NRIG-H7

NATIONAL BUREAU OF STANDARDS REPORT

NBS REPORT NO. 9691

PRESENTATION OF A
COST ANALYSIS/COST SYNTHESIS SYSTEM

TO

MR. LOWELL G. SCHWEICKART
DEPUTY ASSISTANT ADMINISTRATOR
FOR CONSTRUCTION
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NBS

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

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[2] Located at Boulder, Colorado, 80302.

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U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON, D.C. 20234

PRESENTATION OF A COST ANALYSIS/ COST SYNTHESIS SYSTEM

to
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Deputy Assistant Administrator
for Construction,
and Staff
Veterans Administration

February 7, 1968

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BUILDING SYSTEMS SECTION
BUILDING RESEARCH DIVISION

A COST ANALYSIS/COST SYNTHESIS SYSTEM

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1. BACKGROUND

INTRODUCTION

The complex integrated and iterative nature of the system described here precludes all but a brief outline of the system in this document. The supporting documentation is contained in a 450 page, 5 volume document entitled, DATA PROCESSING FOR BUILDING CONTROL: AN INTEGRATED CONCEPT, by George S. Birrell, A.R.I.C.S. and is, a priori, contained herein.

After 3 years of development, the work is at a point where opportunity for application is the prerequisite for final stage development and for project benefits accruing to the system's user.

This Cost Analysis/Cost Synthesis system is itself an Analog of the Building Process and does not require the development of a complex "language" (other than that of Building) for its successful application. It is ideal as a tool for the program builder.

CONTEXT, CONCEPT AND DESCRIPTION

THE CONSTRUCTION INDUSTRY

Everyone in construction is interested in costs. The materials have a cost. The resources used to put the materials in place have a cost. These resources are costed by the duration of time they take to do the job. All of these costs impinge on and are conditioned by the design decisions for the building, which are made to satisfy the clients requirements for a building, one of which is usually cost.

Everyone involved in the contract--the client, his advisors, the contractors, etc.--all must have cost information about the project at each phase of the contract and in the correct manner for that phase. This need for information is so great at all contract phases that each party produces his own in a manner which may bear little correlation to that used by the others or required in other contract phases. The costs of these approximations are borne by the client and are expensive due to multiple production, lack of correlation and resulting loss of efficiency in work execution on each contract. This is true for the industry as a whole.

The client who continually builds pays a large percentage of this all-industry bill. He is continually faced with a "non-system" regarding cost information on every contract he places. Because information for each contract is usually organized differently from previous contracts he is unable to efficiently "parlay" experience gained from past contracts.

We propose a system for an alternate building future. That future could be described as real-time control of the construction industry in

such a manner as to provide continuing iterative benefits to all the users of the information system (the people who are involved in a building contract).

Successful application of the system means greater efficiency by the industry which for the client means the lowering of building costs, faster construction and better value for money spent.

The conceptual work for this system has been completed and is based on contemporary management techniques and practices from industry. The detailed concept is contained in the five volume (450 page) research report "Data Processing for Building Control: An Integrated Concept".

EVOLUTION OF THE COST ANALYSIS/COST SYNTHESIS SYSTEM

The system is based on the proven service function to the construction industry of the quantity surveyor. This professional provides an exact description of the work to be bid TO ALL CONTRACTORS, assuring that all are bidding on an identical "thing". He also develops the method for settling change orders and interim payments.

He has added to his skills by carrying out a degree of formal cost synthesis at the design stage of a contract. These processes remain very much on a manual basis with subsequent limitations to scope, speed and manipulation of the underlying data.

It could be said that regarding building construction cost data the quantity surveyor's skill is that of a manual data processor.

With the arrival of the digital computer he is provided with a tool which, if used wisely, can not only do his existing work faster and with less risk of manual error, etc. but can enable him to widen his scope to that of providing a cost and work control information analog

of the building construction process.

This analog process can be used for all normal building construction projects so that all projects have the same basis. This enables the user to plan and monitor each project in its entirety or study the same aspects, e.g., costs, durations, applied resources, etc. for the similar aspects of a number of projects. The user can thus explore the cost effect of different types of design or construction process.

This analog need not only examine past construction projects but should be used as the:

1. forward planning mechanism for cost budgeting prior to design,
2. controlling design against that budget,
3. providing a common basis for estimating for all the bidding contractors,
4. providing the work plan required by each different bidding contractor,
5. providing the basis for construction work planning,
6. resource allocation,
7. material delivery schedules,
8. settling of change orders,
9. accurate evaluation of interim payments by the client and the settlement of the final cost of the contract.

For each project, the system permits each user (Architect, Client, Builder) to manipulate information in ways that present the process, cost, and time implications of his alternative decisions BEFORE THEY ARE MADE.

2. THE SYSTEM

THE COST ANALYSIS/COST SYNTHESIS SYSTEM

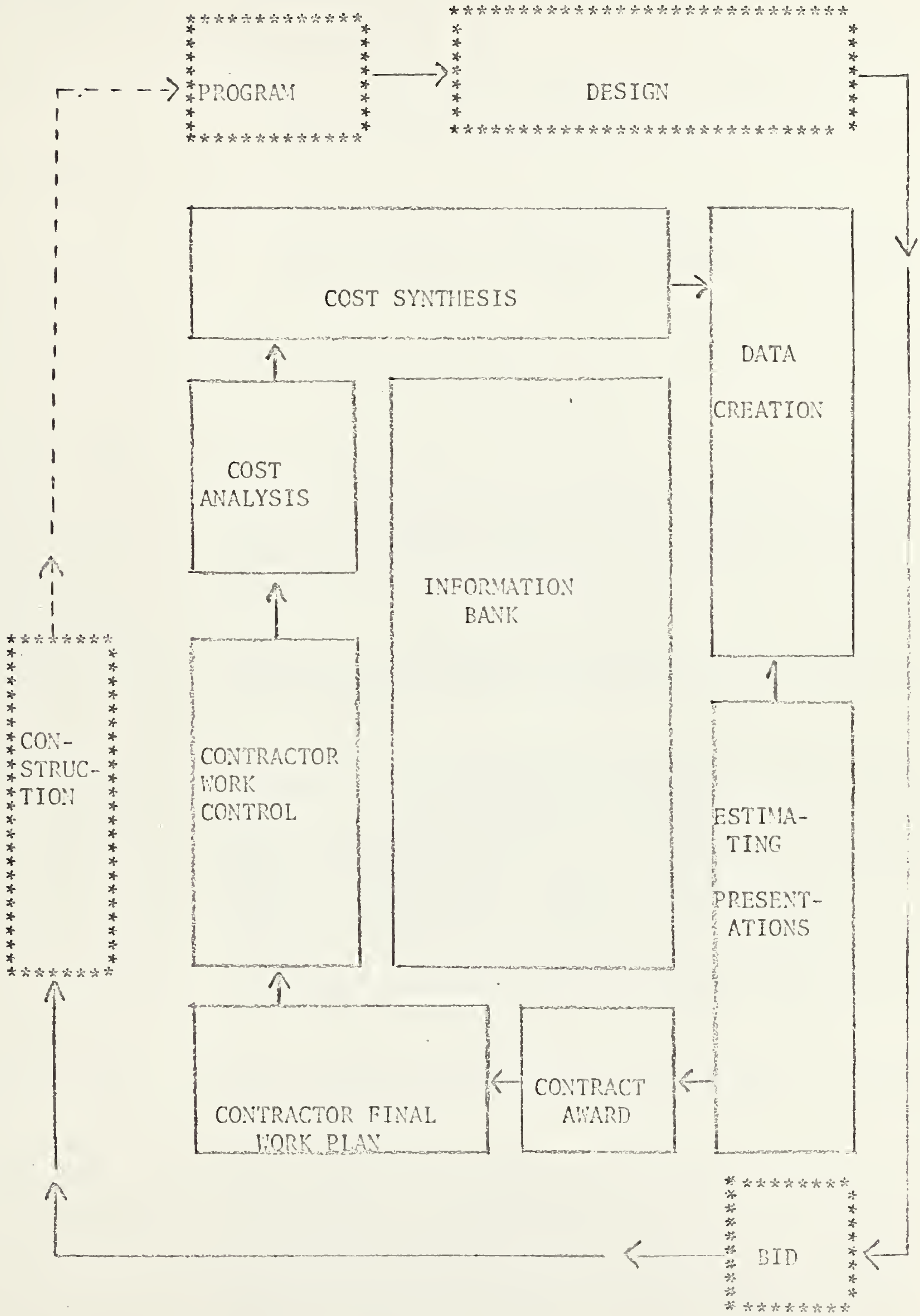
Reference should be made to the diagram on the next page in which the time duration of each contract moves clockwise, beginning at the top left-hand corner.

The outer ring represents the necessary work phases of any building contract while the core is a block systems diagram of the cost information system.

A clear recognition of the phases of a building contract which require cost information (and its producing factors) is a prerequisite of the integrated cost information system. Such work phases can be named Program, Design, Bid and Construction.

Program	In the description of the building he requires, the client wants to match a realistic total cost to the building he requires <u>or</u> find out what building he can get for his stated total cost. Realistic total cost being a budget cost which is close to the eventual bid figure.
Design	Designing the building to meet the needs of the client within the budgeted total cost.
Bid	The estimation of the total cost of the building process by each bidding contractor to produce his bid figure.
Construction	The actual construction of the building by the contractor.

The components of the Cost Analysis/Synthesis system which provide the cost information required by these work phases in the form most suitable for use at that time can be named Cost Synthesis, Data Creation, Estimating Presentations, Contract Award, Contractor Final Work Plan, Contractor Work Control, Cost Analysis and Information Bank. These cost data processes carry out their work contiguous with their relevant contract work phases.


PROGRAM
DESIGN
COST SYNTHESIS
DATA
CREATION
COST
ANALYSIS
INFORMATION
BANK
CON-
STRUC-
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CONTRACTOR
WORK
CONTROL
ESTIMA-
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PRESENT-
ATIONS
CONTRACTOR FINAL
WORK PLAN
CONTRACT
AWARD
BID

Cost Synthesis	(a) During Program Work Phase The alternatives are: (1) From the building construction chosen the synthesis of a total cost which will be close to the total of the Bid. (2) The taking of a budgeted total cost for a project and arriving at the construction alternatives available for that budget to produce "a building for the money". (3) A mixture of (1) and (2). (b) During Design Work Phase The maintenance of the previously set total budget by the matching of cost increase changes during design by equivalent cost saving design changes or in other words, designing to a flexible cost budget while maintaining a total budget.
Data Creation	Subsequent to Design completion the semi-automated creation of the coded and quantified description of the building.
Estimating Presentations	This process is the presenting of the data to the contractor in the forms most suitable for estimating. These are (a) bulk quantities of each item for the whole job presented by trade and (b) plans of each bidding contractors' chosen construction work order. These may be different from one contractor to another. The latter presentation facilitates evaluation of contract duration and complexity of his chosen overall construction process which have considerable bearing on his estimate of cost.
Contract Award	The evaluation of the various contractors' bids as regards cost and contract duration and the awarding of the contract.
Contractors Final Work Plan	The creation of the work plan which is used to plan and control the construction process. This work plan may be the estimating work plan or it can be an accepted improvement upon that plan as regards shorter duration or less resources required, but either will be achievable within the contractors bid.

Contractor Work Control	The process of controlling the construction work against the Final Work Plan by monitoring construction progress as it happens against the Plan and adjusting the remainder of the Plan to accommodate changes to keep the construction process in line with the cost and time target.
Cost Analysis	The analysis of the cost of the project into the form which is used for cost synthesis of future work.
Information Bank	The storing in a similar structured manner of costs, durations and resource records of past contracts and their correlation and projection into the future (e.g., on a time series) to facilitate their use in all phases of future construction contracts.

One of the products of the use of the system is a standardized information system for all normal building contracts, and if a number of building contracts have been executed on this standard information system the feedback data which has been stored can be analyzed and projected into the future to enable the planners and controllers of future work to execute their work more efficiently. The process of analysis of these feedback records, is, in general terms, to isolate the better methods of execution of all of the work phases and employ such better methods on future contracts.

The logic of the required computer programs along with the reasoning behind them and also their potential uses, the processes of work planning, coordinating and control and the integration of the data processes, etc. are all described in the five volume research report referred to in the introduction, and which is, a priori, part of this report.

THE CODING OF DATA

The core of the manipulating mechanism is the 6 faceted code used to present the descriptive and quantified data as required by each work phase.

Each descriptive and quantified item is coded against each facet of the 6 faceted code which is structured in the following manner:

Element	Storey	Trade	Type of Item	Individual Description	Unit of Measurement

Element — is produced by a matrix analysis of the building against (a) the building as an end product and (b) the broad work phases of the construction process.

Storey — is the storey of the building on which the item is a part.

Trade — is the trade which executes the work of the item.

Type of Item — is potential for anlysis of both On Site/Off Site work and Production/Erection work.

Individual Description — gives an individuality number to each item.

Unit of Measurement — is the item's quantity unit of measure.

It can be realized that as each descriptive item has a quantity and a unit of measure it can be rated and priced. As each item is coded against all of the facets one can manipulate all of the items or their quantities or prices (and the latter can reflect times, durations and resources) into an order defined by a single facet or permutation of facets. Such orders of items can provide the Presentations of information required as each work phase of the building contract and provide the requirements of the information bank.

These Presentations may be structured for analysis by each party to the building process....that is, not everybody is interested in the same information, or will manipulate it the same way.

3. COST/BENEFIT ANALYSIS

COST/BENEFIT ANALYSIS

For the building client the cost of carrying out this work contains two elements

(1) Start up and development costs and

(2) Eventual "on-stream" costs.

It is the latter cost element which should be mainly considered in the cost/benefit analysis.

For the building client the benefits of carrying out this work are of four major elements:

(a) process of estimating

(b) use of successful bid as basis for contract interim payments

(c) settlement of variations and final cost of contract and

(d) use of contract cost analyses as budgeting figures for future work.

While considerable cost and procedural benefits to the client can be envisaged by use of benefit elements (b), (c) and especially (d) for simplicity this cost/benefit analysis will be confined to comparing cost element (2) and with benefit element (a).

It will be realized that the benefit to the building client will be the dollar value of the difference between the present cost of producing a take-off for estimating and the future cost of producing a take-off for estimating. This figure can be expressed as a percentage of the cost of the building project.

This percentage can then be related to the yearly construction cost of each government department and to the whole Federal Government.

The Federal Government spends on its own building construction direct account approximately $2 billion per year.

QUANTIFIED COST/BENEFIT ANALYSIS

Taking the example of a $5 million high rise government office building it is estimated that the cost of creating a quantity take off for bidding purposes by all successful and unsuccessful general contractors, subcontractors and their suppliers, etc. is in the region of $540,000.

For the building client to employ the proposed system of preparing such documents the cost would be in the region of $100,000.

	$ COST	PERCENTAGE
Project	5,000,000	100%
Existing Process	540,000	11%
New Process	100,000	2%
Difference Existing Minus New	440,000	9%

At this point it should be remembered that this 9% saving is only at the estimating presentation stage of the contract. This new process has advantages in that it opens the door for further efficiency creating and cost saving procedures to be implemented. Each of these procedures will be cost viable within its own right thus the cost saving effect will be cumulative.

The figures from which the above cost/benefit analysis is derived are contained in the following section.

BUILD UP OF COST/BENEFIT ANALYSIS

(1) Existing Cost of Producing a Quantity Take Off

For each job sent out to Bid there are a number of general contractors each with subcontractors and suppliers. This is further complicated by the ensuing cross bidding, e.g., a subcontractor or supplier bidding to a number of general contractors.

To establish a cost of creating a take off under these circumstances an estimate was taken from two general contractors, (a) a very large New York contractor and (b) a medium sized Massachusetts contractor. Each was given as a basis a high rise government office building or housing project costing about $5 million. The following are their figures evaluated from their records and compiled in their own chosen manner.

		$	$
(1) (a)	General Contractor		19,830
	17 Major Sub Contractors) 10 Minor Sub Contractors)	28,200	
	Sub Sub Contractors	5,500	
	Suppliers	1,800	35,500
	Salary Costs		55,330
	Overhead Factors(x2 or x3)	say =	x2
	Cost of One Successful Bid by One General Contractor and One Sub Contractor for Each Trade		110,660
	Each General Contractor will take bids from usually about four Sub Contractors for each Trade but each Sub Contractor will bid to more than one General Contractor. Balance is evaluated that cost for a Total Bid will be doubled for work of unsuccessful Sub Contractors $28,200 + $5,500 in Salaries = $33,700		110,660
	Overhead Factors (as above)	x2	67,400
			178,060
	This Cost is for Take Off and Pricing and it is evaluated that the cost breakdown will be 50% each		x50%
	Cost of Take Off for One General Contractor Bid		89,030
	On each Job for bidding there are usually between four and twelve General Contractors with an average of seven		x7
	Cost of Take Off for total bids of General Contractors bidding on One Job		623,210 To Summary

		$	$
(1) (b)	General Contractor		5,000
	3 Major Sub Contractors @ 2500	7,500	
	5 Minor Sub Contractors @ 1500	7,500	15,000
	40 Material Suppliers @ 200	8,000	8,000
			28,000
	Conservative overhead factors		x2
	Cost of One Successful Bid by One General Contractor and One Sub Contractor for Each Trade		56,000
	Cost of unsuccessful but necessary bids by Sub Contractors and allowing for cross bidding to more than one General Contractor produces additions of 50% to cost of Sub Contractors $15,000 x 50% = 7,500		
	Conservative overhead factor (as above) x2		15,000
	Full Cost of One Bid by One General Contractor		71,000
	Cost of Take Off to Pricing breakdown considered to be 80% Take Off to 20% Pricing		x80%
			56,800
	For each Job there will be an average of about eight General Contractors		x8
	Cost of Take Off for all Bids on One Job		454,400

(2) Future Cost of Producing a Quantity Take Off

In Great Britain the Royal Institution of Chartered Surveyors has a standard fee scale for this type of Take Off Production. This scale is evaluated by cost of building project and type of the building and is expressed as a percentage. For work such as used on the example the scale would be between 1 1/4% and 1 1/2% of the cost of the building work, say....1 1/2% of $5 million....$75,000 say $100,000.

SUMMARY

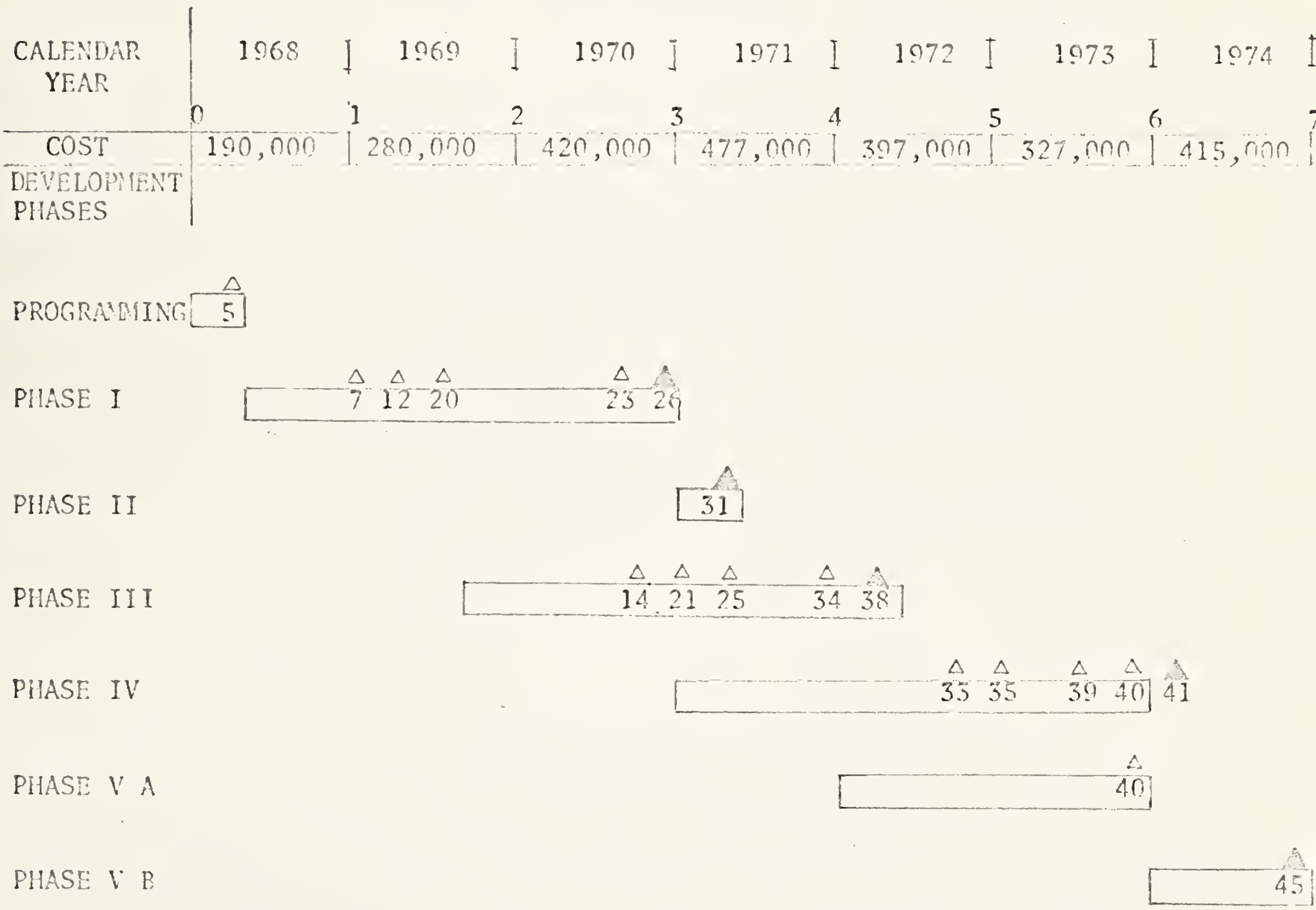
		$		$
(1)	Cost of Existing Take Off Process			
	(a) New York Contractor	623,210		
	(b) Massachusetts Contractor	454,400		
		1,077,610		
		÷ 2		
	Average Cost of Producing All Take Offs for One Building Contract	538,805	say	540,000
(2)	Cost of Future Take Off Process	75,000	say	100,000
	PROJECT COST/BENEFIT.			440,000

4. THE DEVELOPMENT PROGRAM for applying the system

DEVELOPMENT PROGRAM: CONTENTS

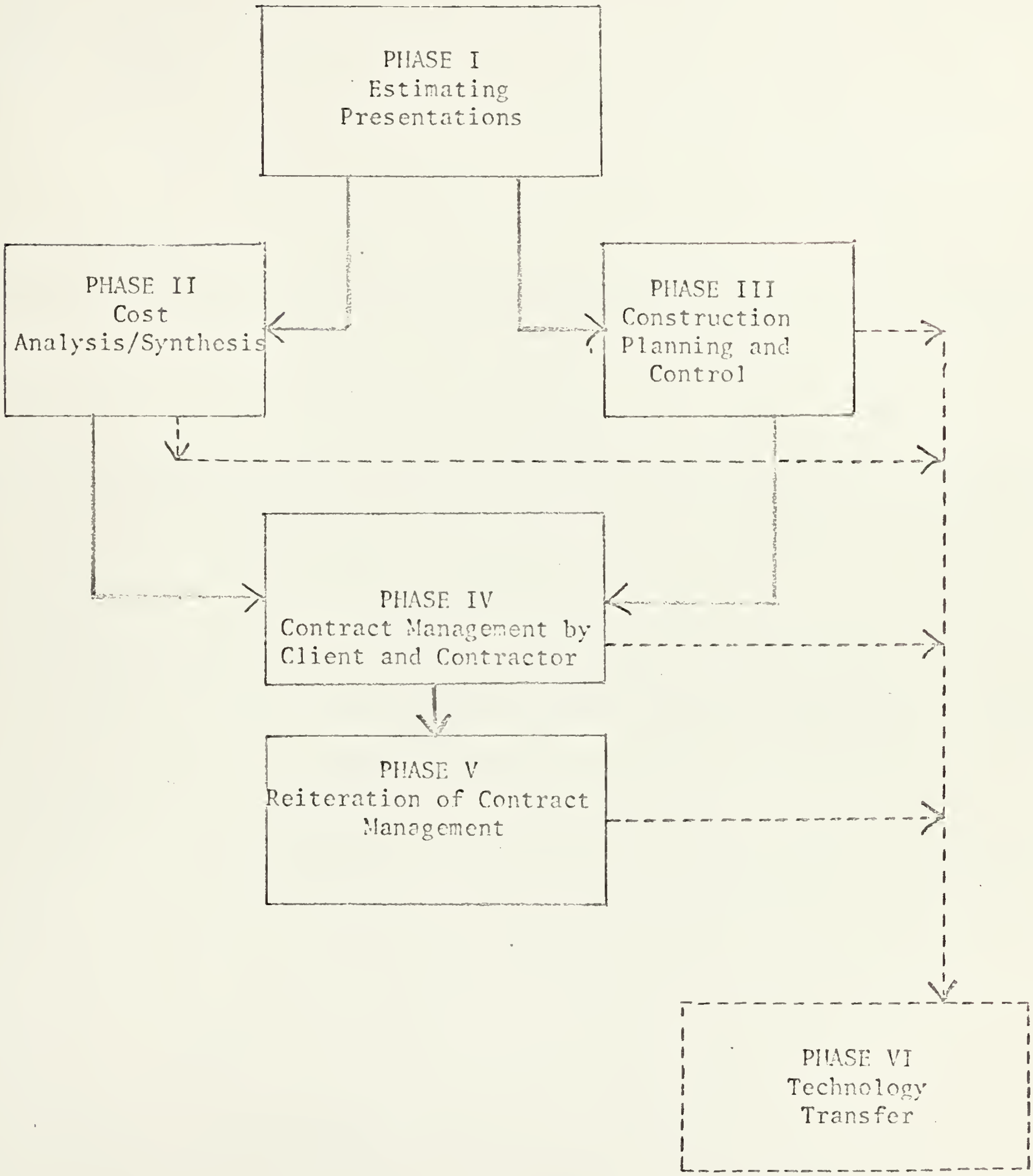
It must be emphasized that while this project is laid out on a total approach involving 7 years of effort and 2.5 million dollars of project cost, each intermediate phase provides beneficial output worth that intermediate cumulative investment.

The time phasing of the project breaks down the total effort with end of phases at major milestones. Project output at major milestones and certain (minor) milestones provides the Federal construction manager with a guage of his risk for continued support to the project.



A more detailed statement of Phase I and II is shown here:

PHASE	OUTPUT NODE	MAJOR or MINOR	TYPE OF OUTPUT	WORK EXECUTED
Programming	5	Minor	Computer Programs complete	Computer Programs written
I	7	Minor	Completion of Bid Documents	Semi-automated quantity take-off coded and presented for Estimating
	12	Minor	Bids received from Contractors	Contractors have compiled their bids by use of Bid Documents
	20	Minor	Bids checked and Contract awarded	
	23	Minor	Construction Job complete	Variations and Interim Payments evaluated and made from Bid Documents
	26	Major	Finalization of Contract	Settlement of Final Price for the Job
II	31	Major	Test Price Analyses Complete	Simulation of Cost Analyses carried out


PHASE I
Estimating
Presentations
PHASE II
Cost
Analysis/Synthesis
PHASE III
Construction
Planning and
Control
PHASE IV
Contract Management by
Client and Contractor
PHASE V
Reiteration of Contract
Management
PHASE VI
Technology
Transfer

RESEARCH PHASE	ACTIVITY DESCRIPTION	ACTIVITY NODES	DURATION (In Months)	CRITICAL PATH	RESOURCES
PROGRAMMING	Computer Programming	1 5	4	*	Building Systems Section Consultancy and Supervision
	Get Project for Phase I	3 4	3		
	Get Staff	2 5	4		George Birrell
					IAT Computer Center

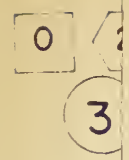
RESEARCH PHASE	ACTIVITY DESCRIPTION	ACTIVITY NODES		DURATION (In Months)	CRITICAL PATH	RESOURCES
PHASE I	Drawings Preparation (Outside)	4	7	7		Building Systems Section Consultancy and Supervision
	Preparing Estimating Documents	5	7	8	*	
	Legality of Estimating Documents	6	7	2		George Birrell
	Explaining to Contractors	7	10	1	*	2 Quantity Surveyors
	Bid Duration	10	12	2	*	1 Contractor Estimator
	Checking Bids	12	20	1	*	4 Research Associate Assistants
	Contract Variations and Interim Payments (Construction Duration)	20	23	18	*	1 Secretary/Copy Typist
	Contract Settlements	23	26	2		

RESEARCH PHASE	ACTIVITY DESCRIPTION	ACTIVITY NODES	DURATION (In Months)	CRITICAL PATH	RESOURCES
PHASE II	Test Price Analyses	26 28	2		Building Systems Section Consultancy and Supervision
	Test Work Planning	28 31	2		George Birrell
					2 Quantity Surveyors
					1 Contractor Estimator
					4 Research Associate Assistants
					1 Secretary/Copy Typist
					1 Educationalist

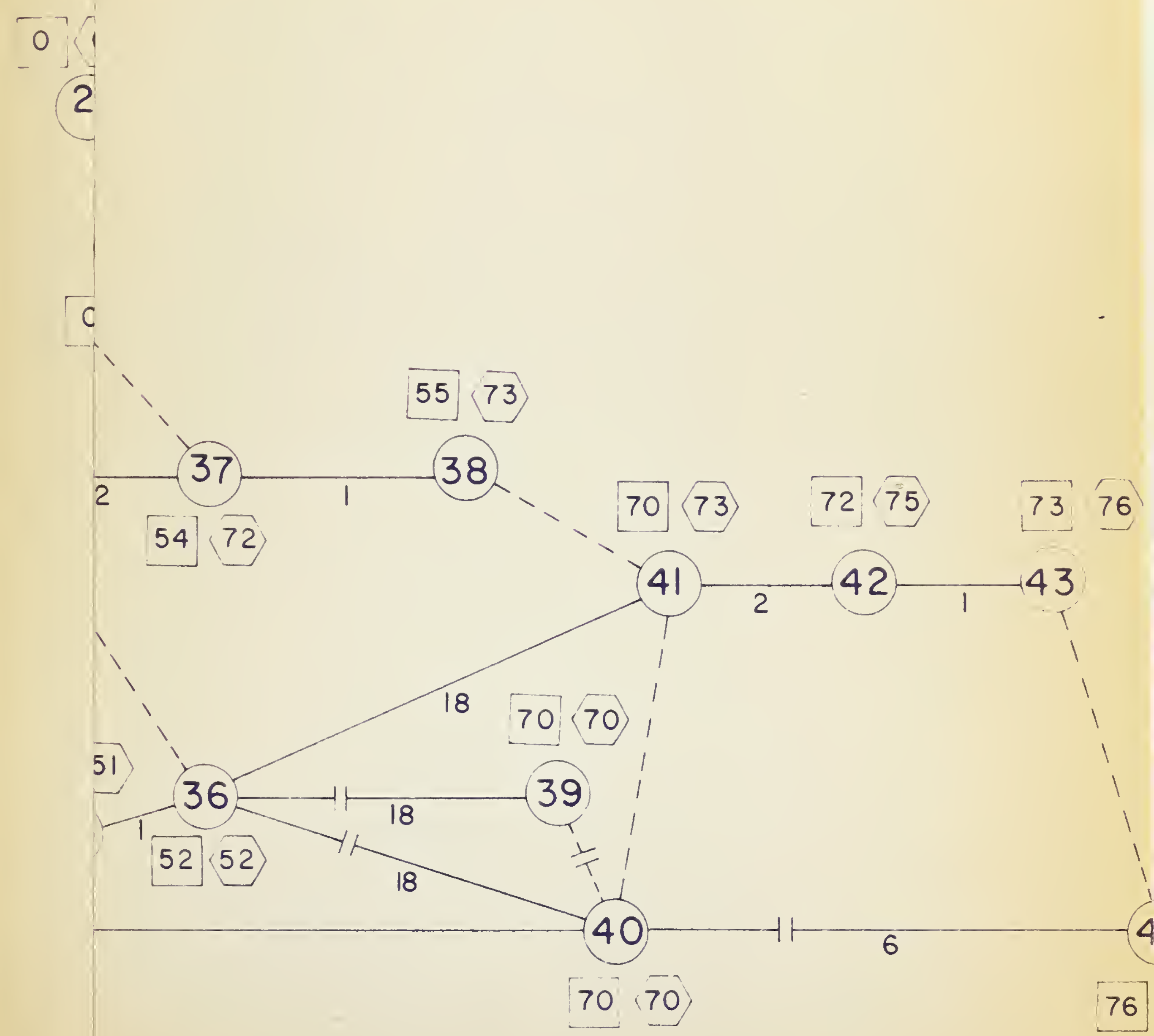
RESEARCH PHASE	ACTIVITY DESCRIPTION	ACTIVITY NODES		DURATION (In Months)	CRITICAL PATH	RESOURCES
PHASE III	Get Project for Phase III	4	8	3		Building Systems Section Consultancy and Supervision
	Get Additional Staff	8	13	4		
	Drawing Preparation (Outside)	8	14	7		George Birrell
	Prepare Estimating Documents	9	14	8		2 Quantity Surveyors
	Legality of Restricted List of Contractors	11	14	2		1 Contractor Estimator
	Explaining to Contractors	14	21	1		1 Contractor Work Planner
	Bid Duration	21	22	2		8 Research Associate Assistants
	Checking Bids	22	25	1		1 Secretary/Copy Typist
	Produce Work Plans Required By Contractor	25	29	1		1 Educationalist
	Dummy Run Resource Allocation and Timing	29	32	1		1 Programmed Learning Writer
	Contract Variations and Interim Payments (Construction Duration)	25	34	18	*	
	Contract Settlement	34	37	2		
	Contract Price Analysis	37	38	1		

RESEARCH PHASE	ACTIVITY DESCRIPTION	ACTIVITY NODES		DURATION (In Months)	CRITICAL PATH	RESOURCES
PHASE IV	Get Project for Phase IV	9	15	3		Building Systems Section Consultancy and Supervision
	Get Additional Staff	15	17	4		
	Drawing Preparation (Outside)	15	19	7		George Birrell
	Prepare Estimating Documents	16	19	8		1 Quantity Surveyor
	Legality of Restricted List of Contractors	18	19	1		1 Contractor Estimator
	Explain to Contractors	19	24	1		1 Contractor Work Planners
	Bid Duration	24	27	2		1 Cost Accountant
	Checking Bids	27	30	1		8 Research Associate Assistants
	Contract Variations and Interim Payments (Construction Duration)	36	41	18		1 Secretary
	Contract Settlement	41	42	2		1 Copy Typist
	Contract Price Analysis	42	43	1		1 Educationalist
	Produce Work Plans Required By Contractor	30	33	1		2 Program Learning Writers
	Resource Allocation	33	35	1		
	Calendar Work Phase Timing	35	36	1		
	Carryout Feedback Work Control and Work Plan Adjustment	36	39	18	*	
	Paying Wages, Etc.	36	40	18	*	

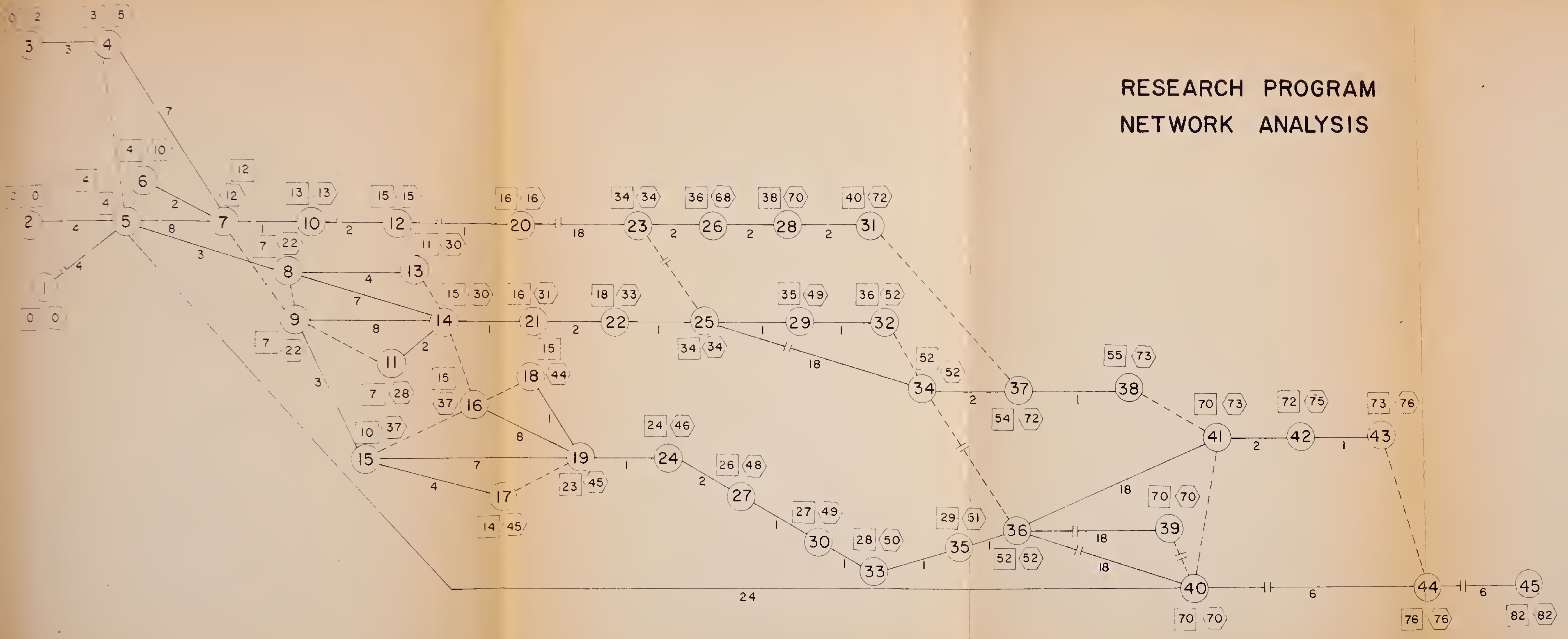
RESEARCH PHASE	ACTIVITY DESCRIPTION	ACTIVITY NODES		DURATION (In Months)	CRITICAL PATH	RESOURCES
PHASE V	Computer Programming	4	40	24		Building Systems Section Consultancy
	Information Analysis and Synthesis and Computer Simulations and Evaluations	40	44	6	*	George Birrell
						1 Quantity Surveyors
	Structuring Full Time Education and Final Report	44	45	6	*	1 Contractor Estimator
						1 Contractor Work Planne
						1 Cost Accountant
						1 Operational Research Statistician
						8 Research Associate Assistants
						1 Secretary
						1 Copy Typist
						1 Educationalist
						2 Program Learning Writers
						IAT Computer Center



RESEARCH PROGRAM NETWORK ANALYSIS



RESEARCH PROGRAM NETWORK ANALYSIS



5. THE SPECIFIC APPLICATION TO THE VETERAN's ADMINISTRATION PROGRAM

The Contruction Program of the Veteran's Administration (and the type and phasing of building projects in that program) and the Outlined Development Program of the COST ANALYSIS/COST SYNTHESIS SYSTEM of the Institute for Applied Technology have a common interface.

The following is a short discussion of that interface and reference should be made to the BAR CHART and its subsequent OUTPUT CHART. This actual project proposal is tentative, and is "open to discussion".

PROJECT NO. 1

The work of the phases Programming and Phase I to mode 7 should be carried out using an hospital research addition as the "test bed". The cost of this development work would be $150,000 and its duration would be approximately one year unless time progress of working drawings and cooperation of the chosen architectural engineer altered the duration.

On completion of Project No. 1 with results satisfactory to both V.A. and I.A.T. the development work could continue by carrying out a second project (Project No. 2) and the continuance of the development team supervising the remainder of the building contract for Project No. 1 (Project No. 3). More fully these are:

PROJECT NO. 2

The carrying out of the same work on a second hospital research addition as was carried out for Project No. 1 (i.e., to node 7). The cost of this work would be $50,000 and its duration would be approximately six months again dependent on time progress of working drawings and cooperation of the chosen architectural engineer.

PROJECT NO. 3

The continuance of the development team supervising the remainder of the building contract of Project No. 1 until completion and contract settlement.

By referring again to the preceeding output chart this Project No. 3 would be the carrying out of the remainder of Phase I to completion i.e., node 26. Provided that Project No. 2 was being carried out the cost of this work would be very small and its duration would be the duration of the construction of the buildings plus two months for settlement.

PROJECT NO. 4

Referring to the preceeding output chart this project would be the complete work of Phase II to output node 31. The cost of this work would be $10,000 and its duration would be four months.

PROJECT NO. 5

This work would be the same work as for Project No. 3 but carried out on the second hospital research addition and the costs and durations would be similar to that project. At completion the work of Project No. 4 could be rerun with the additional information from the second hospital research addition.

PROJECT NO. 6

Subsequent to the satisfactory completion on the above small Projects the development team would have a very good, sound foundation from which to tackle a large new hospital project such as the 540 bed

San Francisco hospital scheduled to begin Working Drawings in December 1969 and construction work in April 1970. At present it would be hazardous to estimate a cost and duration for this project but the cost would certainly be no more than the percentage relationship of cost to construction cost of Project No. 2.

DEPARTMENT OF COMMERCE ★ NATIONAL BUREAU OF STANDARDS ★