4,209	2,767	1,671	4,644	153
$198,894	$189,623	$189,682	$331,088	

[a] 1950 dollars of expenditure per kilowatt increase in capacity.
n.e.c. = not elsewhere classified.
Source: Worksheets of the Federal Power Commission.

COMMENT

EVSEY D. DOMAR, The Johns Hopkins University

Robert N. Grosse and Edward B. Berman's paper is based on the assumptions that (1) capital coefficients and (2) the longevities of different kinds of capital are known with sufficient precision to allow estimates of replacement requirements to be made. The first assumption is bold, but its validity, so thoroughly discussed in the other papers in this volume, can be excluded from the present one. The second assumption is very common and, I imagine, unavoidable in the present context, but it may be somewhat incompatible with what follows.

The problem falls into two parts: (1) the determination of a general method of measuring replacement requirements, and (2) the development of special techniques to overcome the insufficiency of statistical data. Until very recently, the first part would have been solved by simply identifying replacement requirements with depreciation charges, more or less as reported in financial statements. It is well known, however, that these charges are related more closely to tax considerations than to actual wear and tear of capital. If has also been observed that a large, and perhaps a major, part of our industrial capital is so well maintained that its productive capacity hardly declines with time; it is retired in response to technical obsolescence rather than to actual deterioration. In a stationary society this observation would be of little importance, insofar as our problem is concerned, because replacement requirements would be reasonably close to depreciation charges, provided that the longevity of capital was estimated correctly and price changes accounted for. But even under these conditions, in an economy like ours, characterized by growth and fluctuations, the disparity between replacement and depreciation can be quite large. For these reasons the authors equate replacement requirements not with depreciation charges but with investment undertaken (more correctly—capacity installed multiplied by the proper capital coefficient) u years earlier, u being the longevity of capital. On the whole this is a step in the right direction; yet I wonder if the improvement is not a bit overdone and if the implied assumption on which it rests—that capital retains its full productive capacity to the very end—is universally true. Since the purpose of the paper is not to present a theoretical model but a practical method for estimating replacement requirements, this question cannot be settled without factual information. It may very well happen that the diminution in productive capacity suffered by capital during its life span differs considerably from one kind of capital to another and that therefore, depending on the actual situation, replacement requirements will be somewhere between investment undertaken u years earlier and current depreciation charges and in some rare cases may even lie beyond either limit.

Having taken the position just described, the authors estimate the investment undertaken (capacity installed) u years earlier. For this estimate an age distribution of assets was required, but unfortunately was not available. In its absence, an indirect and a rather ingenious method was developed with which I have no quarrel. The skeptics may be consoled by the thought that the results derived by it can be compared with those obtained in other ways; for instance from algebraic formulas based on some assumed rate of growth. These formulas are too rigid to be used directly, but they can help in deciding whether the estimates obtained by the authors' method are reasonable or not.

It seems to me, however, that the main difficulty lies not in estimating, in one manner or another, the amounts of capital constructed in the past, but in the validity of the assumption that capital will actually be replaced after a definite interval of time. If the productive capacity of a given piece of capital equipment remains relatively unimpaired over time, as was assumed and not without reasons in the paper, its longevity must be a rather flexible magnitude, and its replacement can take place after $u + n$ years, where n may be one or three or five years or even more. Even if the amount of capital constructed u years previously were known precisely, there would be no assurance that it has not already been replaced; nor if it still exists, that it will be replaced as expected. The magnitude and nature of recent investment activity are certainly not irrelevant here. It is reasonable to suppose, for instance, that whatever the exact distribution of investment some u years earlier might have been, the most pressing replacement requirements accumulated during the depression and World War II have been met in the last eight years or so and that not very many are now left. For these reasons I doubt if the *annual* figures obtained on the basis of the methods presented in the paper will be trustworthy. Their reliability will naturally increase if they are made for longer periods, such as three or five years.

Very little is said in the paper about the special problem created by the gradual, though not necessarily continuous, relegation of capital to less important uses in the same firm or about its sale to others. This subject, as well as the general field of used equipment, deserves much more attention, both on theoretical and empirical levels, than it usually gets.

In evaluating the present paper, as well as the others presented on this program, we should compare their results not with those obtained by some ideal method—here the disparity is of course great—but with what can be done by some reasonably practical alternatives. So viewed, these papers appear to be steps in the right direction, but in a long journey.