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CAPACITY EXPANSION PLANNING FACTORS

Part One: Methods and Sources

by

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Part One

METHODS AND SOURCES

CONTENTS

FOREWORD

MANY OF THE CONCEPTS and much of the data on which this volume was based were developed under the PARM Project (Program Analysis for Resource Management) for the Office of Emergency Planning, Executive Office of the President, under contract CDM-SR-59-39. The PARM Project developed data and computer models for planning economic recovery after a nuclear war, and for appraising the economic impact of major peacetime policy and program changes, actual or hypothetical.

The work on capital coefficients for manufacturing industries initiated under the PARM Project was completed and prepared in form for general use under contract AID/csd-753 for the Agency for International Development, Department of State. This volume is the end result of that contract.

The concepts and data underlying the Input:Capital factors which comprise the bulk of this volume were developed by Robert M. Waddell, Senior Industrial Economist, based largely on his extensive experience in engineering economics, planning and analysis for new plant construction and operation for several of the largest U.S. corporations. The concepts and data for the construction modules were developed by Robert A. Lewis, Senior Consulting Engineer. Mr. Waddell and Mr. Lewis were assisted by Mary Frances leMat, Assistant Mathematician, and Michele Holzman, Research Assistant.

The concepts and data underlying the Capital:Output ratios were developed by Philip M. Ritz, Principal Economist, and Hugo A. Facci, Senior Consulting Engineer, assisted by Roger Clough, Research Assistant.

John DeWitt Norton, Deputy Director, prepared the text for Chapter I-1 and 1-3. Philip M. Ritz prepared the text for Chapter I-2.

The National Resource Evaluation Center, Office of Emergency Planning, performed the machine computations involved in preparation of the factor tables in Part II.

Marshall K. Wood
Marshall K. Wood
Director, Economic Programming Center

Chapter 1

INTRODUCTION

PLANNING FACTORS have long been needed for estimating and projecting the costs involved in expanding capacity. This need is shared by engineers, economists, and development planners concerned with individual projects as well as with analysis at the corporate, regional and national levels.

TWO TYPES OF FACTORS

To meet this need two distinct types of factors are required:

> Capital:Output Ratios, expressing for each industry the ratio of the total cost of plant and equipment to the output at capacity obtained therefrom.
>
> Input:Capital Ratios, expressing within each industry the ratio of the inputs of each item of a comprehensive list of products, services and occupations to the corresponding total cost of plant and equipment.

Factors of the first type might appropriately be called Capital Capacity Ratios. However, conventional usage, sanctioned by many previous studies, will be followed here.

Note that numerators of factors of the first type are the same as the denominators of factors of the second type. The common term may be cancelled out to obtain Input:Output Ratios for capacity expansion, thus:

$$\frac{\text{Capital}}{\text{Output}} \times \frac{\text{Input}}{\text{Capital}} = \frac{\text{Input}}{\text{Output}}$$

Nevertheless, it has seemed preferable to us to maintain the distinction between the two types of factors explicitly to permit the user of this manual to exercise his own judgment respecting the components of investment cost. More significant, perhaps, is the observation that these two types of factors involve the determination of only three sets of numbers. This chapter will focus on methods of estimating these three terms.

The need for these planning factors points to three distinct and major gaps in the economic statistics of the United States. Not one of the three sets of numbers is the subject of direct, regular inquiry. Although each term of these ratios may be construed as a member of an ideal system of national accounts, no estimates are presently furnished in such a context. At present, as in the past, the need must be met largely by statistical improvisation.

Since its compilation in 1953, Capital Requirements for the Expansion of Industrial Capacity by Robert N. Grosse [1] has served, if not as a definitive source, at least as a useful guidebook. Its contents were extracted from studies prepared by several government agencies and universities participating in the Inter-industry Economics Research Program (1948-54) sponsored by the U.S. Air Force. The factors compiled by Grosse were based mostly on new plants or expansions of existing plants during World War II, supplemented by a few from the Korean War records and from applications for accelerated tax amortization certificates. Gaps in coverage were synthesized from such corporate financial manuals as "Standard & Poor's."

For industries for which specific information was available, the studies covered only a small and not necessarily representative set of plants. The technology reflected in this sample has by now become seriously out of date. Since the source data were of uneven quality, significant inconsistencies, errors and omissions also resulted. In particular, insufficient attention appears to have been given to the problem of ascertaining the actual operating capacities subsequently achieved by the plants considered. The role of capacity in the determination of input requirements is obscured by presentation of the factors in the implicit form of Input-Output Ratios.

The Industrial Fact Sheets [2] and underlying Industrial Profile Studies [3], prepared for the Agency for International Development, are another more recent source of planning factors. This compilation, unfortunately, is also deficient in various ways. It was designed primarily for pre-investment analysis of individual projects. The studies pertain mostly to small scale and simplified industrial operations which may involve a kind of built-in obsolescence. They represent technologies adaptable to initial industrialization in developing countries rather than best current practice in the United States. On the input side the Fact Sheets lack detail. The studies, also, are neither comprehensive in industry coverage nor consistent or complete in input classification. A more balanced, detailed treatment seems needed for the purpose of projecting national development strategies.

TWO APPROACHES

This manual presents a complete set of estimates for Capacity Expansion Planning Factors for the 252 industry groups into which the manufacturing sector has been classified. Factors of the desired types may be derived from two different standpoints which may be differentiated suggestively as the national accounts approach and the sample approach. In default of systematic data collection, it is often necessary to make out with such sporadic and incomplete information as happens to be at hand. Both approaches are expedients for making out. Although the samples were not drawn probabalistically and the information is not always consistent in classification, both the Grosse compilation and the Industry Fact Sheets may be taken as prototypes of the sample approach. In this manual Capital:Output Ratios will take the national accounts approach. The Input-Capital Ratios will be based on a sample approach, modified by cost engineering estimating techniques.

"A national accounts approach" seems an apt description of the method followed here in developing Capital Output Ratios for two reasons. 1. The quantities entering into the ratios are expected to be inclusive of the manufacturing sector and consistent with or reconcilable to published national account aggregates. 2. Gaps in the available data are bridged by statistical constructs of forms familiar in national accounts work. Similarly, "a sample approach" seems justified to describe a significant aspect of the method used to derive the Input Capital Ratios. Although the available samples did not cover the full spectrum of all manufacturing industry groups, the samples did offer sufficient evidence of adaptable relationships and were incorporated in the procedure. It is hoped that one day more adequate samples will be collected which will be more directly applicable to each industry group.

INDUSTRY AND ITEM CLASSIFICATIONS

At the outset it is important to distinguish between (a) the industry for which an investment in capacity expansion may be made and (b) the items which are inputs to such an expansion. These capacity expansion inputs are further differentiated in the procedure of this manual into product items, module items, and occupation items. The industry and products are identified by five or six digit codes developed by NPA as adaptations of the U.S. Standard Industrial Classification. Because of the greater differentiation required of products, the industry and product codes may not always conform beyond the third digit.

Industry Codes. The NPA industry codes were developed for use in another context for the U.S. Office of Emergency Planning, Executive Office of the President. In its 1958 Study of Interindustry Sales and Purchases, The Office of Business Economics, U.S. Department of Commerce used an aggregated classification including 51 manufacturing sectors, excluding ordnance. In the NPA industry codes these 51 sectors have been disaggregated into 252 industrial activities, or at a level approximating that between the third and fourth digits of the U.S. Standard Industrial Classification. The five or six digit NPA codes are keyed to, but not indentical with, the SICs.

The Industrial Activities for which Capacity Expansion Tables have been developed are listed by NPA code on pages II-2 and 3. The individual Capacity Expansion Tables in Part Two contain a section in which each industry is defined in terms of the U.S. Standard Industrial Classification.

Note that most industries as defined by NPA codes cover an extensive product mix. For example, Meat Products NPA 20110, comprises all processing functions: slaughtering, dressing, packing and canning of cattle, hogs, sheep, lambs, calves and horses. Even though the range of products of the industry so defined is broad, the major processing equipment input to capacity expansion is defined in a comparatively narrow product band which can be identified only at the seven digit level of the Census Product Code, namely 3551311 Meat and Poultry-Packing Plant Machinery and Equipment.

Product Codes. For the reasons just mentioned greater differentiation is required among product input items than among industries whose capacities are to be expanded. Accordingly, the NPA product codes have been based on the seven digit U.S. Census Product Classification. Nevertheless, an effort was made to avoid unnecessary detail. For manufactured products, a selection of all relevant input items was made from the "Numerical List of Manufactured Products, 1958 Census of Manufactures," Bureau of the Census, U.S. Department of Commerce. These items were examined in relation to their position in increasingly differentiated product groups at classification levels from three to seven digits. In some cases the product was adequately described at the four digit level, for instance, 3535 Conveyors & Conveyor Equipment. In many cases the seven digit level was needed to distinguish significant differences between inputs, for instance, 3534013 Electrical Freight Elevators and 3534015 Hydraulic Freight Elevators. But for a few cases, the seven digit level itself was too aggregated. Thus 3559589 Other Special Industrial Machinery and Equipment needed to be further differentiated by type to serve appropriately as the characteristic input of a Process Module. The NPA Product Code is a five digit number of which the first three correspond to the SIC and the last two are reserved for numbers and letters. The levels of differentiation in manufactured products are summarized as follows:

Digit Level		Number of NPA Product Codes
3		1
4		73
5		71
7		89
7+		40
	Total	274

Fifteen agricultural and service input items were added to this list to cover the corresponding requirements. These are keyed to the 1957 Standard Industrial Classification. A further item, Profits, Depreciation, Taxes, etc. was included to cover contractors charges so allocated.

Module Codes. Modules have been designed by NPA as an aggregation device for conveniently packaging special combinations of inputs. The modules and respective codes are identified on pages II-306 and 307.

Occupational Codes. The list of occupations used in the report, Employed Persons, By Industry Group and Detailed Occupation, 1964, Bureau of Labor Statistics, U.S. Department of Labor, provides the basis for the NPA classification of occupations. These occupation groups are shown on pages II-306 and 307.

FIRST TERM:
STOCK OF CAPITAL

In estimating the terms of the Capital Output Ratio within the national accounts framework there are two alternatives. We can consider both terms as increments. That is, the expenditure on the expansion of plant and equipment in a given year versus the increase in capacity obtained thereby. This alternative has the advantage of focusing attention on a relatively homogeneous, contemporary, vintage technology. In view of process improvements and increasing automation, involving the substitution of capital for labor, the incremental Capital:Output Ratio for individual industry groups cannot be expected to remain constant from year to year. In estimating capital requirements the use of a recent incremental ratio would be desirable because it would be likely to more nearly represent the technology which would actually be installed.

Unfortunately, the available statistics do not encourage an attempt to isolate the incremental terms of capital and of output at capacity. Expenditures by industry group, separately for plant and equipment, are published in the Annual Survey of Manufactures. But these figures combine true additions to capacity with replacements consisting of duplicates of the original items, replacements including modernization, and accelerated replacements due to obsolescence predicated on cost savings. To be sure, these expenditures do reflect contemporary technology. But the plant and equipment bought by an industry during any year is likely to be a very mixed lot, far different in composition from the balanced distribution required to determine the incremental Capital: Output Ratio. Further, it is almost impossible to estimate reliably the increment to capacity which results therefrom.

Under the circumstances, therefore, it is necessary to turn to the other alternative. This is to determine for each industry group the cost of all existing plant and equipment, in constant dollars, in relation to the corresponding output at capacity. An elaborate exercise in statistical exegesis is involved. Consider now only the numerator term, the existing stock of capital goods.

The stock of capital goods to be determined represents that equivalent 1957 dollar amount which was in use by United States manufacturing industries in 1957 needed to produce the goods that could have been produced in 1958 if the plants had been operating at capacity throughout 1958. The capital stock is a composite of new and old plants, with varying degrees of new and old equipment, and different sizes of plants from extremely large down to very small. The large plants may employ over 2,500 persons in some industries; the same industries also may have plants which employ four or fewer persons.

Although information on this topic had not been collected regularly, fortunately in this case, the Gross Book Value of depreciable assets was obtained in an inquiry adjunct to the 1958 Census of Manufactures [4]. This represents the acquisition cost of plant and equipment, exclusive of land, in historical dollars.

To serve in Capital:Output Ratios, these costs need to be converted to the prices of a recent base year. There is the difficulty. Gross Book Value as reported combines plant and equipment, yet each component is subject to different price changes and to replacement at the end of service lives of different duration. However, the Censuses and Annual Surveys contain series which break down investment into annual expenditures for plant and equipment for 1947 and subsequent years. A complex graphical iterative procedure was devised to facilitate the reconstruction, from fragmentary data, of the requisite historical series of expenditures for the plant and equipment which survived in use through 1957 from plant and equipment purchased prior to 1947. The series before 1947 were truncated and represented by aggregates. Each series was repriced in constant 1957 dollars by application of appropriate deflators.

This analysis was carried out at the three-digit level of the pre-1957 Standard Industrial Classification. Subsequently the results were converted, first to the revised (post-1957) SIC to be consistent with Census publications beginning in 1958, and then to the NPA Industry Classification. Price adjustments were also made, first to 1958 prices, then to the 1963 base year.

SECOND TERM
OUTPUT AT CAPACITY

Currently there is no regularly available and comprehensive information on the individual capacity of U.S. manufacturing industries [5]. There is even less information available about the increment to capacity added by the balanced expansion of completely new plants. Consequently, with respect to the output term also, we have had to abandon the incremental basis for estimating Capital Output Ratios.

Although capacity figures are published for a few industries [5], mainly continuous process basic commodities, we decided to adopt a basis of estimation applicable to all manufacturing industries. According to one plausible definition, capacity may be equated with the peak output attained. This approach has been adopted here. For this purpose the Federal Reserve Board (FRB) Index of Production may be taken as an appropriate indicator. The index for each industry was plotted by months for a span of years including 1957. Straight lines connecting the major peaks were then drawn. The mathematical envelope of such line segments may be taken to represent the capacity of the industry. This procedure results in a capacity index measured from actual output in the base year. These indexes are readily translated into equivalent dollar output, the form desired for insertion as the denominator in the Capital Output Ratios. As with the numerator term, various classification conversions and price adjustments were necessary to get everything in proper alignment.

To test the general reasonableness of the capacity estimates so derived, a comparison was made between the capacity utilization rates derived from them and capacity utilization rates in 1958 for local industry groups published in the McGraw-Hill Survey [7], which reflect the subjective judgments of corporate executives concerning the ratio of their actual to their maximum operating rates. Because they represent corporate, rather than establishment (plant) estimates, and are based on a small sample, only broad industry groups can be tabulated. Weighted aggregations of the NPA estimates were made to conform approximately to the McGraw-Hill classification. The comparisons follow.

1958 Capacity Utilization Rates, Percent

Industry	McGraw-Hill	NPA
Iron and Steel	73	63
Nonferrous Metals	77	73
Machinery (incl. electrical)	75	73
Transportation Equipment (incl. motor vehicles)	75	65
Fabricated Metal Products and Instruments	80	81
Chemicals	80	84
Paper and Pulp	87	87
Rubber	78	76
Stone, Clay and Glass	79	80
Petroleum Products	87	91
Food and Beverages	82	79
Textiles	87	82
Other Manufacturing	84	81
All Manufacturing	80	77

With few exceptions, the NPA utilization rates are somewhat lower than the McGraw-Hill rates. This suggests that the maximum annual operating rates in these industries were considered by corporate executives to be somewhat below the peak monthly attainment levels. In a few cases, the reverse is true, indicating that these industries had never attained their estimated capacity in any month. On balance, there does not seem to be any way to improve on the procedure used, within the limits of the data available. However, the user of the data may wish to make some allowances for the differences indicated in the above table.

THIRD TERM:
SPECIFIC INPUTS

The flow of private fixed capital expenditures has recently been estimated in a preliminary, unpublished study by the Bureau of Labor Statistics. In a form comparable to the 1958 Industry Sales and Purchases (Input-Output) Tables prepared by the Office of Business Economics, it shows, across the rows and down the columns, all the private transactions on capital account to and from each of the 86 sectors into which the U.S. economy has been defined. To obtain Input:Capital Ratios all that is needed is to divide the transaction given in any cell by the corresponding column total, namely, by the aggregate expenditure by the industry for its own plant and equipment.

Here we have the national accounts approach already worked out for us. Such a table, unfortunately, would be an inappropriate source of the planning factors which are required for the purposes of this manual.

> Both the industries making expenditures and the items purchased are too highly aggregated. Decisions to expand capacity and to purchase equipment are always made in terms of more specifically defined products and services.
>
> Expenditures for replacement, modernization and expansion are not differentiated. These components of investment depend significantly on different things: replacement on the age structure of the existing stock of capital; modernization on the rate of innovation in the industry; and expansion on current and expected capacity utilization. The distribution of purchases for these purposes varies widely. Moreover, within any industry the relative importance of replacement, modernization and expansion changes from year to year and with the phases of the business cycle.

We conclude, therefore that Input:Capital Ratios derived from the BLS table would not be applicable to balanced expansions. We turn then to the sample approach.

Expansion Estimating. One of the authors, while employed by a major industrial corporation, developed a method of estimating the total cost of a new manufacturing facility, given the delivered cost of the major equipment to be installed [8]. The quantitative implementation of the method involved statistical analysis of 11 new site expansion projects, including 244 separate structures housing 94 types of major equipment; capacity was created to produce 46 commodities and the total cost of the projects was nearly one billion dollars. Pilot plants, research and development facilities and management headquarters buildings were excluded.

Exhibit 1.1

COST SUMMARY Project ______________ Structure ______________

	Labor	Material	Total
A. Structure Direct Costs			
Building Accounts			
Foundation and Superstructure	xxx	xxx	xxxx
Services			
Fire Protection	xxx	xxx	xxxx
Heating, Insulation	xxx	xxx	xxxx
Electric Lighting	xxx	xxx	xxxx
Plumbing, Sewers	xxx	xxx	xxxx
Subtotal Building Accounts	xxxx	xxxx	xxxx
Equipment Accounts			
Equipment	xxx	xxx	xxx
Installation			
Foundation and Supports	xxx	xxx	xxx
Electrical Wiring, Controls	xxx	xxx	xxx
Piping, Valves, Insulation	xxx	xxx	xxx
Instruments	xxx	xxx	xxx
Duct	xxx	xxx	xxx
Subtotal Equipment Accounts	xxxx	xxxx	xxxx
Total Structure (Bldg & Equip) Direct Costs	xxxx	xxxx	xxxx
B. Other Project Direct Costs			
On-Site Outside Lines	xxx	xxx	xxx
On-Site General Facilities	xxx	xxx	xxx
Total Other Project Direct Costs	xxxx	xxxx	xxxx
A + B Total Direct Costs	xxxx	xxxx	xxxx
C. Project Indirect Costs			
Distributive Costs			
(Field, Home Office, Design)	xxx	xxx	xxx
A + B + C Total Plant Costs	xxxx	xxxx	xxxx

Data going into the analysis consisted of cost summaries for each structure and purchase orders for 16,000 pieces of vendor furnished equipment. The format of the summary is shown in Exhibit 1.1 Part A, Structure Direct Cost, was prepared for each of the 244 structures. Sheets prepared for the 11 projects totaled the direct costs of included structures, as well as Parts B and C, direct and indirect costs, associated with the project as a whole. A list of 400 possible equipment types was prepared for coding the information on the purchase orders. Only 177 types were found represented in the file. Further preliminary analysis showed that the 25 most expensive items purchased for any project accounted for at least 87 percent of the delivered cost of equipment. On this basis a list of 94 Significant Equipment items was developed. The two bodies of data were then merged into a common computer file for use in multiple regression analysis.

The probable cost of such Significant Equipment can be known at a comparatively early stage in the consideration of an investment project. The problem of Expansion Estimating is to expand such costs, item by item, to approximate the total cost of buildings and equipment for each structure including installation materials and labor. To put it another way, the problem was to determine a coefficient, b_k, called the Expansion Factor, which when multiplied by the cost, E_k, of the Significant Equipment item, k would determine the portion of the total cost of the structure buildings and equipment, attributable to the item. The Expansion Factors were evaluated in a multiple regression analysis determining the equation

$$(1) \quad G = b_1 E_1 + \ldots\ldots b_n E_n ,$$

where G is the total cost of buildings and equipment included in the structure, and the subscripts 1 .... n refer to the various items of Significant Equipment.

In the estimating procedure, total project costs are built up layer by layer. Separate estimates are made for each process and auxiliary facility included in the project. From this project subtotal estimates of direct costs for outside lines and general facilities are added. The factors used for this purpose were derived from analysis of the project Cost Summaries. The final layer, Indirect Costs, is added by a similar process.

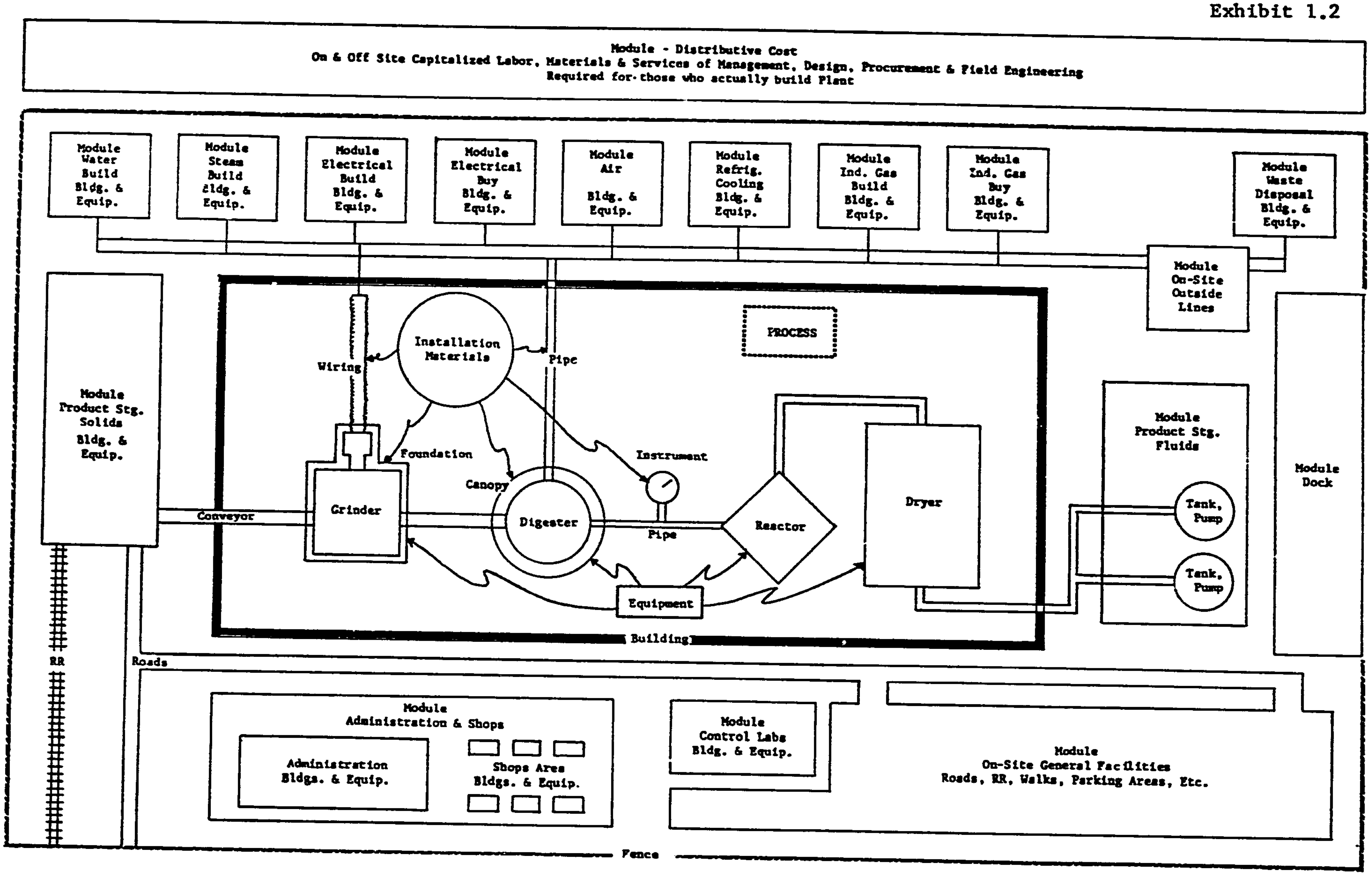
In unpublished studies made concurrently with the development of Expansion Estimating, this author explored intensively the relationships and ranges of variation among the variables reported on the Cost Summaries.

21 June 1965
RMW

SCHEMATIC PLANT LAYOUT

MODULAR CONSTRUCTION

Exhibit 1.2



Proportional Part Estimating. For Input:Capital ratios, as computed, the denominator is implicitly unity. The problem of estimating input factors may thus be interpreted as one of breaking down a known total into proportional parts. Instead of starting with a known part and building up through successively larger subtotals to an estimate of the cost of the whole, it is a matter of taking a known total and dividing into successively smaller subtotals to arrive at estimates of individual items. Thus the direction of solution in Expansion Estimating can be reversed. The same relationships, looked at from the opposite point of view, provide a foundation for what may be called Proportional Part Estimating.

Modular Concept. To facilitate the application of this procedure we assert that the list of inputs for expansion of a given industry can be represented by a set of Modules. A Module is a "package" of inputs of fixed proportional composition. The relation of modules to each other and to total cost of investment in an industry is shown in the schematic plant layout of Exhibit 1.2. A heavy black wall incloses the Process Module which includes the Building, typical Significant Equipment and Installation Materials. All the other Auxiliary Facilities, except Off site Motor Vehicle Operation (not shown), are arranged within the plant fence. Outside is the Distributive Cost Module. In the case of small plants, for which in effect the fence and the process building wall coincide, building costs are prorated among the facilities included.

Process Modules are unique to the industries with which they are identified. For this reason, in the tabulated list of inputs for an industry, a factor for the Process Module does not appear as such. Instead factors for the individual items included in the Process Module are given. Process Modules as separate entities figure chiefly in intermediate steps in Proportional Part Estimating.

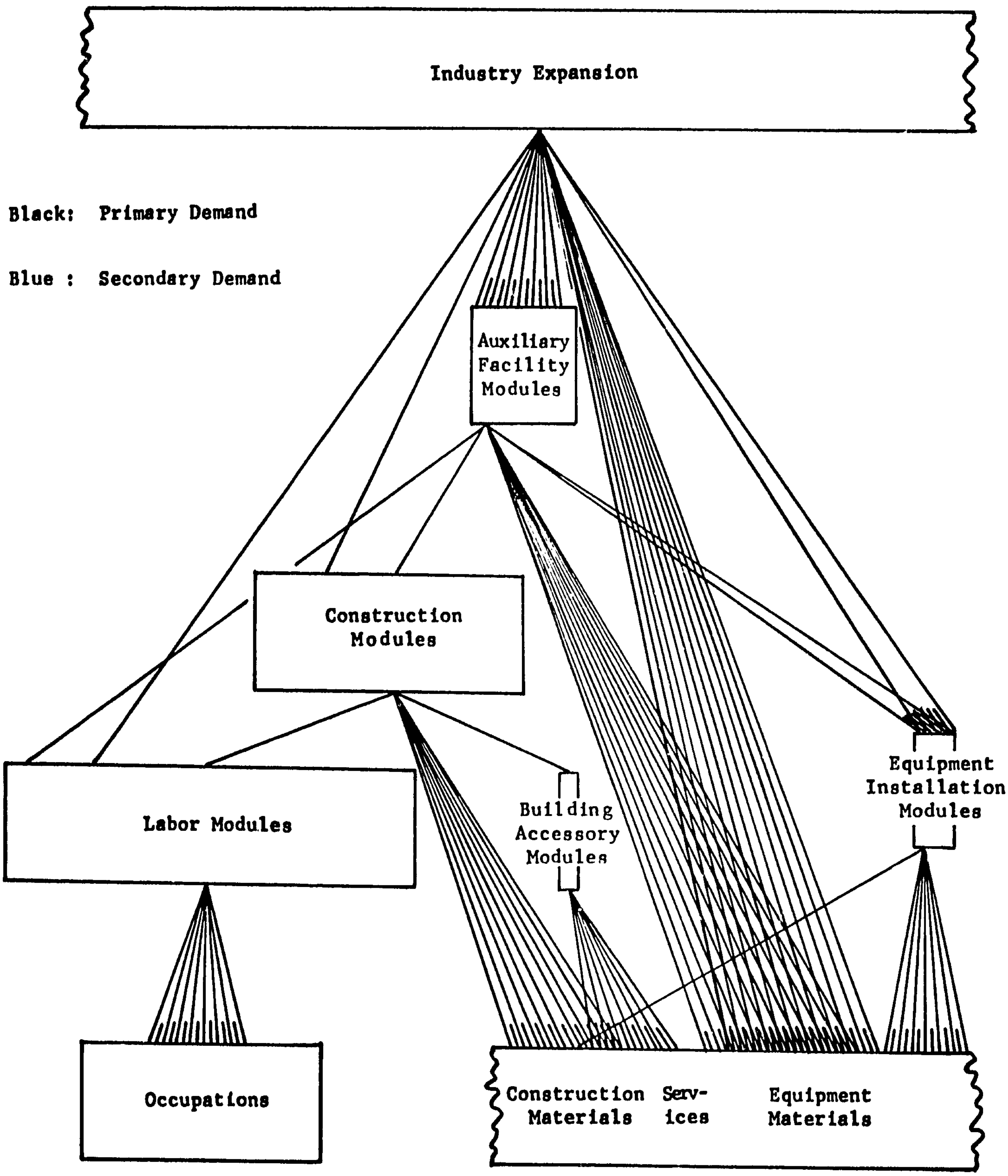
The other modules, which provide for Auxiliary Facilities, Installation Materials and Labor, Construction, and Distributive Costs, appear explicitly in the lists of inputs. Each of these modules has its own input list.

The modules have been defined for analytical and computational convenience. Requirements for items procured from vendors may be computed indirectly, stepwise, in some cases, involving a chain of as many as four modules. The Demand Flow of modular computations is illustrated in Exhibit 1.3.

21 June 1965
MFL

Exhibit 1.3

MODULAR CAPACITY EXPANSION
DEMAND FLOW



Item Selection Lists. For use in Proportional Part Estimating, exhaustive lists of candidate items have been prepared. These are applicable to each of the successive Bases which are to be subdivided into more than two parts. The lists developed for this purpose may be found among the Supporting Tables on pages II-301 through 309. In considering the expansion of each industry it is initially helpful to eliminate the items which do not apply. A significant contribution toward determination of the factor for each item can often be made simply by ranking the relative importance of the relevant items. The ranking often may appear obvious to the analyst.

"The Sample." Engineers and economists practicing cost estimation habitually collect information about the construction projects known to them in their various capacities. For purposes of comparability, the data is usually normalized in percentage, or--in the sense of this chapter--index form. Such information provides the basis on which professional judgment is exercised. Its range of application is likely to be, to an extent, limited by the professional experience and specialization of the individual or group concerned. The coverage cannot be expected to provide a systematic, much less, a probabilistic sample. Uneven though it may be, the quality of information contained in these collections is such that experts are ready to risk their professional reputations on generalizations made from it.

In the preparation of this manual NPA has had access to data collected during the course of their professional careers by members of its staff and consultants. The information covers more than 500 industrial structures built at an expense of several billions of dollars. Although the projects included were not necessarily representative of all manufacturing, analysis by type of structure provides greater applicability than might otherwise be expected. A powerhouse, for example, is very much the same whether it is included in a petroleum refinery or a steel mill. The extent of the coverage is shown in Exhibit 1.4, which cumulates by S.I.C. industry or product level the number of industries or products for which Equipment Expansion Factors were provided wholly from within the data of "the sample," or were estimated. Out of 59 industries at the four-digit level, Expansion Factors for all Significant Equipment required by 48 industries were derived from information available

DERIVATION OF EXPANSION FACTORS

Cumulatively by Level of Classification

S.I.C. Industry or Product Level	Number of Industries or Products for Which Equipment Expansion Factors Were: Wholly in Sample	Partly in Sample	Wholly Estimated	Total
2-digit	7	2	-	9
3-digit	23	3	1	27
4-digit	48	7	4	59
5-digit	54	2	11	67
7-digit	32	-	39	71

Number of Items for Which Equipment Expansion Factors Were: Wholly in Sample	Wholly Estimated	Total
96	50	146

in "the sample." Out of 146 Expansion Factors, 96 were so derived. Expansion Factors for items for which no direct information was available could often be estimated by analogy with known equipment. Often the distinction between the processing of solids and fluids is the key to finding appropriate analogies. The availability of data from this point of view is summarized in Exhibit 1.5. To the extent feasible published economic statistics have been used to supplement, or substitute for, data from "the sample." Unless otherwise indicated, however, all the Input Factors listed in the Expansion Tables of Part Two have been derived from "the sample" by the methods described in Chapter 3.

Estimating Procedure. For clarity of exposition we designate as Input Factors the proportional parts of the total cost of expansion in an industry. These are the Input:Capital Ratios as previously defined. In contrast we designate intermediate subtotals (variables) as Bases. In the preliminary phase of each step of estimation each Base is assumed equal to unity. Associated with each Base are Indexes (coefficients) which divide the subtotal into appropriate parts.

Three of these Bases, the Process Module, Significant Process Equipment and Equipment Installation, mark critical stages in the unfolding of the estimates. It is convenient to adopt the cost of the Process Module as the first Base. Relative to this Base, Indexes were developed from which the cost of each Auxiliary Facility Module could be calculated. The total cost of expansion for the industry is determined as the sum of the costs of the Auxiliary Facilities Modules and the Process Module. This total then becomes the Base from which Input Factors for specific modules and items can be derived as they are reached in the successive stages of the estimating procedure.

The Installed Cost of Significant Process Equipment is reached by subtracting these successive layers of subtotals from the Cost of the Process Module. Indexes derived from "the sample" determine the needed intermediate Bases for buildings and miscellaneous equipment.

The Installed Cost of Significant Process Equipment breaks down into three components: the delivered cost of Common Equipment and of Specialized Equipment, and the cost of Equipment Installation. Specialized Equipment comprises items generally closely identified with a particular industry. Common equipment,

Exhibit 1.5

EXPANSION FACTORS FOR SIGNIFICANT EQUIPMENT

by Category and Source

Category		Expansion Factor	Number of Equipment Types for Which Expansion Factors Were: In "Sample"	Estimated	Total
Portable Equipment	Unhoused	1.0	12	3	15
	Housed	1.1	4	-	4
Transporting solids		1.2	6	-	6
Mechanical and electrical machinery for processing solids		1.3	16	10	26
		1.4	17	34	51
		1.5	2	-	2
Heating and drying equipment for solids, including boilers		1.6	3	-	3
		1.7	5	-	5
		1.8	4	1	5
		2.0	2	-	2
Instruments		2.1	7	1	8
Heating, cooling, transporting, and storing of fluids		2.2	2	-	2
		2.3	6	-	6
		2.5	5	1	6
Continuous chemical processing of fluids		2.7	3	-	3
		2.8	2	-	2
Total, All Equipment Types			96	50	146

used by two or more industries, is further divided into Functional Groups of related items. Requirements for Common Equipment are first estimated by group and then subdivided by item. Requirements for Specialized Equipment are determined as a residual after the Common Equipment items have been estimated.

In this step it is convenient to use the Delivered Cost of Significant Process Equipment as the Base. Expansion Estimating techniques and data can then be used. Installation cost, of course, is the difference between delivered and installed costs. But since the Expansion Factor associated with each item differs, the total installation cost cannot be known until after the expanded delivered costs of each item are known and totaled. It is then possible to estimate in turn the total installation costs, total delivered cost of Significant Equipment, and Input Factors corresponding to the delivered costs of individual equipment items. A further step divides total installation costs into Equipment Installation Materials by type and Installation Labor.

This procedure is described in detail in Chapter 3 in a series of 25 equations. As outlined above, procedures used for deriving Input Factors for the modules and items listed in Industry Expansion Tables have been covered. Supplementary tables and procedures cover the derivation of Input Factors for the various modules.

CAPITAL:OUTPUT RATIOS are first in the series of relationships defined in this manual which can be used to assess investment requirements for industry expansion. To provide the numerator term of these ratios, we have estimated the ratio in constant dollars of the stock of capital existing as of mid-year 1957. To provide the denominator term we have estimated the corresponding output at capacity. The presentation in 1963 prices and in the NPA Industry Classification has involved two shifts in base year prices and two realignments in classification.

EXISTING STOCK OF CAPITAL

The method adopted for estimating fixed capital makes use of data collected by the Census Bureau in a special survey of its Annual Survey sample of establishments, giving Gross Book Value (GBV) of plant and equipment as of the end of 1957 [1]. It further makes use of annual plant and equipment expenditure data collected by the Census Bureau in its Censuses of Manufactures [2] and Annual Surveys of Manufactures [3] for 1947 and each year from 1949 through 1957.

In order to develop estimates of the fixed capital assets in use in 1957, it was necessary to reprice the GBV from historical dollars into constant 1957 dollars. This required an estimate of the age distribution of the capital assets. Because of the sharply different life span of plant and equipment, it was necessary to do this separately for these two components of the fixed capital assets.

The basic approach to deriving constant 1957 dollar estimates of the plant and equipment in place in mid-1957 for each of the industries used in the NPA classification system was to begin with the "book value" (or acquisition cost) of plant and equipment still in use for Census Bureau manufacturing industries (pre-1957 SIC) as shown in the special survey [1]. This was associated with the Census of Manufactures: 1958 but covered the 1957 Annual Survey panel of reporting establishments. These book value data (in historical dollars) were adjusted by various devices to arrive at separate estimates for plant and for equipment in the requisite constant dollars. To these were added imputed constant dollar values of leased plant and equipment as derived from data in the same Census source plus materials from a variety of other sources. The following sections describe in somewhat more detail the methods by which the first set of estimates were derived for the 3-digit industries of the old SIC.

In essence the problem breaks down to using the knowledge of expenditures for plant and equipment from the earlier Censuses and Annual Surveys of Manufactures, along with data from the Internal Revenue Service (IRS) and elsewhere on useful lives, to determine the composition of the gross stock figure, and then to use proper price deflators to put everything in constant dollars of the desired year. For this purpose it was possible to use Census data for all the years from 1947 through 1957, except for 1948 (for which no survey was conducted). The year 1948 was interpolated by charting the expenditures for contiguous years and selecting levels which matched the trends but keeping in mind as a constraint the reported GBV for 1957.

In a number of instances the capital expenditure data for one or more items was missing for various years. Missing data were imputed in similar fashion, but within two-digit controls which were always available for this purpose. Often total capital expenditures were given with no separation into plant or equipment; these were estimated in similar fashion, but usually with more confidence. In a very few instances two-digit controls were obviously inconsistent and had to be revised.

Another important adjustment was to include allowances for capital expenditures by establishments under construction as well as those in operation. Data for these were available only at the two-digit level and only for years after 1950. Estimates for all plants in a three digit industry were made by distributing the two-digit separate totals for plant and for equipment proportionately in line with expenditures for these items by establishments in operation. The years 1947 and 1948-1950 were estimated by using the average relationship derived for the years 1951-1957.

<u>Separation of Gross Book Value into Plant and Equipment.</u> For years prior to 1947, no data were available by industry for annual expenditures for plant and equipment. However, estimates for total manufacturing were obtained from unpublished worksheets prepared by the Office of Business Economics in support of the study "Expansion of Fixed Business Capital" [4]. It was assumed that the investment pattern of each industry for years prior to 1947 approximated the investment pattern of all manufacturing industries, adjusted for variations in the useful life of plant and equipment by industry.

The adjustment for variations in useful life was based on the assumption that the total capital expenditures were dominated by expenditure for replacement and modernization, and that capital expenditures for expansion of capacity were either relatively small, or highly correlated with replacement expenditures.

A graphical method was used to separate plant and equipment expenditures. A set of charts was prepared, based on the above assumptions, showing relationships among the following variables:

L_p = Assumed life of plant, taken initially as 35 years

L_e = Assumed life of equipment, derived from IRS "Bulletin F" and "Depreciation Guidelines and Rules," and some industry sources, such as publications of the Machinery and Allied Products Institute (MAPI) [5].

n = L_p/L_e

e' = Proportion of expenditures on fixed capital assets accounted for by equipment expenditures, valued in historical dollars (based on 1947-1957 expenditures, unless otherwise indicated)

$\bar{e}$ = Proportion of total fixed capital assets in use accounted for by equipment in use, valued in historical dollars

e = Proportion of total fixed capital assets in use accounted for by equipment in use, in constant dollars.

In general, there is only one pair of values for L_p and L_e which will be consistent with the reported capital expenditure data and the preceding assumptions. It was also determined that L_p and L_e were generally dominated by the reported capital expenditure data for 1947-57, and were not very sensitive to any reasonable changes in the assumptions cited above.

An initial set of estimates for L_p and L_e were made for each industry, based on a number or previous studies. These initial estimates were then checked for consistency with the data and assumptions described above. Successive adjustments were made and tested for consistency, in an iterative application of this graphical process, until consistency was achieved.

When a final decision was made as to $\bar{e}$ with respect to each three-digit manufacturing industry, then it was possible to estimate plant and equipment in historical dollars as of 1957, consistent with the GBV estimates. The next step is to calculate in detail the yearly build-up of these book value components and then reprice into constant 1957 dollars.

Calculation of Plant and Equipment Components in Constant Dollars. Given the gross book value of plant in 1957, the successive annual expenditures for plant were subtracted, leaving a residual amount for plant as of the end of 1946. The assumption is that any plant built from 1947 on was still in use in 1957. The residual amount was multiplied by a constant factor (2.8) to represent the composite effect of price difference between year of construction and 1957. This factor was determined by studying a series of price indices for industrial building construction for a period of years back to 1923 and judging the average disuse factors for plants constructed prior to 1940. The result of this analysis led to a fairly consistent result in terms of a possible multiplier for plants with service lives of 30 to 45 years and hence it was decided to use the single multiplier for the plant component of each industry.[1/] The expenditures from 1947 forward were repriced to 1957 dollars by using a construction cost index series for structures which is a composite of five other indices (e.g., Boeckh, Turner, Fuller, etc. [6]). The result of this is to provide a set of yearly plant expenditures for the period 1947 through 1957, priced in 1957 dollars, and an estimate for the stock of buildings existing at the end of 1946, also repriced to 1957 dollars. The sum of these thus provides the estimate of the value of plant as of the end of 1957 as if it had all been constructed under the 1957 price structure. The 1957 plant expenditure figure is then divided by two and the total adjusted to reflect the estimated status as of the middle of 1957.

The equipment estimates are handled in similar fashion except

(1) Each industry has a separate set of price indices, depending upon the equipment composition;

(2) Each industry has a separate set of equipment disuse factors, depending upon the equipment life decided for the industry (L_e);

(3) The overall adjustment factor differs for the equipment installed before 1947, to the extent that it was multiplied by a constant factor of 2.0.

The price indices for the equipment portion were developed by considering the four or five (and sometimes more) major kinds of equipment used by each industry, usually adding to well over two-thirds of total equipment costs and always adding to more than half of total. Price indices were calculated for each of the component equipment items and a weighted average price index was determined for each industry for each year from 1947 to 1957. The equipment

1/ The multiplier for 25-year life plants would have been about 10 percent less than the factor chosen, but this possible variation was ignored, mostly because there were only a handful of industries estimated to have service lives of less than 30 years for plants.

disuse factors were determined by study of various MAPI publications, especially George Terborgh, Realistic Depreciation Policy [7]. Curves were developed relating normal life to proportion of equipment still in service after each year and a table reflecting these results was prepared. The constant multiplier for equipment more than 11 years old and still in use in 1957 was developed by examining various lives over 11 years and applying appropriate price indices. The range of possible multipliers appeared to be within two to three percent of the 2.0 factor finally selected, which seemed to be a reasonable compromise in terms of arithmetic simplicity.

The succeeding steps to place the equipment portion of capital stock into constant 1957 dollars were matters of simple arithmetic adjustments. The sum of the equipment and the plant values thus became the new plant and equipment estimate as of mid-1957, stated in 1957 dollars. When the final estimates of plant and equipment in constant dollars had been calculated, it was possible to calculate an actual e factor (i.e., the ratio of equipment to total capital stock). This actual e was then compared with the theoretical e, calculated earlier, to determine possible mistakes. When the difference was substantial (more than 2 or 3 percentage points), the previous steps were re-examined. If imputations for gaps had been made which could have caused the differences and were not firmly founded, they were adjusted to help close the difference. These adjustments were few in number and small in amount.

Capitalization of Leased Plant and Equipment. To arrive at a more realistic estimate of the capital stock necessary to produce the output of each industry, a further step was necessary. Since various amounts of leased plant and equipment are used in the different industries, the capital equivalent of the amounts used by each had to be imputed.

The Census report referenced above [1] also provided data on rental payments in 1957 for all the three-digit industries and many of the four-digit industries canvassed in the survey (which produced selected costs and book value of assets). The problem was to relate these payments to plant and equipment separately and to estimate the capital costs of the items from the rental costs.

The only available approach to the separation was to use data for two-digit industries from the Internal Revenue Service's Statistics of Income, 1957-1958, which provided information on "Rentals for Business Property." These latter referred essentially to real estate, but had to be adjusted to exclude "Central Office" operations to be consistent with the Census Bureau data. This adjustment was made by using the total wage ratio for establishment employees as against those in the central office. The modified Internal Revenue Service figure then approximated the real estate rental payments during 1957 by the two-digit industries reported in the Census Bureau study. The remainder was assumed to be equipment rental payments. The equipment rental to total rental ratio for the two-digit groups was then applied to each of the component three-digit industries.

The conversion of rental payments to imputed capital cost involved study of a number of problems, including estimation of profit and interest, amortization, management costs, and maintenance and repair and operation. Sources for this study include material from some leasing companies, from MAPI, and from various OBE studies. The final result for imputed capitalized value of plant was that it amounted to about 10 times the rental charge. For equipment it amounted to about 45 percent of the rental charge multiplied by the service life of equipment for the industry. These factors were then used to arrive at the necessary additions to the previous capital requirements estimates to arrive at total capital requirements in mid-1957 for each three-digit manufacturing industry, as classified under the SIC in use prior to that used in the 1958 Census of Manufactures.

<u>Conversion to the New Three-Digit SIC.</u> For use with more current data, and in particular as a step toward presentation in this manual, it was advisable to restate the capital data in terms of the industry classification now in use by the Bureau of the Census, following the post-1957 Standard Industrial Classification. The differences between the old and the new SIC are not great at the 3-digit level, but there are enough variations, especially in some of the fabricated metal product and other metal durable goods areas, to warrant adjustments to make the estimates consistent with the current industry classification. Furthermore, these adjustments are needed as a prerequisite to translating the capital requirements data into the NPA classification system, which is based on the new SIC and is often at the 4-digit level.

The procedure by which the conversions were made was to adjust the plant and equipment estimates by the same proportions that a component industry (i.e., 4-digit or part of it) came into the new or fell out of the old 3-digit industry, using value-added as the measure of relative importance. In those instances where the book value of plant and equipment were available for a 4-digit industry which switched from one 3-digit industry (in whole or in large part) to another 3-digit industry, the relative book values were used to provide the adjustment factors. There appear to be no better alternatives to this kind of procedure at this time.

Conversion to NPA Industry Classification. The procedure by which both plant and equipment were distributed from the 3-digit SIC to the NPA list depended mostly on the gross book value data given in the previously referenced report [1]. The ratios of the 4-digit industry gross book values to the gross book value of the 3-digit industry of which they were part were used to distribute the constant dollar plant and equipment data. For those 4-digit industries which singly or in combinations represented NPA industries and for which gross book value data were either not available or could not be estimated, proportions were derived by examining the past 10-year history of plant and equipment expenditures when available or by using relative value-added proportions when capital expenditure data were not available.

Price Adjustments. For use in another context by NPA, the estimates of the value of existing capital stock as originally derived were converted to constant 1958 dollars. This was done by applying a single deflator for plant and another for equipment, both based on factors derived from the national income and product accounts. For purposes of this manual a further adjustment to 1963 price levels was required. This conversion was accomplished by similar means.

OUTPUT AT CAPACITY

In this manual estimates of capacity are based on a pragmatic concept of attained output rather than either engineering expectations or economists' definitions. The estimates presented take no account of the possibility that additional shifts might be utilized to enlarge capacity. The concept adopted is that capacity is the level of output which could be attained with normal shift practices if the trends over past peak periods had been maintained.

Peak Attainment for SIC Three-Digit Industries. Using the detailed production indices of the Board of Governors of the Federal Reserve Board (FRB), the monthly levels for a period of about seven years surrounding and including 1958 were plotted on graph paper. The selections were made for each product grouping which came closest to matching the three-digit SIC industries in manufacturing. In a few cases it was necessary to secure other production data when FRB data were too aggregative or were not available. Sometimes inferences were drawn from related industries.

Lines connecting several sets of peak levels were drawn and those most relevant to 1958 capacity were selected. Considerable judgment had to be applied in order to spot turning points and to choose among conflicting slopes or levels.

The peak attainment figure for mid-1958 was read from the envelope of lines described above. This was an index number related to 1958 average actual production as a base (i.e., 100 percent), thus giving the percentage difference between capacity and actual output. The actual capacity levels were then determined by relating this percentage increase to the dollar levels of output for the three-digit industries in 1958.

Value of output for each of the three-digit industries was determined from the Census of Manufactures: 1958 [8]. For those few industries for which output was given directly it was used without adjustment. For most industries it was necessary to adjust value of shipments by subtracting resales and adjusting for change in inventories in final products and work in progress. The capacity values then determined by increasing value of output by the ratio between capacity and output represent the estimated capacity for each three digit manufacturing industry in 1958.

Peak Attainment for NPA Industries. To estimate capacity for the more detailed list of NPA industries it was necessary to carry on a similar process, but for a larger number of product groups. Again, the FRB production index data were the most important sources. However, because of the need for more detail, there were more gaps in the identification of FRB product groups with NPA industries. To close these gaps a similar peak attainment study was made for monthly employment in the detailed industries. The results of these studies were used to distribute the major FRB groups of which these industries were a part. In a very few cases the break-out of NPA industries from a larger group was done by considering the annual output data for a series of years, using Census Bureau sources.

Given the relationship between capacity and output, as determined by the above procedure, the value of output for each NPA industry was multiplied by the relationship to give a value of output at capacity. Output for each industry was valued by the same techniques described above for three-digit industries. As noted earlier, many of the three-digit calculations could be used directly, whenever an NPA industry was identical with the composite of one or more three-digit industries.

Adjustment to 1963 Price Levels. Another intermediate step remained before Capital:Output ratios could be calculated. It was still necessary to develop price indices for adjusting the output of each NPA industry from 1958 to 1963 price levels. This was done by using the Wholesale Price Index [9], plus a few supplementary sources, such as the Consumer Price Index [10] and some of the implicit deflators in the national income and product accounts [11].

VALUE OF CAPITAL STOCK, OUTPUT AT CAPACITY, AND CAPITAL: OUTPUT RATIOS
As of 1957 in 1963 Prices
for 252 Manufacturing Industry Groups
Capital Stock and Output in Thousands of Dollars

Code	Description	Capital Stock	Output at Capacity	Capital Output Ratio
20110	Meat Products	2627.1	17486.9	.150
20150	Poultry Dressing & Egg Process	410.0	2107.0	.195
20210	Creamery Butter	408.9	1299.6	.315
20220	Natural Cheese	339.9	1005.5	.338
20230	Condensed & Evaporated Milk	318.5	1212.4	.263
20240	Ice Cream & Frozen Desserts	800.3	1257.3	.637
20260	Fluid Milk & Cottage Cheese	2435.3	7590.7	.321
20310	Canned & Cured Seafoods	45.9	492.7	.093
20320	Canned Specialties	375.7	1860.1	.202
20330	Canned Fruits & Vegetables	903.9	4266.4	.212
20340	Dehydrated Fruits & Vegetables	139.9	336.5	.416
20350	Pickles & Sauces	208.7	783.8	.266
20360	Fresh or Frozen Packaged Fish	77.2	496.2	.156
20370	Frozen Fruits & Vegetables	336.0	1776.7	.189
20410	Flour & Meal	665.5	2560.0	.260
20420	Prepared Animal Feeds	755.8	3500.0	.216
20430	Cereal Preparations	144.8	487.4	.297
20440	Rice Milling	24.1	301.2	.080
20460	Wet Corn Milling	420.2	553.3	.759
20510	Bread & Other Bakery Products	1751.3	4235.4	.413
20520	Biscuits & Crackers	408.1	1020.7	.400
20610	Raw Cane Sugar, Domestic	126.1	114.8	1.098
20620	Cane Sugar Refining	359.6	1463.5	.246
20630	Beet Sugar	556.5	1420.9	.392
20700	Candy & Related Products	753.2	2928.5	.257
20820	Malt Liquors	2029.1	2648.0	.766
20830	Malt	134.6	234.8	.573
20840	Wines & Brandy	101.0	418.0	.242
20850	Distilled & Blended Liquors	425.2	1366.8	.311
20860	Bottled & Canned Soft Drinks	1275.5	2032.8	.627
20870	Flavoring Extracts & Sirups	244.1	549.8	.444
20910	Cottonseed Oil	327.1	368.0	.889
20920	Soybean Oil	382.9	1071.8	.357
20930	Other Vegetable Oils	53.1	221.3	.240
20940	Grease & Tallow	162.1	272.5	.595
20950	Animal Oils, Except Lard	89.4	58.9	1.518
20960	Shortening, Cooking Oils, Marg	573.1	1082.5	.529
20970	Manufactured Ice	282.4	142.7	1.979
20980	Macaroni & Spaghetti	229.3	193.0	1.188
20990	Food Preparations, nec	696.1	3251.1	.214
21110	Cigarettes	339.1	2616.6	.130
21210	Cigars	92.1	435.6	.211
21310	Chewing & Smoking Tobacco	62.7	232.5	.270
21410	Tobacco Stemming & Redrying	154.7	1164.5	.133
22000	Spinning, Weaving & Dyeing	6259.0	9197.2	.681
22500	Knitting Mills	1264.2	3074.4	.411
22700	Floor Coverings	355.6	854.1	.416
22900	Miscellaneous Textile Goods	532.3	1194.6	.446
22990	Jute, Linen, Cordage, & Twine	157.2	378.1	.416
23110	Mens & Boys Suits & Coats	210.9	1944.2	.108
23200	Mens & Boys Other Garments	366.0	4142.9	.088
23300	Womens & Misses Outerwear	688.9	5648.8	.122
23400	Womens & Infants Undergarments	281.6	1605.8	.175
23600	Childrens & Infants Outerwear	194.8	1197.0	.163
23710	Furs & Fur Goods	45.0	456.6	.099
23800	Miscellaneous Apparel	283.3	1255.5	.226
23900	Miscellaneous Fabricated Textile	165.8	1939.1	.086
23930	Textile Bags	303.7	261.6	1.161
23940	Canvas Products	180.8	142.8	1.266
24110	Logging	802.9	1095.7	.733
24200	Sawmills & Planing Mills	4135.7	2747.8	.664
24310	Millwork & Other Wood Products	2440.7	548.0	.225
24320	Veneer & Plywood	1108.2	416.7	.376
24400	Wooden Containers	522.2	232.8	.446
24910	Wood Preserving	257.8	386.3	1.498

Code	Description	Capital Stock	Output at Capacity	Capital Output Ratio
25110	Wood Household Furniture	1005.6	2790.6	.360
25140	Metal Household Furniture	246.1	589.1	.418
25150	Mattresses & Bedsprings	249.2	726.5	.343
25210	Wood Office Furniture	189.7	87.2	2.175
25310	Metal Office Furniture	96.8	729.4	.133
25400	Partitions, Shelving & Lockers	225.3	655.8	.344
25910	Venetian Blinds & Shades	128.3	207.1	.620
26110	Pulp Mills	560.2	442.7	1.265
26210	Paper Mills	4153.9	3816.4	1.088
26310	Paperboard Mills	2265.9	1827.5	1.240
26400	Converted Paper Products	1472.4	3094.8	.476
26430	Paper Bags	449.8	924.6	.486
26500	Paperboard Containers & Boxes	1666.4	4208.3	.396
26610	Building Paper & Board Mills	575.1	385.4	1.492
27000	Printing & Publishing	7502.8	15318.2	.490
281A0	Alumina	214.1	264.2	.810
281S0	Sulfuric Acid	222.3	204.0	1.090
28120	Alkalies & Chlorine	1111.9	584.5	1.902
28130	Industrial Gases	355.9	241.6	1.473
28160	Inorganic Pigments	418.0	510.6	.819
28180	Industrial Organic Chemicals	4901.4	4347.9	1.127
28190	Industrial Inorganic Chemicals	1671.6	2714.6	.616
28210	Plastics Materials	1776.9	1988.8	.893
28220	Synthetic Rubber	480.4	672.2	.715
28230	Cellulosic & Synthetic Fibers	2406.5	1783.8	1.349
28300	Drugs	1406.9	2831.0	.497
28410	Soap & Other Detergents	914.4	1625.9	.562
28420	Specialty Cleaning & Other Prep	245.5	600.5	.409
28430	Surface Active & Finishing Agent	104.8	130.3	.804
28440	Perfumes & Toilet Preparations	298.5	1074.0	.278
28500	Paints & Allied Products	808.7	2198.9	.368
28610	Gum & Wood Chemicals	358.2	148.2	2.417
28710	Fertilizers	494.1	1400.1	.353
28790	Agricultural Pesticides & Chem	132.9	307.0	.433
28910	Glue & Gelatin	202.5	256.6	.789
28920	Explosives	499.7	306.3	1.631
28930	Printing Ink & Carbon Black	363.3	375.0	.969
28990	Miscellaneous Chemical Prep	827.1	818.8	1.010
29100	Petroleum Refinery Operation	13206.8	15470.1	.854
29510	Paving Mixtures & Blocks	306.5	279.5	1.097
29520	Asphalt Felts & Coatings	206.2	519.5	.397
30110	Tires & Inner Tubes	1451.6	2791.0	.520
30210	Rubber Footwear	139.7	302.1	.462
30690	Fabricated Rubber Products	1486.3	2165.8	.686
30790	Miscellaneous Plastics Products	890.7	2243.9	.397
31110	Leather Tanning & Finishing	330.3	957.9	.345
31210	Industrial Leather Products	27.4	91.0	.301
31310	Boot & Shoe Cut Stock	67.2	376.4	.179
31410	Footwear, Except Rubber	521.3	2905.3	.179
31610	Luggage	91.7	243.3	.377
31700	Handbags, Purses, Etc.	113.3	530.5	.214
31990	Miscellaneous Leather Goods	19.7	163.2	.121
32200	Glass & Glassware	979.7	1418.3	.691
32310	Flat Glass & Glass Products	665.7	1108.8	.600
32410	Cement	2017.1	1378.3	1.463
32500	Structural Clay Products	826.1	932.9	.886
32600	Pottery & Related Products	373.2	492.6	.758
32720	Concrete Products	945.2	1316.4	.718
32730	Ready Mixed Concrete	243.9	2008.7	.121
32740	Lime	22.0	180.1	.122
32750	Gypsum Products	482.8	459.8	1.050
32810	Cut Stone & Stone Products	213.2	244.9	.871
32910	Abrasive Products	262.9	625.0	.421
32920	Asbestos Products	361.1	728.8	.495
32950	Miscellaneous Nonmetallic Min	213.9	326.4	.655

Exhibit 2.1

VALUE OF CAPITAL STOCK, OUTPUT AT CAPACITY, AND CAPITAL: OUTPUT RATIOS

As of 1957 in 1963 Prices
for 252 Manufacturing Industry Groups
Capital Stock and Output in Thousands of Dollars

Code	Description	Capital Stock	Output at Capacity	Capital Output Ratio
32960	Mineral Wool	212.7	272.3	.781
32970	Nonclay Refractories	207.5	223.9	.927
33100	Blast Furnaces & Steel Mills	19832.9	21819.3	.909
33210	Gray Iron Foundries	1378.1	2637.1	.523
33230	Steel Foundries	590.7	915.9	.645
33310	Primary Copper Smelting & Ref	263.7	1236.5	.213
33320	Primary Lead Smelting & Refining	101.3	378.8	.267
33330	Primary Zinc Smelting & Refining	221.8	293.5	.756
33340	Primary Aluminum Reduction	1070.6	916.4	1.168
33390	Nonferrous Metals Refining, nec	89.0	282.7	.315
33410	Secondary Nonferrous Metal Serv	182.8	874.0	.209
33510	Copper Rolling & Drawing	599.8	1578.9	.380
33520	Aluminum Rolling & Drawing	878.5	2084.4	.421
33560	Nonferrous Metal Rolling, nec	241.4	655.0	.369
33570	Nonferrous Wire Drawing	769.0	2156.2	.357
33610	Aluminum Castings	282.1	553.4	.510
33620	Copper Castings	138.4	328.4	.421
33690	Nonferrous Castings, nec	168.4	317.8	.530
33910	Iron & Steel Forgings	477.5	1123.2	.425
33920	Nonferrous Forgings	69.5	143.5	.484
33990	Primary Metal Industries, nec	117.6	233.2	.762
34110	Metal Cans	1201.5	2861.8	.420
34210	Cutlery	86.4	242.7	.356
34230	Hand & Edge Tools, Hand Saws	315.6	696.3	.453
34290	Hardware, nec	850.4	1660.6	.512
34320	Metal Plumbing Fixtures	325.9	523.7	.622
34330	Heating Equipment, Nonelectric	418.1	1125.4	.372
34410	Fabricated Structural Steel	715.8	2017.0	.355
34430	Boiler Shop Products	830.1	1842.9	.450
34490	Miscellaneous Structural Metal	1175.9	2896.5	.406
34510	Screw Machine Products	349.2	624.3	.559
34520	Bolts, Nuts, Screws & Rivets	756.0	1337.1	.565
34610	Metal Stampings	1164.2	2944.9	.395
34700	Metal Plating & Coating	408.0	752.6	.542
34810	Miscellaneous Fabricated Wire	499.5	1003.8	.498
34910	Metal Drums, Barrels, Kegs, Etc.	186.0	327.3	.568
34930	Steel Springs	167.8	168.4	.996
34940	Valves & Pipe Fittings	860.9	1414.5	.609
34980	Fabricated Pipe	126.8	336.7	.377
34990	Miscellaneous Fabricated Metal	304.5	670.1	.454
35110	Steam Engines & Turbines	302.3	1109.9	.272
35190	Internal Combustion Engines	549.2	1339.6	.410
35220	Farm Machinery & Equipment	1246.3	3472.1	.359
35310	Construction Machinery & Equip	1171.3	2940.6	.398
35320	Mining Machinery & Equipment	96.1	443.3	.217
35330	Oilfield Machinery & Equipment	431.4	728.3	.592
35340	Elevators & Moving Stairways	82.6	235.8	.350
35350	Conveyors & Hoists	308.0	699.4	.440
35370	Industrial Trucks & Tractors	118.5	317.7	.373
35410	Machine Tools & Accessories	1203.9	1648.0	.731
35440	Special Dies & Tools	904.4	1575.1	.574
35480	Other Metal Working Machinery	947.3	1878.8	.504
35510	Food Products Machinery	337.7	585.9	.576
35520	Textile Machinery	383.8	481.9	.796
35540	Paper Industries Machinery	193.7	358.3	.541
35550	Printing Trades Machinery & Eq	211.5	378.3	.559
35590	Special Industrial Machinery	648.6	1219.3	.532
35610	Pumps & Compressors	477.3	1383.7	.345
35620	Ball & Roller Bearings	676.4	842.4	.803
35640	Blowers & Fans	176.4	294.1	.600
35660	Power Transmission Equipment	410.9	860.5	.478
35670	Industrial Furnaces & Ovens	76.8	269.3	.285
35690	General Industrial Machinery	257.3	748.1	.344
35710	Computing & Accounting Machines	1008.0	1328.0	.759
35790	Typewriters & Other Office Mach	372.9	662.8	.563
35810	Automatic Merchandising Machines	66.6	173.9	.383
35850	Refrigeration Equipment	552.8	1862.4	.297
35860	Measuring & Dispensing Pumps	42.7	140.8	.303
35890	Service Industry Machines, nec	159.1	438.5	.363
35900	Machine Shop Products	1230.3	2098.5	.586
36110	Electric Measuring Instruments	261.3	901.3	.290
36120	Transformers	516.7	674.7	.766
36130	Switchgear & Switchboard App	437.7	1269.9	.345
36210	Motors & Generators	467.0	1638.2	.285
36220	Electrical Industrial Controls	91.2	576.5	.158
36240	Carbon & Graphite Products	116.6	221.6	.526
36290	Electrical Industrial Apparatus	118.1	703.5	.168
36310	Household Cooking Equipment	153.2	472.9	.324
36320	Household Refrigerators	413.9	1150.2	.360
36330	Household Laundry Equipment	231.8	972.0	.238
36390	Other Household Appliances	510.7	1396.0	.366
36410	Electric Lamps	191.4	639.0	.345
36420	Lighting Fixtures	256.1	903.4	.283
36430	Current-Carrying Wiring Devices	181.4	635.5	.285
36440	Noncurrent-Carrying Wiring Dev	140.0	522.9	.268
36510	Radio & TV Receiving Sets	357.4	2585.6	.138
36520	Phonograph Records	58.6	289.1	.203
36610	Telephone & Telegraph Apparatus	713.7	1672.4	.427
36620	Radio & TV Communication Equip	583.9	2655.5	.220
36710	Radio & TV Tubes, Receiving Type	211.7	444.4	.476
36720	Cathode Ray Picture Tubes	48.8	190.0	.257
36730	Electron Tubes, Transmitting	119.3	303.9	.393
36790	Electronic Components, nec	491.2	1827.5	.269
36910	Storage Batteries	201.2	508.3	.396
36920	Primary Batteries	45.9	178.4	.257
36940	Engine Electrical Equipment	328.3	935.6	.351
36990	X-Ray & Other Misc. Electrical	79.9	338.2	.236
37150	Truck Trailers	93.5	548.8	.171
37170	Motor Vehicles & Parts	9285.0	36466.9	.255
37210	Aircraft	1368.6	7909.1	.173
37220	Aircraft Engines & Engine Parts	1051.2	3909.0	.269
37290	Other Aircraft Parts & Equipment	1230.0	3839.5	.320
37310	Ship Building & Repairing	857.8	2342.6	.366
37320	Boat Building & Repairing	159.7	444.2	.360
37410	Locomotives & Parts	274.4	610.8	.449
37420	Railroad & Street Cars	434.5	1507.2	.288
37510	Motorcycles & Bicycles	55.4	147.0	.377
37910	Trailer Coaches	232.6	614.6	.378
37990	Miscellaneous Transportation Eq	125.3	130.5	.960
38110	Scientific Instruments	241.3	1330.6	.181
38210	Mechanical Measuring Devices	322.5	932.2	.346
38220	Automatic Temperature Controls	178.2	442.7	.403
38400	Medical & Dental Instruments	252.5	824.2	.306
38510	Optical & Ophthalmic Goods	121.3	376.6	.322
38610	Photographic Equipment	904.4	1411.5	.641
38700	Watches, Clocks & Parts	174.0	439.4	.396
39100	Jewelry & Silverware	238.7	1146.1	.208
39310	Musical Instruments & Parts	113.5	300.5	.378
39410	Toys & Childrens Vehicles	290.6	1032.4	.281
39490	Sporting & Athletic Goods	151.0	750.2	.201
39500	Office & Artists Materials	207.1	520.6	.398
39800	Miscellaneous Manufactured Prod	2024.2	2364.8	.856

CALCULATION OF RATIOS

The last step was a simple one. Given capital stock estimates in 1963 dollars, including the breakdown into plant and equipment, and capacity in 1963 dollars for each of the 252 manufacturing industries, the capital items were divided by the capacity figure to give the desired ratios. The ratio for total plant and equipment is the only one shown specifically in the summary tabulation, Exhibit 2.1, and in individual industry tables appearing in Part II of this manual.

It will be noted that these ratios vary from as low as .08 to as high as 242, demonstrating the extreme variability in the capital structure of the different industries. The .08 factor means, of course, that the producing industry needed only 8 units of fixed capital to have the capacity to produce 100 units of product annually, each stated in consistent 1963 dollars. The 242 factor, on the other hand, means that the industry needed 242 units of fixed capital to provide the capacity to produce 100 units of product.

The modular method by which capital coefficients are constructed for purposes of this manual makes it unnecessary to show the plant and equipment ratios separately. In fact, some of the modules cross lines. Furthermore, equipment installation manpower is shown separately, whereas in the development of Capital:Output Ratios it would normally be shown on the equipment cost side. The use of separate estimates for equipment and plant throughout this development of the Capital:Output Ratios was necessitated only to arrive at more accurate final estimates for the sum of the two. In fact, the method used could not have been developed with much confidence without keeping this separation until the last stage.

REFERENCES

[1] U.S. Department of Commerce, Bureau of the Census, Census of Manufactures: 1958; Volume I: Summary Statistics, Chapter IX, "Selected Costs and Book Value of Fixed Assets."

[2] Censuses of Manufactures: 1947 and 1954; Volume I: Summary Statistics.

[3] Annual Surveys of Manufactures: 1949-1953; 1955-1957.

[4] U.S. Department of Commerce, Office of Business Economics, Survey of Current Business, November, 1962.

[5] See various issues of Capital Goods Review, such as December, 1959 (number 40) and September 1964 (number 59)

[6] Various sources; see, for example, 1959 Statistical Supplement to the Survey of Current Business, pp. 42-43.

[7] Terborgh, George, Realistic Depreciation Policy; published by R.R. Donnelly and Sons Co., Chicago, 1954.

[8] U.S. Department of Commerce, Bureau of the Census, Census of Manufactures: 1958; Volume II: Industry Statistics, parts 1 and 2.

[9] U.S. Department of Labor, Bureau of Labor Statistics, Wholesale Price Index, 1958 and 1963.

[10] U.S. Department of Labor, Bureau of Labor Statistics, Consumer Price Index, 1958 and 1963.

[11] U.S. Department of Commerce, Office of Business Economics, Survey of Current Business, National Income numbers for various years, such as July 1964.

Chapter 3

INPUT:CAPITAL RATIOS

THE DERIVATION of Input:Capital Ratios for the expansion of capacity is the subject of this chapter. It will develop the technique of Proportional Part Estimation in a series of equations and show it in action. It will delineate items and modules. It will introduce an appropriate notation. (See Exhibit 3.0.) A series of numerical examples will be furnished based on the derivation of input factors for the expansion of Industry 20110: Meat Products.

MODULAR ANALYSIS

For planning purposes the types of plant facilities utilized in manufacturing may be separated into functional modules. The characteristic of a module is that the included items always occur within it in fixed proportions. There are two major classes of modules: Process Modules, each unique to the industry to which it pertains; and Common Modules, each of which may be utilized by many industries, but always in a proportion to the total cost of expansion appropriate to the given industry.

Modules are analytical and computational devices of great convenience. In the derivation of input factors they provide the series of diminishing subtotals, called Bases in Chapter 1, which facilitate the practice of Proportional Part Estimation. In tabulation and computation they avoid the duplication of the detailed item requirements contained in packages of fixed composition listed among the inputs for each industry.

Each process module is surrounded by a cluster of satellite modules. The Auxiliary Facilities included in such modules provide the industry's requirements for water, steam, electricity, etc. The process equipment characteristic of each industry determines the proportions in which Auxiliary Facilities are required.

A schematic plant layout showing the separation of plant facilities into the Process and principal Auxiliary Modules was presented in Exhibit 1.2 on page I-1.12. All the physical facilities are enclosed within the fence. An additional module has been provided, not shown on the layout, to cover the capitalized

Exhibit 3.0

NOTATION FOR PROPORTIONAL PART ESTIMATING

For each industry the following variables called Index Bases are defined which apply in numbered equations

A_i ≡ Cost of the i^{th} Auxiliary Facility Module

B ≡ Cost of Buildings included in the Process Module

C ≡ Delivered Cost of Common Equipment included in the Process Module

D_i ≡ Delivered Cost of the i^{th} Item of Significant Process Equipment

D ≡ Total Delivered Cost of Significant Process Equipment

D' ≡ Sum of Input Factors for Significant Process Equipment

E_m ≡ Weighted Average Hourly Earnings corresponding to the m^{th} Labor Module.

F_g ≡ Delivered Cost of the g^{th} Functional Group of Common Equipment Items

H_i ≡ Cost of the i^{th} Item

I ≡ Installation Cost of Significant Process Equipment

K_m ≡ Cost of the m^{th} Construction Module

L_i ≡ Cost of Labor in the i^{th} Construction Module

L_w ≡ Normalized Cost of Installation Labor corresponding to the w^{th} Expansion Factor

M ≡ Cost of Miscellaneous Equipment Materials Module

N ≡ Installed Cost of Significant Process Equipment

P ≡ Cost of the Process Module

Q ≡ Installed Cost of Process Equipment

R_i ≡ Manhour Inputs of the i^{th} Occupation

$\hat{R}_m$ ≡ Base for Input Factors of the m^{th} Labor Module

S ≡ Delivered Cost of Specialized Equipment included in the Process Module

T ≡ Total Industry Expansion Cost (Base for Input Factors)

X_w ≡ Expanded Delivered Cost of Significant Process Equipment

Exhibit 3.0
(cont'd)

The following coefficients are defined:

a_i ≡ Input Factor of the i^{th} Item

c ≡ Index of Process Buildings

h_i ≡ Index of the i^{th} Item

r_i ≡ Input Factor for Manhours by Occupation in Construction Labor Modules

s_i ≡ Input Factor for Manhours by Occupation in Equipment Installation Labor Modules

x_i ≡ Expansion Factor of the i^{th} Item of Significant Process Equipment

x_w ≡ Weighted Average Expansion Factor for the Total of All Items of Significant Process Equipment

x_{wm} ≡ A subdivision of the Weighted Average Expansion Factor corresponding to the m^{th} Equipment Installation Module.

The subscript i refers to Items identified by NPA Item Code. The limits of summation for i are explained in the context. The subscript m refers to Modules.

Exhibit 3.1

Use of Modules in Estimation of Item Requirements

Types of Tables	No. of Tables	Types of Tables Using Modules as Inputs										
		1	2	3	4	5	6	7	8	9	10	11
1. Industry Expansion	252											
2. Auxiliary Facility Modules	15	x										
3. Distributive Cost Module	1	x										
4. Industrial Building Modules	35	x										
5. Industrial Building Accessory Modules	3				x							
6. Construction Non-building Modules	6	x	x									
7. Equip. Installation Material Modules	6	x	x				x					
8. Equip. Installation Labor Modules	18	x	x									
9. Industrial Building Labor Modules	35		x		x							
10. Construction Non-building Labor Modules	6		x				x					
11. Distributive Labor Modules	2			x								
Equipment, Material and Service Items	289*	x	x	x	x	x	x	x				
Occupational Groups	35*								x	x	x	x

* Items or Occupational Groups

cost of motor vehicles based at the plant. In the Industry Expansion Tables, however, no provision has been made for other off-site requirements such as central administrative offices, research development and testing facilities, storage warehouses and terminal tank farms, garages, sales offices and distribution facilities.

The modular basis for elaborating item requirements is a multiple-step procedure. Each Industry Expansion Table generates primary, or direct, demands for equipment, materials and services as well as secondary demands for equipment, materials, services and labor by means of primary demand for auxiliary modules in appropriate proportions. The relationships between such primary and secondary demands are shown in Exhibit 1.3 on page I-1.14. These relationships are also illustrated by a two-way array in Exhibit 3.1, in which the x's indicate the use of a module as an input included either in an Industry Expansion Table or in other modules.

Industry Expansion Tables have been prepared for 252 industries. See pages II-4 through 255. The tables are presented in a standard format showing requirements for equipment items included in the Process Module and for Common Modules in proportions appropriate to the given industry. 127 supplemental tables list the input items contained in these Common Modules. The tables have been grouped as follows (the number of modules in each group is shown in parenthesis):

<u>Auxiliary Facility Modules</u> (15) are comprised of equipment items characteristic of the function performed, together with requirements for modules providing for equipment installation materials and labor and industrial construction. See pages II-278 through 283.

<u>Distributive Cost Module</u> (1) covers costs incurred indirectly to build plants such as design, supervision, administration, materials consumed, business services, etc., all of which are capitalized in total cost of plant. See page II-285.

<u>Industrial Building Modules</u> (35) offer different combinations of frames, loading, floors, basements, roofing, cladding and interiors which are commonly used by industry to house equipment and plant operating personnel. See pages II-259 through 276.

Industrial Building Accessory Modules (3) provide means of varying the proportions of plumbing, heating, and lighting to be included in the plant buildings. See page II-277.

Construction Non-building Modules (6) provide for Plant On site Outside Lines, including air, water, gas and sewer lines, and Plant On-site General Facilities including roads, walks, parking areas, etc., which are listed as direct inputs shown on Industry Expansion Tables; and indirect inputs of industrial railroad and road systems, water well drilling and dock foundations, which appear in the Tables of Auxiliary Facility Modules. See pages II-275, 276.

Equipment Installation Material Modules (6) provide respectively for miscellaneous equipment, equipment foundations, wiring and electric accessories, duct work, and instruments. Demands for these modules vary with the type of equipment being installed. For example, in the processing of fluid products piping and instrumentation are emphasized, whereas for solid products the emphasis is on wiring and electrical controls. These modules appear as inputs in the tables for Industry Expansion and Auxiliary Facilities. Two Construction Non building Modules call for inputs from the Miscellaneous Equipment Material Module. See pages II-256, 257.

Equipment Installation Labor Modules (18) are used to convert equipment installation labor cost, stated as inputs in tables of Industry Expansion or Auxiliary Facilities, into manhours by occupation. The pattern of occupations included in each of these modules is keyed to the amount and kind of equipment being installed. For example, if tanks and pumps are installed, a corresponding quantity of pipefitter manhours is included. See pages II-286 through 290.

Industrial Building Labor Modules (35) provide occupational requirements expressed in manhours for each of the 35 Industrial Building Modules. See pages II-291 through 299.

Construction Non-building Labor Modules (6) provide occupational requirements expressed in manhours for each of the six Construction Non-building Modules. See pages II-299, 300.

Distributive Labor Modules (2) provide for manhour inputs by occupation for field distributive labor and for corporate management labor which are capitalized in the total cost of the capacity expansion. These modules serve as inputs to the Distributive Cost Module. See page II-286.

DERIVATION OF FACTORS FOR INPUT OF AUXILIARY FACILITY AND DISTRIBUTIVE COST MODULES

NPA Code	Module Title	Coverage
980100	Water Module	River and lake pump houses, wells, water treatment plants, water storage tanks, basins and reservoirs.
980200	Steam Generating Module	Boiler houses, boiler rooms, power houses, gas metering houses, oil storage tanks, coal and ash handling facilities, stack and breeching, feedwater systems, chemical heating boilers and reboilers.
980301	Electrical Gen/Transf.-Build--Module	Electrical generating stations built on site, substations, transformers, and switch houses.
980302	Electrical Transformation-Buy--Module	Substations, transformers, and switchhouses.
980400	Air Module	Air compressor buildings, air washers and air dryers.
980500	Refrigeration & Cooling Module	.Refrigeration buildings, cooling towers, and air conditioning rooms involved solely with process.
980601	Industrial Gas-Build--Module	Gas generator houses and gas holders built on site.
9I0602	Industrial Gas-Buy--Module	Gas unloading stations, truck spots to hold delivered gas cylinders, gas pumps, compressors, and tanks.
980701	Product Storage-Solids--Module	Product storage warehouses and storehouses complete with bins and material handling equipment.
980702	Product Storage-Fluids--Module	Storage tanks, gas holders, Hortonspheres, pumps, and compressors.
980800	Waste Disposal Module	Waste treatment systems, flare towers, incinerators, burning grounds, waste furnaces, severage pumping stations, tanks and reservoirs.
980900	Administration & Shops Module	Plant administration, personnel, security, medical, engineering, and general stores buildings, gate houses, laundries, cafeterias, garages, change houses, maintenance and repair shops, pipe, sheet metal and electrical shops, fire houses, fire water tanks, and fire pump houses.
981000	Control Laboratories Module	Laboratories used for process quality control. Research laboratories excluded.
981100	Dock Module	Docks and wharves with material handling equipment.
981201	Off-Site Vehicle Operation Module	Motor trucks and trailers capitalized by the plant and used to transport raw material or finished product off-site.
3C1000	Plant On-Site Outside Lines Module	Steam, gas, water, and sewer overhead and underground pipe lines, and overhead and underground electrical lines within plant fence which interconnect various plant facilities. This module also considered as a nonbuilding construction module.
3C2000	Plant On-Site General Facilities Module	Site preparation, landscaping, temporary construction, roads, railroads, sidewalks, parking areas and fences. This module also considered as a nonbuilding construction module.
981400	Distributive Cost Module	Design, engineering and craft supervision, construction stores, taxes, depreciation and profit, construction equipment rental, equipment operation and maintenance, construction administration and corporate expense capitalized.

EXHIBIT 3.2

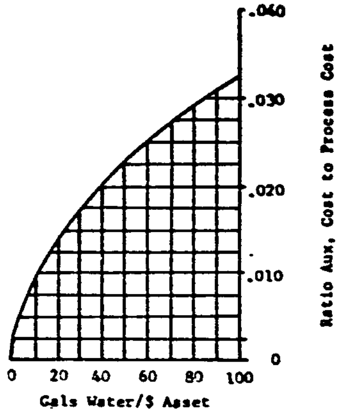
Sample Data Aux. Facility Module Index (AFMI) Plant Relationships [3]	Adjusted By Measure of Relative Importance (MRI) Industry Relationships	Industry Estimate	NPA Code
Water facility costs Process facility costs	Gallons water consumed [1] Dollars depreciable assets [2]	Industry AFMI = .0228 + .0001013 (MRI)* Adjusted by proportion of privately-produced water consumed by industry [1]	980100
Steam facility costs Process facility costs	Gallons boiler feedwater used [3] Dollars depreciable assets [2]	Industry AFMI = .0655 + .00174 (MRI)*	980200
Elect.gen.& transf. facility costs Process facility costs	Kilowatts generated [4] Dollars depreciable assets [2]	Industry AFMI = .0480 + .00627 (MRI)*	980301
Elect. transf. facility costs Process facility costs	Kilowatts purchased [4] Dollars depreciable assets [2]	Industry AFMI = .0094 + .00129 (MRI)*	980302
Air facility costs Process facility costs		Industry AFMI: Solids / Fluids Minimum .004 / .029 Median .006 / .048 Maximum .010 / .092	980400
Refrigeration facility costs Process facility costs		Industry AFMI: Solids / Fluids Minimum .0032 / - Median .0151 / .0206 Maximum .0430 / .0224	980500
Indl. gas gen. facility costs Process facility costs	Industrial users [5]	Industry AFMI: .0301	980601
Indl. gas purch. facility costs Process facility costs	Industrial users [5]	Industry AFMI: .0013	980602
Solid prod. storage facility costs Process facility costs	Dollars inventory (Solids) [6] Dollars depreciable assets [2]	Industry AFMI = -.0050 + .2293 (MRI)*	980701
Fluid prod. storage facility costs Process facility costs	Dollars inventory (Fluids) [6] Dollars depreciable assets [2]	Industry AFMI = .1615 - .2045 (MRI)	980702
Waste disposal facility costs Process facility costs	Gallons discharged water treated [1] Dollars depreciable assets [2]	Industry AFMI = -.0141 + .0006 (MRI)	980800
Adm. & shops facility costs Process facility costs	Number nonproduction employees [7] 10M Dollars Depreciable Assets [2]	Industry AFMI = .0422 + .0495 (MRI)	980900
Control lab. facility costs Process facility costs		Industry AFMI: Minimally controlled = .0050 Moderately controlled = .0100	981000
Dock facility costs Process facility costs		Industry AFMI: .0025	981100
	Guideline [8]: Motor Vehicle Cost / Total Plant Cost	Industry AFMI: Minimum = .0003 Maximum = .2547	981201
Outside lines costs Auxiliary facility costs (980100 through 980800)	Sum of Industry AFMI's for 980100, 980200, 980301, 980302, 980400, 980500, 980601, 980602, 980701, 980702, 980800	Industry AFMI = .0347 + .1801 (MRI)	3C1000
General facilities costs Process facility costs plus auxiliary facility costs (980100 through 980800)	Sum of Industry AFMI's for process module (= 1.0000) plus 980100, 980200, 980301, 980302, 980400, 980500, 980601, 980602, 980701, 980702, 980800	Industry AFMI = -.1049 + .1189 (MRI)	3C2000
Distributive costs Process facility costs of solids and fluids plus all auxiliary facility costs excluding 981201	Sum of Industry AFMI's for process module (solid product = 1.6000; fluid product = 2.1000) plus 980100, 980200, 980301, 980302, 980400, 980500, 980601, 980602, 980701, 980702, 980800, 980900, 981000, 981100, 3C1000, 3C2000	Industry AFMI = .2141 + .0291 (MRI)	981400

* See following page for limits of equations and curves extending limits to point of origin or maxima

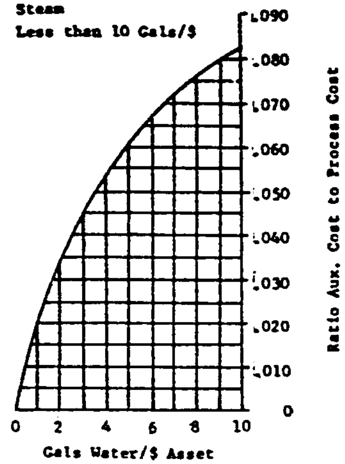
AUXILIARY FACILITY MODULE INDEX EQUATION EXTENSION TO POINT OF ORIGIN OR MAXIMA

Exhibit 3.3

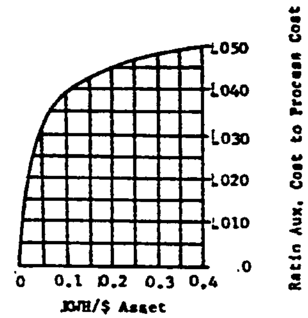
Water
Less than 100 Gals/$



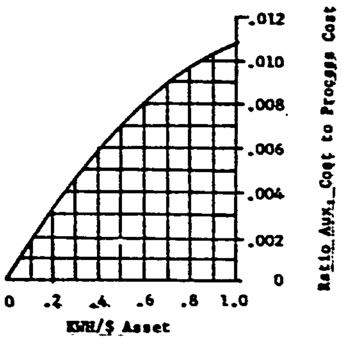
Steam
Less than 10 Gals/$



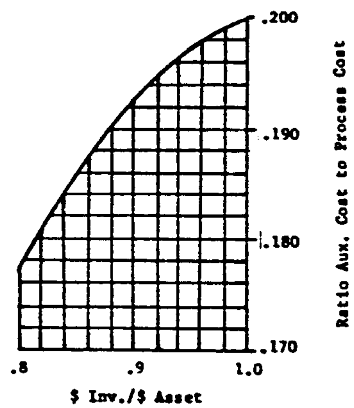
Electrical-Build
Less than 0.4 KWH'S



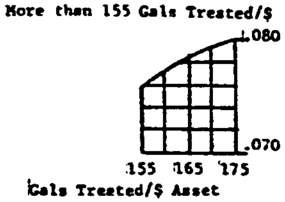
Electrical-Buy
Less than 1 KWH/$



Product Storage-Solids
More than $.8 Inv./$



Waste Disposal
More than 155 Gals Treated/$



Less than 45 Gals Treated/$

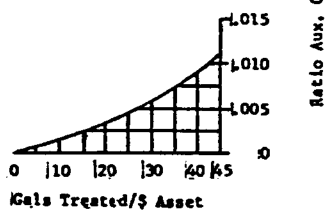
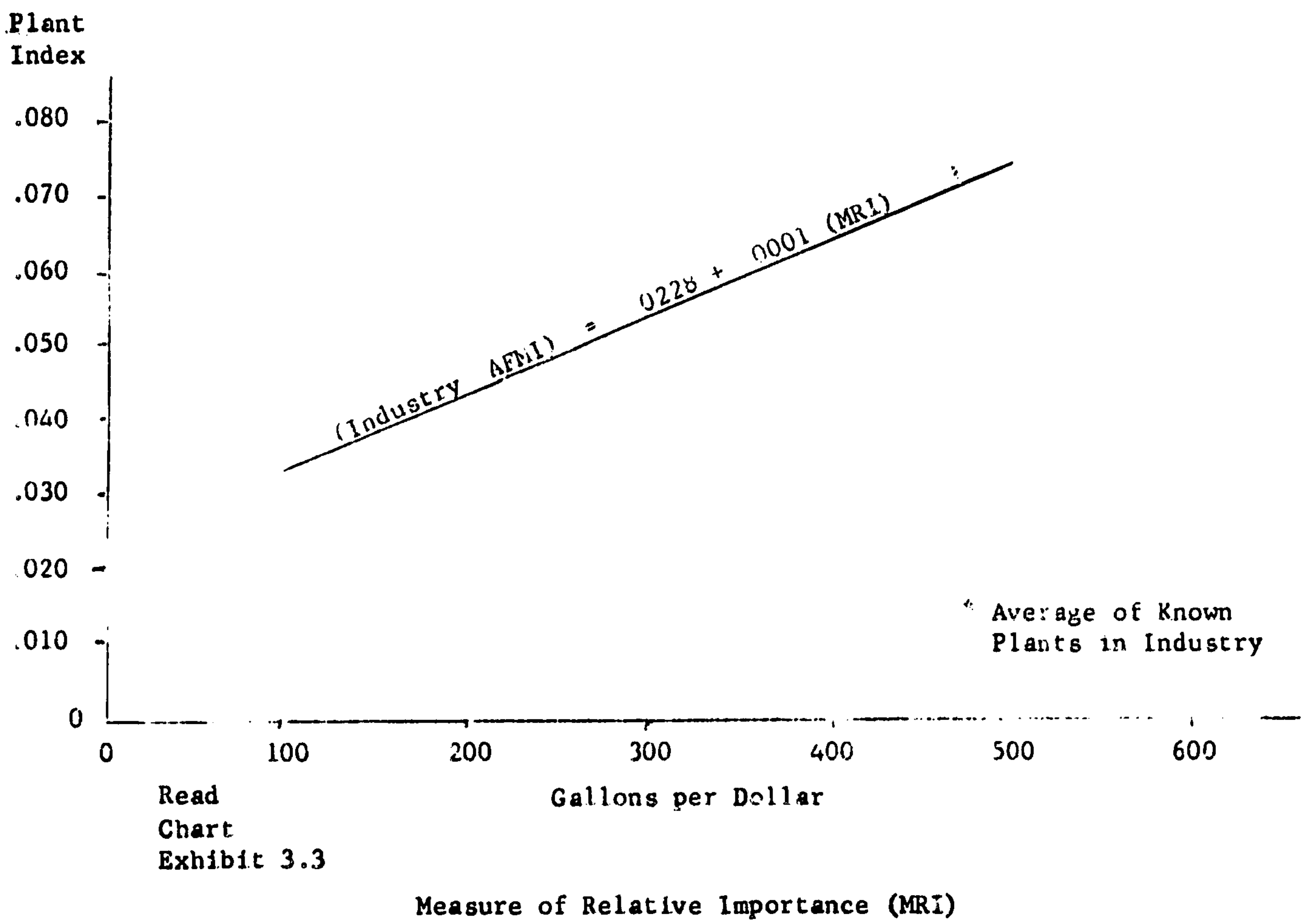


Exhibit 3.4

Regression Analysis for Water Module



AUXILIARY
FACILITIES

The installed cost, P, of the Process Module is the base for estimation of requirements for Auxiliary Facility Modules and for the Distributive Cost Module. According to the notation introduced in Exhibit 3.0 page I-3.0, this relationship is expressed as follows:

$$(1) \quad A_i = h_i P$$

The following Indexes for Auxiliary Facilities were estimated:

Industry 20110: Meat Products

NPA Item Code (i)		Index (h)	Factor (a)
	Process Module (Installed Cost = P)	1.000000	.477151
	Common Modules (Installed Cost = A_i)		
980100	Water	.014700	.007010
980200	Steam Generation	.084600	.040362
980301	Electrical Generation/Transformation-Build	.042500	.020282
980302	Electrical Transformation-Buy	.011500	.005484
980400	Air	.010000	.004771
980500	Refrigeration and Cooling	.043000	.020519
980701	Product Storage-Solids	.089500	.042702
980800	Waste Disposal	.002300	.001097
980900	Administration and Shops	.066400	.031679
3C1000	Plant On-Site Outside Lines	.088400	.042181
3C2000	Plant On-Site General Facilities	.049900	.023572
981201	Off-Site Vehicle Operation	.178300	.086000
981400	Distributive Cost	.275140	.197190
	Total (Industry Installed Cost = T)	1.956240	1.000000

The total cost, T for expansion of the industry is given by the expression:

$$(2) \quad T = P + \Sigma A_i$$

From this base it is possible to calculate the proportional parts, or Input Factors, of all the component modules by appropriate multiplications according to

$$(3) \quad a_i = \frac{P}{T} h_i$$

In what follows such conversions from Index to Input Factor will be made without discussion.

Auxiliary Facility Module Indexes (AFMI, or in the notation of the equations h_i) were derived, in the general case, from two components. The first, called in the accompanying Exhibit 3.2 the "plant relationship" was an Index obtained by examination of relevant examples taken from "the sample." The second, called the "industry relationship," was obtained from published sources. The latter were used to develop a Measure of Relative Importance (MRI) for the given type of facility in the given industry.

The ratio for the industry of gallons of water consumed to dollars of depreciable assets was adopted as the MRI for the Water Module. The applicability of data from "the sample" was generalized by a regression analysis of the plant Indexes and the MRI's for all industries for which both indicators were known. Such an analysis is illustrated in Exhibit 3.4. The general form of the regression is

$$(\text{Industry AFMI}) = h_i = K + b\ (\text{MRI}),$$

where K is the intercept and b is the slope.
Such linear expressions were fitted for all industries and modules for which data were available.

However, the choice of this form of approximation did create problems, particularly for values of the MRI in the neighborhood of the origin. Rather than fit the data to curves of higher order, supplementary free-hand curves were drawn, reproduced as Exhibit 3.3, for estimating values outside the range of application of the linear regressions. In the present example, the MRI for Meat Packing was 59 gallons per dollar. The linear regression was not considered appropriate for so small an amount. Instead, the industry AFMI, .025, was read directly from the chart. A further adjustment was needed to take account of the water available as a public service without capital cost to the industry. In the expansion tables the industry is charged with only that portion of the water consumed which on the average (in the U.S.) is provided at private expense. In this case the average was 58.7 percent and the module index was adjusted downward accordingly to .0147.

The MRI's for the On-site Outside Lines and General Facilities and the

Distributive Cost Modules are based on the sum of the AFMI's for other modules as indicated in Exhibit 3.2. For modules for which MRI's could not be computed, the industry Index was arrived at by judgment exercised within the limits of experience noted in "the sample." For instance, the Air Module for Meat Products was estimated at the maximum observed for plants manufacturing solid products, hence an Index of .0100.

The Input Factors listed under each Auxiliary Facility Module, see pages II-278 through 283, were developed as composites from the experience recorded in "the sample."

PROCESS
MODULE

Having built up the total cost of capacity expansion for an industry from an initial base equal to the installed cost of the Process Module, we were able to establish the factor for the Process Module, or its installed cost as a proportional part of total cost. We now turn to the constituents of the Process Module. The first of these steps concerns requirements for construction and is determined by the equation,

$$(4) \quad B = c\,P$$

The Index, c = .1905, applies to all Process Modules in all industries. It was derived from the data of "the sample." Note that it pertains, not to all buildings included in the expansion of the industry, but exclusively to the buildings contained in the Process Module. This requirement may be further subdivided by type of Industrial Building in non-building construction.

The next step is to "peel off" the building cost to obtain the installed cost of Process Equipment.

$$(5) \quad Q = P - B$$

The Meat Products example continues with the following table covering this step:

NPA Item Code (i)	Module	Index (h)	Factor (a)
	Process Module (Installed Cost = P)	1.000000	.477151
	Less:		
3B2241	Process Building Module Installed Cost = B)	.190500	.090898
	Process Equipment (Installed Cost = Q)	.809500	.386253

Similarly, an allowance is made for the Miscellaneous Equipment Materials Module to arrive at the installed cost of Significant Process Equipment. The Index governing this determination depends directly on the cut-off point used to define Significant Process Equipment. Since the same cut-off was used throughout, it is proper for this index to be constant (h_i = .0476) for all industries. The equations for these steps are:

$$(6) \quad M = h_i Q$$

$$(7) \quad N = Q - M$$

The numerical example continues:

NPA Item Code (i)	Module	Index (h)	Factor(a)
	Process Equipment (Installed Cost = Q)	1.000000	.386253
	Less		
980010	Miscellaneous Equipment Materials Module (Cost = M)	.047600	.018390
	Significant Process Equipment (Installed Cost = N)	.952400	.367863

At this stage, having reached the installed cost of Significant Process Equipment, it is again expedient to adopt a lesser subtotal as the base for calculation. Accordingly, we consider the delivered cost, D, rather than the installed cost, N, of this group of inputs. Using the base, D, we wish to separate the Common from the Specialized Process Equipment. We first concentrate on the Common Equipment. In an analysis of "the sample" we summarized requirements for these items into 12 functional groups. Based on the sum of the delivered cost of all Significant Equipment, D, the analysis showed ranges of the Indexes among industries as follows

Symbol	Common Equipment Function	Industry Range $\left(\frac{F_g}{D}\right)$ Low	High
(F_1)	Containers	.026	.531
(F_2)	Metal Formation	.015	.515
(F_3)	Metal Fabrication	.005	.809
(F_4)	Nonmetal Heating & Cooling	.003	.753
(F_5)	Heating Auxiliary Material	.001	.028
(F_6)	Transporting Solids	.018	.809
(F_7)	Pumping Fluids	.010	.208
(F_8)	Packaging and Bottling	.002	.100
(F_9)	Weighing	.002	.075
(F_{10})	Drivers Purchased Separately	.019	.124
(F_{11})	Miscellaneous Industrial Equipment	.006	.239
(F_{12})	Cleaning	.006	.034

This step is completed in the following equations which indicate the relationships among the delivered costs, respectively D, C, and S, of Significant, Common, and Specialized Process Equipment

$$(8) \quad C = \Sigma F_g$$

$$(9) \quad S = D - C$$

Note that the delivered cost of Specialized Process Equipment is derived as a residual. The details for the Meat Packing industry follow.

Delivered Cost Symbol			Delivered Cost Index
	Significant Process Equipment		1.000
	Less : Common Process Functions		
(F_1)	Containers	.048	
(F_2)	Metal Formation	.	
(F_3)	Metal Fabrication	.	
(F_4)	Nonmetal Heating & Cooling	.109	
(F_5)	Heating Auxiliary Material	.004	
(F_6)	Transporting Solids	.227	
(F_7)	Pumping Fluids	.041	
(F_8)	Packaging and Bottling	.	
(F_9)	Weighing	.075	
(F_{10})	Drivers Purchased Separately	.053	
(F_{11})	Miscellaneous Industrial Equipment	.011	
(F_{12})	Cleaning	.032	
(C)	Subtotal · Common Process Equipment		.600
(S)	Specialized Process Equipment		.400

The final round of subdivision is next. Having obtained estimates of the delivered cost for each functional group of Common and of Specialized Process Equipment, it is necessary to determine within each the delivered cost by item. In this step the Item Selection Lists given on pages II-308, 9 are used. The number of candidate items pertaining to each Common Process Equipment function is small and items inapplicable to a given industry can usually be eliminated on the basis of general technical knowledge. In some instances apportionment of delivered cost among items included in a functional group was suggested by published sales in the base year, in others by judgment reinforced by experience

MEAT PRODUCTS: Delivered & Installed Cost Indexes and Input Factors Exhibit 3.5

NPA Item Code (i)	Item	Delivered Cost Index	Expansion Factor	Expanded Delivered Cost Index	Installed Cost Index	Input Factor
	Total Cost of Industry Expansion					1.000000
	Significant Process Equipment	1.000000		1.474600	.367863	.249472
	Symbols for column items	D_i	x_i	$x_i D_i$		$D_i \frac{N}{X_w}$
	Specialized Equipment					
355AC	Meat Packing Equip	.400000	1.4	.560000		.099791
	Common Equipment (C)					
	Containers (F_1)					
2421A	Dressed Lumber	.034000	2.1	.071400		.008482
2499C	Wood Tank & Vat	.004000	2.3	.009200		.000997
3443H	Metal Tank & Vessel	.010000	2.3	.023000		.002496
	Nonmetal Heating/Cooling (F_4)					
3559U	Furnace, Oven & Kiln-Other Nonmtl Proc.	.055000	1.7	.093500		.013719
3585A	Industrial Refrigeration Equip	.054000	1.3	.070200		.013473
	Heating Auxiliary Material (F_5)					
32550	Clay Refractories	.003000	2.2	.006600		.000750
3433A	Industrial Oil Burners	.001000	1.8	.001800		.000247
	Transporting Solids (F_6)					
3534A	Electric Freight Elevator	.007000	1.2	.008400		.001746
35350	Conveyor	.138000	1.2	.165600		.034431
3536A	Hoist	.026000	1.2	.031200		.006490
3536B	Overhead Traveling Crane & Monorail	.046000	1.2	.055200		.011479
35370	Industrial Truck & Tractor	.010000	1.0	.010000		.002496
	Pumping Fluids (F_7)					
3561A	Industrial Pump	.018000	2.5	.045000		.004488
3564A	Industrial Fan & Blower Equip	.023000	2.5	.057500		.005740
	Weighing (F_9)					
3576C	Industrial Built-in Scale	.075000	1.3	.097500		.018709
	Drivers Purchased Separately (F_{10})					
35660	Power Transmission Equip	.032000	1.2	.038400		.007979
3621C	Electric Prime Mover Generator	.021000	1.3	.027300		.005237
	Miscellaneous Equipment (F_{11})					
3548B	Power Driven Hand Tool	.005000	1.0	.005000		.001243
3569B	All Other General Equip	.006000	2.5	.015000		.001499
	Cleaning (F_{12})					
3564B	Dust Collection & Air Purification Equip	.028000	2.7	.075600		.006983
35840	Industrial Vacuum Cleaner	.004000	1.8	.007200		.000997
	Symbols for column totals	$D = \Sigma D_i$		$X_w = \Sigma x_i D_i$		

of "the sample." Essentially the same procedure was followed with respect to Specialized Equipment, except that in this case the pertinent items were selected from the list for separate consideration. For completeness, these equations may be added:

$$(9) \quad F_g = \Sigma D_i ;$$

$$(10) \quad S = \Sigma D_i ;$$

where, for each F_g and S, i ranges over the corresponding sections or items of the Item Selection Lists.

As the final step in unraveling the Process Module, there remains the conversion of item costs expressed as proportional parts of the delivered cost of Significant Process Equipment ($h_i = D_i/D$), to item costs expressed as proportional parts of the total investment in industry expansion ($a_i = D_i/T$), or as Input Factors. The details of this conversion are shown for our sample industry, Meat Products, in Exhibit 3.5.

Note that the various items, D_i, of Significant Process Equipment have different Expansion Factors, x_i. That is, installation costs vary from item to item. For this reason the conversions from h_i to a_i cannot be obtained by direct application of the ratio $\frac{D_i}{D}$ to the previously determined total installed cost, N, of Significant Process Equipment expressed as an Input Factor. Instead it is necessary to adjust by the ratio, $\frac{D}{X_w}$, of total delivered cost to the total Expanded Delivered Cost. The equations used in the steps illustrated in Exhibit 3.5 follow:

$$(12) \quad D = \Sigma D_i = 1.000$$

$$(13) \quad X_w = \Sigma x_i D_i$$

$$(14) \quad a_i = \frac{D_i}{D} N \frac{D}{X_w} = \frac{D_i}{X_w} N$$

$$(15) \quad D' = \Sigma a_i ,$$

where i ranges over the items of Significant Process Equipment;

$$(16) \quad I = N \cdot D'$$

EQUIPMENT
INSTALLATION

Installation of Significant Process Equipment involves varying amounts of Materials and Labor for Foundation, Electrical, Piping, Instrument and Duct work. An Industrial Pump, Expansion Factor 2.5 may call for extensive amounts of piping, moderate amounts of foundation and wiring, some instrumentation and no duct work. Another item, Industrial Fan and Blower, having the identical Expansion Factor, may have associated requirements for Installation Materials and Labor of a quite different composition. Nevertheless, we have attempted to generalize such requirements relative to the level of the Weighted Average Expansion Factor, x_w.

$$(17) \quad x_w = \frac{x_w}{D} = \frac{x_w}{1.000}$$

The results of these studies are summarized in the table, "Material and Labor Components Included in Equipment Expansion Factor," page II-310. Distributions of the Weighted Average Expansion Factor between the levels tabulated may be obtained by linear interpolation.

Let us refer to entries in this table by double subscripts: w for the level (row) of the Weighted Average Expansion Factor; m for the material or labor component (column), including Significant Process Equipment.

Then,

$$(18) \quad x_w = \sum_w x_{wm}$$

The distribution for our illustrative industry follows:

NPA Item Code (i)		Index ($h=x_m$)	Factor (a)
	Significant Process Equipment	1.000	.249472
980020	Equip Foundation Material Module	.026	.006233
980030	Equip Electrical Material Module	.049	.011461
980040	Equip Piping Material Module	.046	.014707
980050	Equip Instrument Material Module	.023	.005237
980060	Equip Duct Material Module	.011	.002496
990115	Equip Installation Labor - XF 1.5	.321	.078257

The list of Input Items and the Factors associated with each Equipment Installation Material Module were derived from information contained in "the sample."

CONSTRUCTION

In actuality industrial buildings are almost infinitely varied in detail. Nevertheless, we have attempted to represent the spectrum of possibilities by an array of 35 building types. The characteristics of the Industrial Building Modules are presented in the chart on page II-311 and the tables of Input Factors on pages II-259 to 276. The building types comprise different combinations of frames (wood, masonry, concrete, steel), loading (standard, heavy), floors (single, multiple), basement (with, without), roof (pitched, flat), cladding (metal, masonry), and interior (open, finished).

Requirements for such buildings are generated as inputs either directly by incorporation in the Process Module or indirectly through Auxiliary Facilities Modules. For the Process Module, Input Factors for buildings were derived as discussed in connection with Equation 4 above. The distribution of total building costs, as defined, among types of building follows the experience of "the sample."

The Industrial Building Modules are supplemented by 3 Building Accessory Modules which provide for plumbing and introduce variations in lighting and heating. (See page II-277.) Note that these modules provide, for example, only for heating accessories. The heating equipment itself is provided for in an Auxiliary Facility Module.

There are also 6 Non-building Construction Modules (see pages II-275, 276). Requirements for 4 of these are subordinate to the Auxiliary Facility Modules with which they are uniquely associated. The two other modules, Industrial Road and Rail Systems, serve as possible subdivisions of the construction component under the Process Module and are treated in the same fashion as Industrial Buildings.

The Input Factors listed under the Construction Modules were developed by judgment reinforced by the data of "the sample." No account has been taken in the distribution of Input Factors of possible economies or diseconomies of scale.

LABOR

Input Factors generating requirements for Labor Modules are included in Industry Expansion Tables, Auxiliary Facilities Modules, and Construction Modules. For the Industry Expansion Tables and all types of modules except Labor, Input Factors are expressed as proportional parts of a dollar expenditure which in total is left to be determined outside the Expansion Table or Module. Thus

$$(19) \quad a_i = \frac{H_i}{T} ,$$

where H_i is the expenditure on the i^{th} item. In these modules the factor sum, or total module cost, is always equal to unity. In the Industry Expansion Table,

$$(20) \quad \Sigma a_i = T = 1.000$$

Estimates of costs for individual items in an industry expansion can readily be obtained by multiplying the total cost, when known, by the corresponding factor.

For Labor Modules, in contrast, the Input Factors express requirements for Manhours per Dollar of Expenditure. The denominator of the expression, however, differs for the Installation and for the Construction Labor Modules. For construction labor the factor, r_i, is the quotient of manhours by occupation R_i, divided by the expenditure for construction, K, in the given module, m.

$$(21) \quad r_i = \frac{R_i}{K_m}$$

Whereas for installation labor the factor, s_i, is the quotient of manhours by occupation divided by the normalized total expenditure for labor, L = 1.000.

$$(22) \quad s_i = \frac{R_i}{L_m}$$

In the evaluation of factors for manhours per dollar, the average hourly earnings for each occupation in the United States in 1963 were inserted in the equations. In this context "average hourly earnings" is defined as labor expenditure by occupation per hour worked. It includes straight time, overtime, shift premiums, paid vacations, paid sick leave, and has been normalized for differences in grade within occupation. Since the earnings attributed to these occupations were all considerably in excess of one dollar an hour, the factor sums of the Labor Modules are always less than unity.

The requirements for Manhours by occupation, the items of labor inputs, are closely related to the relative amounts and kinds of equipment and materials to be installed and worked on. The information of "the sample" is abundant in such relationships and has been used extensively in the development of Labor Modules.

The "Percentage Distribution of Occupational Manhour Inputs" for each Labor Module is given in the table on pages II-314 through 316. This table may be interpreted as providing an alternative presentation of Input Factors for each Labor Module. In this table inputs are stated as proportional parts of total manhours rather than of dollar expenditure. The table also lists the average hourly earnings for each occupation as well as the weighted average for each Labor Module.

Construction Labor. Each Construction Labor Module is uniquely associated with the corresponding Construction Module. If the factors included in these modules were stated in the same units as the Construction Modules, namely, dollars expended for a labor input per dollar of total expenditure, then the labor factors could have been incorporated directly in the Construction Modules. The sole purpose of separate Construction Labor Modules is to give recognition to the change in units in which the factors are expressed

We now continue with the example of expansion in Meat Products. The Industry Expansion Table calls for an input of an Industrial Building, Type 2241. The Construction Module for this in turn calls for an input of Construction Labor 3B2241 in the amount of .515000 per dollar of expenditure for this building.

$$(23) \quad a_i = \frac{L_i}{K_m} ,$$

where a_i is the total construction labor input, L_i is the total expenditure for Construction Labor in the Construction Module, and K_m is the total expenditure for construction in that module.

The percentage distribution table, page II-315, indicates weighted average hourly earnings, E_m, for this module of $3.10. We divide the total construction labor input by the weighted average hourly earnings to obtain the base, $\hat{R}$, as factor sum, for the corresponding Construction Labor Module.

$$(24) \quad \hat{F}_m = \frac{L_i}{E_m}$$

In this instance,

$$\hat{R}_m = \frac{.515000}{3.10} = .166100$$

A truncated version of the Construction Labor Module follows:

NPA Item Code (i)	Manhours by Occupation	Index (h) (Proportional Part of Total Manhours)	Factor (r) (Manhours per dollar of Construction Expenditure)
990178	Construction Labor 3B2241	1.000	.166100
908000	Laborers	.231	.038370
950700	Bricklayers	.075	.012460
950740	Carpenters	.202	.033550
- - -	- - - - - - - -	- - -	- - -
961800	Truck Drivers	.048	.007970
969990	Concrete Finishers	.025	.004150

The individual Input Factors, r_i, are obtained by multiplying the Index Base, $\hat{R}_m$, by the Index, h_i.

Equipment Installation Labor. Modules for this purpose are distinguished by the level of the Weighted Average Expansion Factor with which they correspond. Graduated in tenths, the modules cover a range of factors from 1.0 to 2.8. The same module may appear in a number of Industry Expansion Tables. There is then no unique relationship between table and module as there is between Construction Modules and Construction Labor Modules. The Installation Labor Modules, therefore, must be presented in the usual normalized form in order to accept varying demands from Industry Expansion Tables.

Again we take up the Meat Products example. The Industry Expansion Table calls for an input of Installation Labor XF-1.5. The percentage distribution table, page II-314, indicates weighted average hourly earnings, E_m, for this module of $3.33. We divide the unit expenditure, L = 1.000, for installation labor by the weighted average hourly earnings to obtain the base $\hat{R}$, or factor sum, for the module

$$(25) \quad \hat{R}_m = \frac{1.000}{3.33}$$

In this instance

$$\hat{R}_m = .299930$$

A truncated version of the Equipment Installation Labor Module follows:

NPA Item Code (i)	Manhours by Occupation	Index (h) (Proportional Part of Total Manhours)	Factor (s) Manhours per dollar of Labor Expenditure
990115	Installation Labor XF-1.5	1.000	.299930
908000	Laborers	162	.048590
950640	Boilermakers	.021	.006300
950740	Carpenters	.120	.035990
- - -	- - - - - - - -	. .	. . . .
961800	Truck Drivers	.046	.013800
962020	Welders	.018	.006600

As before the individual Input Factors, s_i, are obtained by multiplying the Index Base $\hat{R}_m$ by the Index, h_i.

LEADTIMES

Each Input:Capital Factor, as listed in the tables in Part Two, has two associated leadtimes. The Mean Leadtime is the average time in months prior to the completion of a plant in operating condition, by which the material, equipment, or manpower defined by the input item is needed on the plant site. The Leadtime Semi-Range (shown in the table as Range/2) is the range in months before and after the mean leadtime during which the input item is needed on the plant site. It is implicitly assumed that the quantity defined by the input factor should arrive on the plant site at an approximately uniform rate, starting at the mean leadtime plus the semi-range and ending at the mean leadtime minus the semi-range, measured in months prior to the date at which the plant is to be ready for operation

For example, the mean leadtime for a specific input may be 4.50 months. This means that half of this input must be on the plant site 4.5 months before completion of plant construction. The semi-range may be 2.50 months. This means that the start of this input would be 4.50 + 2 50 months, or 7.00 months before completion of plant construction, and, that completion of this input would be 4.50 - 2.5- months, or 2.00 months before completion of plant construction.

Industry input leadtimes appear only in the Industry Expansion tables. The leadtimes for modules are included in the module input factors as they appear in the Industry Expansion tables.

Leadtimes for individual input items were first estimated as percentages of total elapsed construction time on site, based on engineering experience and judgment, and on the data of "the sample". These percentage leadtime estimates are given in the table on pages II-312 and 313.

The next step was to estimate the total onsite construction time for each industry. The data of "the sample" were used to construct a curve relating total onsite construction time to the total cost of the project.

This equation was:

log (Number Construction Months) = -.01865 + .203795 log (Average Book Value)

This equation was based on a five-day work week, with 70% of manhours on the first shift, 20% on the second shift, and 10% on the third shift.

Data from the 1957 Annual Survey of Manufactures were then used to determine the average book values of establishments in each industry. Separate estimates were made for "large plants" and for "small plants." Large plants were defined as including those size classes (grouped by number of employees) which collectively produced approximately 80% of the value added by manufacture in the industry. Small plants included all other plants in the industry. The construction leadtime for each industry was then determined by substituting these average book value figures in the equation given above. For both large and small plants the industry's total elapsed construction months were multiplied by 1.5 to allow sufficient months for preconstruction months required for design and procurement of equipment.

REFERENCES

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[2] U.S. Department of Commerce, Bureau of Census, Census of Manufactures: 1958; Volume I: Summary Statistics, Chapter IX, Table 1, "Selected Costs and Book Value of Fixed Assets."

[3] U.S. Department of Commerce, Bureau of Census, Census of Manufactures: 1958; Volume I: Summary Statistics, Chapter XI, Table 2, "Quantity of Water Used and Discharged by Manufacturing Establishments, by Purpose of Industrial Use."

[4] U.S. Department of Commerce, Bureau of Census, Census of Manufactures: 1958; Volume I: Summary Statistics, Chapter VI, Table 3, "Fuels and Electric Energy Used."

[5] U.S. Department of Commerce, Bureau of Census, Industry Reports, "Industrial Gas Users." Various years

[6] U.S. Department of Commerce, Bureau of Census, Census of Manufactures: 1958; Volume I: Summary Statistics, Chapter V, Table 2, "Value of Manufacturers' Inventories."

[7] U.S. Department of Commerce, Bureau of Census, Census of Manufactures: 1958; Volume I: Summary Statistics, Chapter 1, Table 3, General Statistics for Operating Manufacturing Establishments."

[8] U.S. Department of Labor, Bureau of Labor Statistics, Division of Economic Growth, "1958 Capital Flows," April 1965 (Unpublished)