TITLE: COMPUTER PROGRAMS FOR CAPITAL COST ESTIMATION, LIFETIME ECONOMIC PERFORMANCE SIMULATION, AND COMPUTATION OF COST INDEXES FOR LASER FUSION AND OTHER ADVANCED TECHNOLOGY FACILITIES

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INTRODUCTION

Among the most important tasks of the systems analysis group at LANL's Power Division is the assessment of the economic merit of various concepts for the production and application of inertial confinement fusion energy, e.g., for electricity production, as a thermal energy source for synergetic fuel production, and for process energy in general. Occasionally, we also perform assessments for more conventional production. In these assessments are required by program planners to provide national leaders in the context of cost, and system facts delivered on a consistent basis from the pool of research and development funds.

To automate, to the extent possible, calculations performed in these assessments, early in its operations, and at reasonable cost, a program of conceptual, conceptual, and analytical developments, commercial and experimental data was developed, and components of a comprehensive package were implemented. Among these programs are: H.P@n3wg-ass, IM+-+-%—, and HP@n3wg-ass. These programs automate in independent stands, and are run in separate runs. However, these programs can be merged if a comprehensive package is desired. The programs, however, may be more easily used if separate assessments are made for the programs. Benefits from the automation of such computer tasks include:

- Lower computational costs,
- Less computer time required, and
- More sophisticated and accurate assessments made.

In developing these programs, it was also attempted to provide computer programs to assist in the development, while simultaneously making use of work of national leaders in present and future development for the needs of the assessment. As a result, the programs allow users to concentrate only on the stages of development which are necessary to meet their needs. The programs can be used to assist in the production of independent runs, or to make up the complete set of runs for any particular set of objectives. The programs can also assist in the production of independent runs, or to make up the complete set of runs for any particular set of objectives. The programs can also assist in the production of independent runs, or to make up the complete set of runs for any particular set of objectives.
has been made to provide data bases for them. The
user must supply all data, either as input or
through merger or linkage with other computer pro-
grams.

No detailed users' manuals have yet been writ-
ten for these programs. However, programs listings
are being provided on request, and the provision of
tapes or card deck can be discussed. Clearly, the
inclusion of program listings, detailed instruc-
tions for use of these programs, and detailed de-
scriptions of the computational methods are not pos-
sible in the allotted space. Therefore, the fol-
lowing discussion of the programs can only stress
their general characteristics and capabilities.

**Account Structure Treated by CAPITAL**

The subsystems, components, and subcontracts
that make up the facility whose capital cost is
being estimated can be grouped in a semi-arb-
trary manner by the user of CAPITAL and assigned to
accounts that constitute the entities with which CAP-
ITAL associates costs. Each account can be identi-
ified by an account number, associated with an arbi-
trary description of the items included in the ac-
count, e.g., equipment, materials, or contract
work. The account numbering system has the fol-
lowing features:

- Each account number consists of six two-digit
  numbers, separated by decimal points, with each
two-digit number corresponding to an account
level and with the highest (lowest) account
level corresponding to the first (last) two-di-
git number.

- If two account numbers have the same first n
  two-digit numbers, but the (n+1)st and subse-
quently two-digit numbers are zero for one of the
two accounts, then that account is included in
the other as a subaccount.

- This account numbering system is very flexible
  and should accommodate almost any breakdown of
  almost any construction project. An example of the
  account numbering system is presented in Table 1.

**Table 1**

<table>
<thead>
<tr>
<th>Account Number</th>
<th>Description of Items Included in Account</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>Electric plant equipment</td>
</tr>
<tr>
<td>24.01</td>
<td>Switchgear</td>
</tr>
<tr>
<td>24.01.01</td>
<td>Generator Circuits</td>
</tr>
<tr>
<td>24.01.02</td>
<td>Station Service</td>
</tr>
<tr>
<td>24.01.03</td>
<td>Station Service Equipment</td>
</tr>
<tr>
<td>24.02.01</td>
<td>Station Service Institution</td>
</tr>
<tr>
<td>24.02.02</td>
<td>Transformers</td>
</tr>
<tr>
<td>24.02.03</td>
<td>Low Voltage Unit Substation and Lighting Transformers</td>
</tr>
<tr>
<td>24.02.04</td>
<td>Battery System</td>
</tr>
<tr>
<td>24.02.05</td>
<td>Diesel Engine Generators</td>
</tr>
<tr>
<td>24.02.06</td>
<td>Gas Turbine Generators</td>
</tr>
<tr>
<td>24.03.01</td>
<td>Motor Generator Sets</td>
</tr>
<tr>
<td>24.03.02</td>
<td>Switchboards (Including Heat Tracing)</td>
</tr>
<tr>
<td>etc.</td>
<td></td>
</tr>
</tbody>
</table>
The user designates a semi-arbitrary subset of the entire set of accounts as base-level accounts for which basic cost data are to be supplied and basic cost estimates are to be computed. No account designated as base-level can be contained in another base-level account. However, not all accounts designated as base-level accounts need be on the same level. This involves the tacit assumption that costs for all the items contained in higher-level accounts are to be lumped. The available cost data may, of course, be in unlumped form or it may be convenient to lump costs if acceptable loss in accuracy is involved.

The user can also designate several arbitrary subsets of the entire set of accounts as summary account subsets. For each summary account the costs associated with all base-level accounts contained in the summary account are summed and printed. Base-level accounts can be designated as summary accounts.

Features and Capabilities of Subsets:

Eleven cost categories are associated with each base-level account:
- factory equipment,
- spares,
- site materials,
- engineering and design,
- inspection and testing,
- craft labor, which can be further divided into individual craft labor types,
- equipment and transportation,
- package deal or subcontract,
- use taxes,
- overhead, and
- profit.

Factory equipment costs for each base-level account for each construction period during which expenditures for that type of equipment are made are computed as the product of a base cost for that equipment, the scaling law for that account, the amount of equipment purchased for that account during that construction period, a site factor for that account, an escalation factor for that equipment during that period, and a contingency factor for that account. Spares, engineering and design, inspection and testing, equipment and transportation, and package deals or subcontracts are estimated in a similar manner. Craft labor costs for a base-level account covering a particular construction period during which that account is active for each craft labor type is computed as the product of a labor productivity factor for that craft labor type, an efficiency factor for that craft labor type, an expression that takes into account overtime for that craft labor type, a supervision factor for that craft labor type, a basic hourly wage for that craft labor type, the number of hours of craft labor of that type required for that account during that construction period, a site factor for that account, and an escalation factor for that craft labor type during that construction period.

Use taxes are assessed against the total of the computed costs for the various cost categories in each base-level account for each construction period by multiplying by a use-tax factor for that construction period. Overhead and profit are estimated by multiplying the sum of the computed costs by the use-tax factor for each base-level account and then multiplying the result by a profit factor for that account. Values for most of the parameters listed in this and the preceding paragraph must be supplied by the user, but a number of default values for some of the parameters are provided. Also, common parameter values may be distributed over all construction periods, individual accounts, or craft labor types, where such precedences exist, to reduce the number of input data. In such simplifications are made, a list of data or the resulting loss of accuracy is optional.

The total cost associated with each project is obtained by use of a scaling law in the form:

\[ C = a + bN + cN^2 \]

where \( a \), \( b \), and \( c \) are scaling-law parameters for
that account and \( S \) is the scale, i.e., size, capacity, or number of the items covered by that account relative to some reference scale.

An arbitrary construction schedule is defined by specifying an arbitrary number of construction periods of arbitrary durations.

Several optional methods for computation of interest on borrowed capital incurred during construction are available to the user of CAPITAL. They are listed in Table II. The calculations are straightforward and will not be discussed in further detail here. The interest expense incurred and the cost of labor during each construction period and the cumulative interest expense incurred and the cumulative cost time through each construction period can be computed, printed, and point-plotted. Note that all construction projects are to be of exactly the same size, then the associated interest expenses can be interest rates and, if computed, will comprise generally compounded annual rates. If all construction periods are to be of equal duration, but not equal to one year, and if the interest rate associated with each construction period is the same, then relating these interest rates to annually compounded annual rates is relatively straightforward. For other cases, the relationship of interest rates to annually compounded annual rates can still be deduced, but with some difficulty.

Costs: for generic facility equipment, such as wiring or piping, can be summed across account boundaries using CAPITAL. This is a relatively standard architectural-engineering firm cost estimating practice. However, this practice appears to be useful for estimating costs of facilities into distinct subsystems and associating with each the costs of the necessary wiring, or piping, which are logically regarded as constituting integral parts of those subsystems.

### Table II

<table>
<thead>
<tr>
<th>Option Number</th>
<th>Time of Borrowing</th>
<th>Time of Repayment</th>
<th>Interest Rate per Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No</td>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>No</td>
<td>B</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Yes</td>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Yes</td>
<td>A</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>No</td>
<td>B</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>No</td>
<td>B</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Yes</td>
<td>A</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>Yes</td>
<td>A</td>
<td>?</td>
</tr>
</tbody>
</table>

**PROGRAM VENTURE**

VENTURE was developed for simulation of the economic performance of proposed or conceptual publicly or privately owned, single- or multiunit electric power stations, energy parks, or entire utility organizations using a discounted cash-flow method, the venture-value method. A recent discussion of the venture-value method is presented by Happe and Jordan. Although the terminology of VENTURE is that of the electric power industry, VENTURE can be readily adapted for evaluation of the economic performance of virtually any commercial enterprise.

A discounted cash-flow method was adopted because there appears to be widespread agreement that this approach to practical assessment is the most accurate and useful for complex enterprises. According to the General Electric system, all economic factors are properly treated. The widely used, simpler fixed-charge fixed method cannot treat multiple investments separately. Thus, many nuclear plant concepts involve periodic replacements of major pieces of
equipment, which will have to be capitalized rather than treated as ordinary expenses for income tax purposes. There are also limitations on the scale of investments that can be treated by using the fixed-charge-rate method, and changes in tax and insurance rates cannot be treated accurately. In addition, one is not to lose sight of the various factors that make up a fixed charge rate, and blind application of the method can lead to serious error under rapidly changing economic conditions. VENTURE permits parameter studies involving variations in all the basic economic variables. Arbitrary time dependences of the values of the basic economic parameters can also be treated, permitting the consequences of various scenarios of economic conditions to be explored. However, where appropriate, i.e., in the case of a single investment under constant economic conditions, VENTURE also computes an equivalent fixed charge rate.

One parameter of particular interest in assessing the relative merits of competing thermoelectric reactor power plant conceptual designs is levelized unit product cost. VENTURE can also be used to compute a levelized unit cost of power production.

Definitions

Definitions of a few basic terms may provide better understanding of the foregoing introduction to VENTURE and the following discussion of its features. A discounted annual profit or loss for a venture is defined as the algebraic summation of discounted annual costs and revenues for the venture in a particular venture year. The venture worth for that venture year is defined as the arithmetic sum of the discounted annual profits and losses for the venture for all the years during which the venture was conducted. It represents the profit for (loss) on the venture relative to the cost of doing business for the venture including return on invested capital, discounted to the base year, and the time value of money and normal inflation, if present.

Venture worth represents an economic figure of merit for a commercial intervention. Selecting projects for investments of corporate funds with highest present worths will maximize future worths of companies.

The levelized unit cost of electric power for an electric utility venture is defined as the constant unit sales price for electric power for which the venture worth of the venture is zero. It represents the cost of doing business on a unit electrical energy output basis. Transmission and distribution costs can be included in the estimation of levelized power cost, in which case a delivery cost is computed. If transmission and distribution costs are not included, then a levelized production cost is obtained.

Under the proper circumstances, i.e., if:

- all capital investment is made at the start of the life of the venture,
- the utility organization represents a limitless reservoir of funds from which funds can be withdrawn or into which funds can flow without appreciably affecting other utility activities,
- the utility organization is sufficiently prof-itable that immediate advantage can be taken of all tax credits,
- the cost of money, capital recovery payments, tax rates, etc., remain constant over the lifet ime of the venture,

the fixed-charge-rate method can provide a simple, single figure of merit for assessing the merits of alternative investment opportunities. The goal is calculation of an equivalent levelized annual cost of owning and operating the venture associated with each investment option. The total cost of owning and operating a venture is conveniently divided into fixed and variable charges. Fixed charges result from the investment involved in owning the venture and the variable charges cover operation, maintenance, fuel, etc. The fixed charges include the cost of money acquired to finance the capital investment, income taxes on equity portion of the utility if investor-owned, capital recovery, property taxes, and property damage insurance minus investment tax credits and depreciation.

A rule of thumb regarding the maximum size of investments that can be treated accurately by the fixed-charge-rate method is that care must be exercised if the investment whose economic worth is being assessed exceeds 10% of the total worth of
the organization making the investment. For many utility organizations this means that the fixed charge rate probably should not be used in assessing the economic viability of entire generating plants. A more detailed description of the fixed charge rate and or the fixed-charged-rate method as applied to electric utility ventures has been published by James. (4)

Structure of Electric Utility Ventures Treated by VENTURE

An arbitrary number of depreciable capital investments of the same or different arbitrary values made at the beginning of the same or different arbitrary venture years and salvaged during the same or different arbitrary estimated and actual (greater than estimated) venture years with the same or different arbitrary estimated (for income tax purposes) and actual salvage values can be treated by VENTURE. An arbitrary number of nondepreciable capital investments of the same or different arbitrary values made at the beginning of the same or different arbitrary venture years and disposed of during the same or different arbitrary venture years for the same or different arbitrary sales prices can be accommodated. Nondepreciable capital investments include, e.g., land and permanent improvements. The same or different arbitrary working capital requirements for each venture year can be treated.

An arbitrary number of operating units with the same or different arbitrary operating characteristics for each unit and venture year, i.e., nominal power ratings, plant factors, and thermal efficiencies, and the same or different arbitrary operating histories, i.e., venture years in which normal operations commenced and venture years in which the units are decommissioned and decommissioning costs, and which comprise the same or different numbers, kinds, and amounts of fuels per unit of generated power can be accommodated.

Both investor-owned and publicly owned utility companies can be treated, with the principal differences in treatment of the economic performance of the two types of utilities being that:

- Investor-owned utilities are assessed income taxes, whereas publicly owned utilities are not.
- Investor-owned utilities finance power plant ventures by a combination of debt and equity, whereas publicly owned power plant ventures are wholly debt-financed.
- The size and profitability of investor-owned utility organizations are assumed to be sufficiently great that immediate advantage can be taken of all income tax credits, e.g., arising from investment tax credits, net negative taxable incomes, etc., so that carry-forward and carry-back provisions of the income tax laws need not be invoked, whereas such considerations do not apply to publicly owned utility organizations.

Features and Capabilities of VENTURE

The annual cash flows treated by VENTURE, incomes and outlays during a venture year, include:

- Revenues from sales of electric power,
- Operating costs,
- Maintenance costs,
- Capital recovery sinking-fund deposits,
- Decommissioning sinking-fund deposits,
- Decommissioning costs,
- Returns on capital investments, including working capital,
- Income (or losses) resulting from actual salvage values for depreciable investments, which differ from salvage values estimated for income-tax depreciation purposes,
- Capital gains (or losses) arising from sales of nondepreciable capital investments,
- Federal, state, and local income tax payments,
- Federal, state, and local investment tax credits,
- State and local property tax payments,
- State and local sales or gross receipts taxes collected,
- State and local franchise tax payments,
- Insurance premiums, including premiums for public liability, business interruption, comprehensive crime, venture property damage, employee benefits, workmen’s compensation, and special hazards insurance, and
expenditures for fuel.

The latter two categories can be treated as part of operating costs, if desired. The principal reason for separating insurance premiums from operating expenses is that property damage insurance premiums contribute to the fixed-charge rate.

The annual revenue from sales of electric power is computed as the product of the total electric power generated by generating units that are operational during the year and the unit sales price during that year. The total electric power generated during a venture year is computed as the summation of the products of the nominal power ratings and availability factors for all units operational during that year. The nominal thermal power of each operating unit is calculated by dividing its nominal power rating by a unit thermal conversion efficiency.

Annual operating and maintenance costs and the decommissioning cost for each generating unit are specified directly. The decommissioning cost for each unit is associated with the venture year in which that unit is decommissioned. The annual cost of money to the venture is calculated as the summation of the products of the fractions of financings by bond sales, common stock sales, and preferred stock sales, and the interest rate paid to bond purchasers and rates of return received by common and preferred stockholders respectively. Annual capital recovery sinking-fund deposits for each depreciable investment and decommissioning sinking-fund deposits for each operating unit are calculated by using the computed annual cost of money to the venture in the standard manner. The depreciable capital to be recovered is basically the difference between the original and estimated salvage values of the depreciable investment, but can be increased by an amount sufficient to ensure that the purchasing power of the original investment value is recovered. Nondepreciable investments are recovered by sale of the investments, and working capital is recovered intact as a matter of course.

Income (or losses) resulting from differences in the actual salvage values and the salvage values estimated for computation of depreciation allowances for income tax purposes for depreciable investments are computed as the difference between the actual and estimated values and can be negative. The income (or loss) associated with each depreciable investment is assigned to the venture year during which that investment is actually salvaged. Taxable capital gains (or losses) arising from sales of nondepreciable investments are computed as the product of the difference between the original cost of the investments and their sales prices and a fraction of the capital gain or loss, which is specified is taxable according to the current tax laws. The capital gain (or loss) associated with each nondepreciable investment is assigned to the venture year in which that investment is disposed of.

Annual state and local property taxes can be assessed against the total of either the depreciable or undepreciable depreciable capital investment in force during the venture year, the total nondepreciable capital investment in force during the year, and the working capital for that year. The tax assessments are computed as the products of the corresponding tax rates, assessed valuation factors, which can be greater than one to permit taxation at depreciated values, and the values of the capital investments. State and local franchise tax payments are computed as the products of franchise tax rates and directly specified franchise tax bases.

Annual public liability, business interruption, comprehensive crime, and special hazards insurance premiums are specified directly. Annual worker’s compensation and employee benefits insurance premiums are calculated as the products of the corresponding insurance rates and the total annual payroll. Annual property damage insurance premiums are calculated as the summation of the products of corresponding insurance rates and the total of the nondepreciable and the total of either the depreciated or the nondepreciable depreciable capital investments in force during the venture year.

The number and types of fuels for each operating unit can be specified. The amount of each fuel required by each operating unit per unit of
thermal energy supplied to that unit and the unit cost of that fuel can be specified. The annual fuel cost for each operating unit is computed as the total thermal energy liberated in that unit during the venture year multiplied by the summation of the products of the amounts of each fuel required by that unit per unit of thermal energy and the cost per unit of that fuel. The total annual expenditure for fuel is the summation of the annual expenditures for fuel for each generating unit that is operational during the venture year.

The basic taxable income for a venture year is computed as the algebraic sum of the following annual quantities for that year:
- total revenue from sale of electric power (positive),
- depreciation allowance (negative),
- difference between estimated and actual salvage values for depreciable investments salvaged during year (positive if actual salvage value greater than estimated; negative otherwise),
- portion of return of invested capital which is interest (negative),
- operation costs (negative),
- maintenance costs (negative),
- state and local property taxes paid during year (negative),
- state and local franchise taxes paid during year (negative),
- state and local sales taxes paid during year (negative),
- decommissioning costs incurred during year (negative),
- portion of capital gains (or losses) from sale of nondepreciable assets during year which is taxable (positive if gain, negative if loss),
- insurance premiums (negative),
- expenditures for fuel (negative).

State and local income taxes paid during year are subtracted from federal taxable income. At the option of the user, federal income taxes can be subtracted from state and/or local taxable incomes, and/or state income taxes can be subtracted from local taxable income and/or vice versa.

Annual federal, state, and local income tax liabilities are calculated as the products of the corresponding tax rates and the federal, state, and local taxable incomes for that venture year minus federal, state, and local investment tax credits applicable during that venture year. Federal, state, and local investment tax credits granted during a venture year are computed as the products of the corresponding tax credit rates and specified fractions of depreciable capital investments made during that venture year and are subtracted directly from income tax liabilities.

Arbitrary distinct values can be specified for all the economic parameters for each investment, venture year, operating unit, fuel type, etc., where applicable when desired. When less detailed treatments are acceptable, values common to all investments, and/or venture years and/or operating units and/or fuel types can be input for an arbitrary subset of the economic parameters. The required data input can be reduced significantly in this manner.

Two methods can be invoked by the user of VENTURE for computation of depreciation allowances for income tax purposes, the straight-line method and the sum-of-years'-digits method. The first method is simple and easier to understand and the second method provides more realistic accelerated depreciation during the early portion of the service life of a depreciable investment. The use of these two methods is widespread and the simple formulas for the depreciation allowance factors will not be derived here. The depreciation allowance for each depreciable investment for each venture year is computed as the product of the depreciation factor for that year for that investment and the difference between the original value of that investment and its estimated salvage value.

Seven methods for discounting cash flows are available to the user of VENTURE. They are identified by the type of cash flow to which they are intended to apply:
- single, annual, discrete, end-of-year,
- single, annual, discrete, beginning-of-year,
- equal, semiannual, discrete, end-of-year, but
not beginning-of-year,
- equal, semiannual, discrete, beginning-of-year,
  but not end-of-year,
- equal, quarterly, discrete, end-of-year, but
  not beginning-of-year,
- equal, quarterly, discrete, beginning-of-year,
  but not end-of-year,
- uniformly distributed throughout the year.

Treatment of equal, discrete, monthly cash flows
was not included in VENTURE because the differences
between discounted uniformly distributed cash flows
and discounted equal, discrete, monthly cash flows
is generally not significant. Because there is an
infinity of nonuniform continuous cash flow distribu-
tions, no attempt was made to address discounting
of such cash flows. The modular nature of VENTURE
should, however, make it easy to introduce alterna-
tive discounting schemes. The discounting formulas
are easily derived and will not be reproduced
here. The cost of money to the venture is used in
the usual fashion to compute the discount factors.

A simple iterative root-finding technique, the
regular-false method, which requires two starting
values for which the function venture worth must
have opposite signs, is used to find levelized pow-
er cost. The calculations involved are essentially
the same as for venture worth calculations when a
constant sales price for electric power is speci-
fied. The function venture worth has only a single
root.

The output provided by VENTURE includes the
following options:
- an immediate echo check on raw input data,
- venture worth and annual and cumulative dis-
counted venture profits or losses,
- levelized unit electric power cost, and
- equivalent fixed-charge rate where applicable,
- detailed tables of input data and intermediate
  computed results, including all cash flows and
discounted cash flows.

**PROGRAM INDEXER**

INDEXER was developed to automate the process
of computation of values of cost indexes used to
convert estimates or known values of capital, oper-
ating, maintenance, production, etc., costs for
conceptual or proposed, conventional or advanced-
technology facilities, subsystems, or components
valid for one time interval or point in time to
values valid for another time interval or point in
time. The use of such indexes allows cost informa-
tion, which may have been laboriously developed for
one time frame, to be transformed easily to provide
useful cost estimates for another, usually later,
time frame, without having to repeat the entire
cost estimation process for the new time frame. We
feel that INDEXER and its associated data base pro-
vide ready access to an enormous amount of cost
index data, and a convenient means of using this
data.

**Basic Definitions**

In discussing the capabilities of INDEXER, we
begin with a few basic definitions. A cost index
is a representation of the cost of an item, i.e., a
facility or one of its subsystems or components, a
unit of a raw material, a manufactured product, a
unit of labor, a plant maintenance or operation
activity, etc., relative to its cost for some refer-
ence time or during some reference time inter-
val. The value of a cost index for a specified
time frame is usually expressed as the ratio of its
cost during that time frame to its cost for the
reference time frame or as this ratio multiplied by
100. We have adopted the latter method of express-
ing the value of a cost index. Under this conven-
tion, a value greater than 100 for a cost index
corresponds to an increase in cost for the item
represented by the cost index relative to its cost
during the reference time frame. A value less than
100 corresponds to a decrease in cost.

We refer to a cost index included in the data
base for INDEXER or supplied by a user as a compon-
ent cost index, although such indexes may them-
selves have been computed from many more basic cost
indexes. A weighted, normalized sum, whose values
represent the time dependence of the cost of some
composite item relative to its cost for some refer-
ence time frame, of component indexes, whose values
represent the time dependences of the component
items which make up the composite item in the pro-
portions indicated by the weighting factors, all
relative to the same reference time frame, we call a composite cost index.

A divisor of a cost-index value, which modifies that value to account for the effect of changes in productivity and is usually applied to craft labor hourly wage indexes, engineering and design cost indexes, operation and maintenance cost indexes, etc., we refer to as a productivity factor. Productivity factor values greater than one, corresponding to increases in productivity, may arise as a result, e.g., of the introduction of superior techniques, new machinery and equipment, or experience acquired in the design, engineering, and construction of similar items or projects in the past, or to the introduction of new work rules. Productivity factors less than one, corresponding to decreases in productivity, may result, e.g., from the introduction of more restrictive work rules through the collective bargaining process by agreement with craft, operating and/or maintenance unions, or from the introduction of more restrictive work rules and/or design restrictions mandated by regulatory bodies for reasons of construction, operating, and/or maintenance personnel health and safety, public health and safety, and environmental protection.

Features and Capabilities of INDEXER

The user of INDEXER defines a composite cost index by designating an arbitrary set of component cost indexes for which values are contained in the data base for INDEXER or for which values have been supplied by the user and a corresponding set of arbitrary weighting factors to be associated with an arbitrary time frame. Monthly, quarterly, and yearly index values can be easily added to the data base provided for INDEXER or provided as input to INDEXER. Monthly, quarterly, and yearly index values, any or all at user option, can be computed for arbitrary sequences of months, quarters, or years within the time period covered by the component cost index values included in the data base for INDEXER or provided to INDEXER by the user as input. Quarterly and yearly composite cost index values are computed as averages of the corresponding composite cost index monthly values. Monthly composite cost index values can be computed using any mix of monthly, quarterly, and yearly component cost index values because quarterly and yearly component cost index values in the data base or provided as input are automatically assigned to the corresponding months.

The user-specified weighting factors can be maintained constant throughout the period for which index values are to be computed or can be automatically updated for each time interval, i.e., month, quarter, or year, during the period. The automatic updating of weighting factors is based on relative changes in the costs of the component items that make up a composite item as indicated by the time dependences of the values of the component cost indexes themselves.

The reference time frames for any or all component cost indexes for which values are contained in the data base or are supplied by the user and/or for computed composite indexes can be arbitrarily altered by the user by providing new reference index values for the component cost indexes whose reference time frames are to be altered and/or the composite cost index. Each new reference value is then divided into all the index values for the appropriate index. Default values of 100.0 are provided for all reference index values in INDEXER.

Arbitrary productivity factor values can be specified for any or all of the component indexes used to compute a composite index, and for the composite index as well, for each month in the period for which composite index values are to be computed. Default values of 1.0 are supplied by INDEXER.

We illustrate the computation of composite cost index values by giving the formula for a monthly composite cost index value with automatic updating of weighting factors for the kth month in the sequence of months for which values are to be computed:

\[ I_{C,M,k} = \frac{1}{I_{C,RPC,k}} \]
\[
\sum_{n=1}^{N} w_n k \left( \frac{I_{M,n,k}}{p_{n,k}} \right) \left( \frac{I_{n,n,k}}{p_{n,k}} \right) I_{M,n,k}
\]

where:

- \( I_{C,n,k} \) = monthly composite index value for \( k \)th month,
- \( I_{C,R} \) = reference index value for composite index (different from 100.0 only if the reference time frame is to be altered),
- \( P_{C,k} \) = composite index productivity factor value for \( k \)th month,
- \( W_n,k^* \) = \( n \)th component cost index weighting factor value for \( k \)th month,
- \( I_{M,n,k} \) = \( n \)th monthly composite index value for \( k \)th month,
- \( I_{n,n,k} \) = \( n \)th monthly component index value for \( k \)th month,
- \( I_{R,n} \) = reference value for \( n \)th component index (different from 100.0 only if reference time frames are to be altered),
- \( P_{n,k} \) = \( n \)th component index productivity factor value for \( k \)th month,
- \( P_{n,k}^* \) = \( n \)th component index productivity factor value for \( k \)th month, and
- \( N \) = number of component cost index values used in defining composite cost index.

Simpler formulas apply if computation using constant weighting factors is specified.

The types of output provided by INDEXER in addition to computed composite index values include:
- automatic echo check on raw input data,
- any part of the data base for INDEXER, whether or not used in computing composite index values, at user option, and
- only that part of the data base for INDEXER or component index values provided as input which was used in computing composite cost index values, at user option.

**Data Base for INDEXER**

The number of component cost indexes for which values have been included in INDEXER's data base is now 400 and new ones are being continually added. Sources of the component cost index values or cost data from which they have been derived include the following:
- Bureau of Labor Statistics, Wholesale Price Indexes,
- Bureau of Labor Statistics, Monthly Labor Review,
- Bureau of Labor Statistics, Employment and Earnings,
- McGraw-Hill, Chemical Engineering,
- McGraw-Hill, Oil and Gas Journal,

The reference time frame for all the component indexes covered by the data base for which the raw data were available in that form, or for which the information necessary for conversion of the raw data to give index values corresponding to that time frame was available or could be accurately estimated, is the average for 1967. This includes a majority of the cost indexes covered by the data base. All other indexes for which values are included in the data base have a reference time frames the reference time frames associated with the raw data. We have not hesitated to fill in small gaps in the data base by interpolation or estimation. The period covered by the data base for the majority of the component indexes is January 1970, to May 1977. For some, more-recently-introduced, component indexes, the period covered extends past May 1977. In other cases, reporting of component index values was not instituted until after January 1970, and, hence, values from January 1970 are not available. We plan to update and add values for new component indexes to the data base as time and resources permit. The data base is presently slanted toward, e.g., construction, operating, and maintenance costs conversions for process industry and energy-related facilities, systems, and components, but could be enlarged to cover, e.g., general manufacturing and the service industries. We feel that the data base for INDEXER represents a unique compilation of cost index data not readily available elsewhere to the public.
**REFERENCES**