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DEVELOPMENT PROJECT MANAGEMENT:

AN INTEGRATED APPROACH TO PROJECT

PLANNING AND IMPLEMENTATION

PLANNING PROCESSES FOR PROJECT MANAGEMENT
VOLUME 1

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DEVELOPMENT PROJECT MANAGEMENT:

AN INTEGRATED APPROACH TO PROJECT

PLANNING AND IMPLEMENTATION

Planning Processes for Project Management

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To Potential Users of AID Project Management Training Materials

These materials were developed by the Graduate School of Management, Vanderbilt University under contract to the Technical Assistance Bureau (Development Administration Division) of the United States Agency for International Development. The present unit is one of eight units:

An Integrated Approach to Development Project Management (Overview)

Learning Packages

Planning Processes for Project Management
- Volume 1 Narrative and Exercises
- Volume 2 Readings

Organizations and Project Organizing
- Volume 1 Modules 1-2 (Project Organization
  Developing Project Organizational Systems)
- Volume 2 Modules 3-5 (Staffing the Project
  Influence Processes
  Developing Human Resources)
- Volume 3 Modules 6-10 (Team Building
  Motivating and Supervising Project Members
  Conflict Resolution
  Planning for Acceptance
  Divesting Project Resources)

Project Management Problem Solving
- One volume

Management of the Project Environment
- One volume

Project Management Control Processes
- Volume 1 Module 1 (Introduction to Control)
- Volume 2 Module 2-3 (Formal Project Control Systems and Techniques
  Behavioral Aspects of Control)

Technology Assessment, Transfer and Adaptation
- Volume 1 Module 1 (Managing Development Project Technology)
- Volume 2 Module 2 (Technological Factors in Development Project Generation and Preliminary Design, Narrative and Recommended Readings
- Volume 3 Module 2 Bibliographies, Cases and Exercises
- Volume 4 Module 3 (Transferring and Diffusing Project Technology, Narrative and Recommended Readings)
- Volume 5 Module 3 Bibliography, Cases and Exercises

Project Management Information Systems
- One volume

To benefit from these materials, users should recognize the intentions and limitations of their development and intended use. First, the materials were developed to reorient the training that is currently associated with development projects. The reorientation of these materials provides a perspective with an increased emphasis on management as a discipline, implementation of projects rather than improved or increased a priori planning and appraisal, and innovation as a necessary ingredient for successful development projects. A second intention was to supplement areas where other training materials were sparse rather than to add to those areas, such as economic and financial analysis, in which good materials already exist. However, since the areas purposefully ignored by this materials development effort are also crucial to improved project management, references are made to other sources. The intention is that these newly-developed materials would supplement previously existing materials to provide a more comprehensive training program potential.

The materials are not intended for self instruction although the introductory papers and readings in the various learning packages could certainly be used by individuals to increase their knowledge about project management. The materials have been developed for use by trainers who will make selective usage and modification as necessary to meet their specific training needs.

Finally, it is suggested that the overview volume on project management be used to introduce the subject matter of any learning packages that are adopted. The purpose of the overview volume is to provide a conceptual

framework which places the content of a particular package into an overall perspective of project management. This does not mean to imply that the volume must be read by all trainees; it is merely a suggestion to trainers that an overall framework be provided initially by some means since each learning package treats only one of many crucial aspects of project management knowledge and skills.

General Introduction

This learning package is concerned with the design and implementation of pragmatic and operational processes for effective planning in developmental projects. The output of a developmental project is not a steady stream of goods and services. The output is the development of new or increased capability to provide goods and services within a developing society.

This package is divided into three sections: narrative and exercises in volume one and readings in volume two. In the narrative, project planning is described as planning for implementation. Planning is viewed as a continual management activity which occurs throughout the project as problems are encountered. Project planning is distinguished from centralized planning as a "bottom-up" rather than a "top-down" planning approach. The planning-implementation-control cycle of project management is discussed and the distinctiveness of planning for implementation is defined. Following this is a presentation of the steps in elaborating the logic of project planning. The narrative concludes with a conclusion of project scheduling. Several charts as representations of schedules are presented.

The second section of volume one contains several exercises, including case discussions which can be of use to project participants in developing their knowledge and skills for project planning. The exercises are presented as material that can be utilized to simulate many of the issues discussed in the narrative section.

The second volume contains a series of readings which may be of interest and assistance to project participants. These readings are intended to supplement the material covered in the narrative.

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Planning for Implementation

Introduction

Project planning is often described as a process of analysis that defines the scope and feasibility of a project and its relationships to other projects, programs and development plans. In this context, plans and programs identify development needs and define project outputs; feasibility studies are made and funding proposals generated. Project planning in many less developed countries is considered completed when these analyses have been undertaken. Implementation is then seen as a separate and distinct activity to be performed by an operating agency or production organization.

The perspective of project planning that is presented in this paper differs radically from traditional approaches. The process of project planning described here is planning for implementation. It includes the definition of the project and its relationship to more highly-aggregated plans. But planning is viewed as an integral part of management. Therefore project planning continues as problems are encountered that necessitate modification of initial plans. Planning cannot be neatly separated from implementation; it is a continuous process that begins with the identification of a development need and ends only after the results of the project have been accepted by the users and diffused throughout society.

Project Planning and Centralized Planning

The development project planning process is initiated with the identification of a development need. Frequently this need is discovered by a centralized national

planning system or a sectoral planning model.[1] In a "top-down" planning process, analysis is based primarily on macro-economic models that identify needed outputs and the capacity required to produce these outputs. The gap between desired output and existing capacity defines the type of development projects that are undertaken.

In many developing nations with a central planning organization, national economic development planning follows a rather standardized set of procedures that have been described by Tinbergen:

1) Reconnaissance of the economic structure and its possible future development;

2) A provisional choice of the optimum rate of growth implying a necessary rate of savings;

3) An estimation of the expansion of demand, both internal and external, in various sectors of the economy;

4) Identification of industrial investment projects to fill sector production estimates in the national economy and to maintain a favorable balance of payments in foreign trade; and

5) Designation of implementation procedures and review techiques.[2]

Analysis, using input-output models or similar techniques, derives sectoral and industry demand from interindustry demand. This demand is based on estimates of future exports, import substitutions, and private and governmental consumption. If investment is to be made by the government, project proposals are often initiated by a central planning agency. If the increased productive capacity is to be provided by private investment, project proposals must be solicited from

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1. For a description of how such a model was used to solicit and evaluate projects in developing the Korean Second Five-Year Plan, see Lee Hee Il, "Project Selection and Evaluation: Formulation of an Investment Program," in Irma Adelmen (Ed.), Practical Approaches to Development Planning (Baltimore: Johns Hopkins Press, 1969). For a description of the historical evolution of centralized development planning to a current annual planning cycle in Pakistan (and how projects are defined by the planning process), see Mahbub ul Hag, "Annual Planning in Pakistan," Journal of Development Planning, No. 2 (1970), pp. 81-113.

2. Jan Tinbergen, Central Planning, (New Haven: Yale University Press, 1964), Chapter 4. The reader should note that Tinbergen's description is somewhat out of date. More elaborate models of the economy are now frequently used and Step 4 usually includes other sectors than industry, particularly agriculture.

private firms or industrial associations.

Centralized development planning may also establish a set of objectives for directing the search for projects and evaluating proposals through the analysis of the national development process.[3] Objectives such as the reduction of unemployment, income redistribution, and the improvement of balance of payments help to identify sectors and geographic regions that might be particularly fruitful in the generation of "high-yield" projects.

Examination of the frequent failures of centralized national planning has led some experts to suggest the need for a "bottom-up" approach to planning or at least the combination of central planning and sectoral planning.[4] Particularly in those developing economies in which the private sector can provide a substantial proportion of the capital required for growth, market needs must be identified by entrepreneurs who are willing to invest resources to satisfy those needs. When the size of the required investment or the rate of return discourages the entrepreneur from investing private capital to meet critical development needs, the government has two alternatives: either public funds must be appropriated or sectoral or national plans must identify development policies that provide investment incentives for private capital in specific sectors and regions. In some non-industrial sectors such as education or health, provision of the proper incentives is extremely difficult. Low-interest loans, tax advantages, and other economic aids are frequently ineffective in directing private investment into key sectors. In some developing countries, however,

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3. Objectives in the search process translate into criteria for evaluation of proposals once the proposals have been generated. This inter-relationship is examined in more detail below.

4. For an example of such a recommendation, see Albert Waterston, "An Operational Approach to Development Planning," International Development Review, September, 1969, pp. 6-12.

centralized planning does direct the investment of both private and public funds into the formulation of projects in certain sectors such as industry, agriculture, and transportation.

The Planning-Implementation-Control Cycle of Project Management

Descriptions of the process of management frequently divide it into subprocesses or managerial functions that form an iterative cycle from planning to implementation to control and back to planning. In too many instances, however, development project planners divide these functions artificially among different institutions at different stages of project execution. Project planning is often done by planning ministries or agencies, sometimes assisted by experts from various development assistance organizations. This stage of project planning usually consists primarily of economic analysis and appraisal of project potential in terms of various development criteria. If the funds for the project are provided by the government or multinational donors, market, technological, and economic feasibility studies may be performed by a planning staff (to the extent that they are done). This planning staff will usually bear no responsibility for actually implementing the plans. Because the implementation is to be assigned to some other individual or institution, there is little incentive for planners to assure the practicality and feasibility of the plans. Thus, frequently plans become unrealistic aspirations rather than pragmatic guides for action.

In the private sector, the situation is usually somewhat different -- the entrepreneur who does the preliminary market, technological, and financial feasibility studies will most likely execute the project. Private entrepreneurs, however, often lack formal management training and have few skills for generating complete and realistic project plans. Frequently private capital must be supplemented by loans. In this case, the development banks will force the

entrepreneur to supplement his initial analyses with additional economic studies so that proposals conform in format and content to the requirements of the bank. This additional analysis often results in some genuine planning by the entrepreneur. Sometimes, however, it becomes an exercise in finding those forecasts and projections that result in a satisfactory rate of return to obtain the loan. In any case, the project plans consist almost entirely of feasibility studies and formulation of funding proposals.

In many less developed countries "planning" is completed and the funding secured before project managers are assigned to implement the plans. Managers with experience in implementing projects are scarce in most less developed countries. The search for implementation managers often overlooks local personnel (who lack training and experience) in favor of either expatriates who have been involved in training or technical assistance, foreign consulting firms, government officials, or those professionals with technical expertise related to the sector. An agronomist working in a regional agricultural extension service, for example, may be hired to direct the construction of a new banana plantation. Under these circumstances, a project manager is found and appointed and then given the project "plan" to be carried out. Because of uncertainties in the environment -- severe quality problems in raw materials, the lack of good planning information, the politics of securing funding for proposals -- the project plans are often unrealistic.

Project managers, when finally selected, should frequently begin by reviewing the realism of the feasibility studies and proposals and by replanning the project to meet specific requirements, constraints and opportunities for implementation. This replanning should incorporate additional information from proposed project beneficiaries and technical experts. Additional market and technical studies may be necessary to validate crucial planning assumptions.

One partial solution to the scarcity of trained managers in the less developed countries would be creation of at least a temporary cadre of project managers within important development sectors (particularly those which do not attract private entrepreneurs). These project managers could be responsible for both the planning at the project level (with the collaboration of planning specialists, ministries, commissions, or assistance agency experts) and the execution of plans. In this manner, planning and implementation would be closely integrated. In many less developed countries, the inadequacy of project management talents is a basic deterrent to improving the development process. Few comprehensive training programs exist to address this scarcity, especially for project managers with a particular sectoral orientation and expertise. In most instances, local training capabilities are not sufficient and must be developed themselves before training can begin on a wide scale. In the interim, when foreign talents must be used to perform the project management functions, establishment of local counterparts can increase the effectiveness of the management and provide a partial training opportunity. This experience-based learning for indigenous talent would be significantly enhanced, however, when supplemented with formal management training programs.

The last phase of the cycle, project control, frequently involves periodic reports of progress and final evaluation of project results. Again this function is often separated from project planning and implementation. Periodic review is not sufficient to control the dynamic environment of most development projects. During the process of implementation, project managers must provide internal control that identifies unsatisfactory intermediate results or unanticipated problems and initiates remedial action through changes in project plans and activities.[5]

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5. The process of managerial control of development projects is elaborated in the learning package on project control.

Planning for Implementation*

Much confusion exists among writers and practitioners with regard to the use of terms such as project planning, appraisal, scheduling, and evaluation. Indeed, in many cases, it is not clear that there exists a common conception of a project. For that reason, it is necessary to explore briefly the concept of a project, as it will be used here, before discussing the elements that are included or excluded from project planning.

Projects are commonly defined as development activities that innovatively invest scarce resources in order to increase the capability of society to produce additional goods and services. Projects have a specified output (the development of new capability); a limited scope in terms of time, inputs, and space; and an element of novelty or uniqueness. Within this definition, the construction, staffing and supplying of a public health clinic, for example, is a project until it begins routinely processing patients. The project consists of the activities that developed this new health delivery capability -- the analysis of needed health services, the generation of the funding proposal, the construction of facilities and the training of personnel. A crucial point to note is that project activities are almost all investments; few direct benefits accrue during the life of the project. The result of the project is an output system (the clinic) that has a potential for providing new services once operations begin. The vast majority of the direct benefits are derived after the project is complete and the new potential or capability is exercised indefinitely to provide a continuous stream of goods or services. To be consistent with this definition of a project, one must reach the somewhat startling conclusion that the financial or economic rates of return of most development projects themselves are close to zero. The point to be emphasized here is that most "project planning" as it is currently done is actually the design and appraisal of the

* For outline of cognitive learning outcomes expected from this section see page 67.

project output system, not of the project. Consider what is commonly viewed as the identification and preparation of projects, as the terms are used by the World Bank. Activities such as interindustry input-output analysis, demand and market studies, engineering designs, site location analysis, and determination of working capital requirements usually comprise the planning of the project. What is really accomplished by these activities is, however, the determination of new productive capacity if the project is successfully completed. Thus, project planning must include this design and appraisal of the project output system, but it must also plan the activities of the project -- the act of building the new productive capacity.

Consider what is commonly meant by the appraisal of a project. It is not the appraisal or feasibility analysis of development activities. It is the appraisal of the value of the stream of goods and services (usually discounted) that are generated by the project output system after the project is completed, compared to the investment made during the project.[6] Figure 1 depicts the relationship between a project (and its associated output system) and the steady-state operations that utilize the new capability. The distinction between project management and steady-state management is critical. The former requires the generation of changes that develop human, physical, technological, and structural components of the new capability. The management of routine operations emphasized the efficiency required to produce continuously a low-cost, high-quality service or product. The two distinct types of management require different management styles, knowledge, and skills and this is reflected in distinct planning practices for projects.

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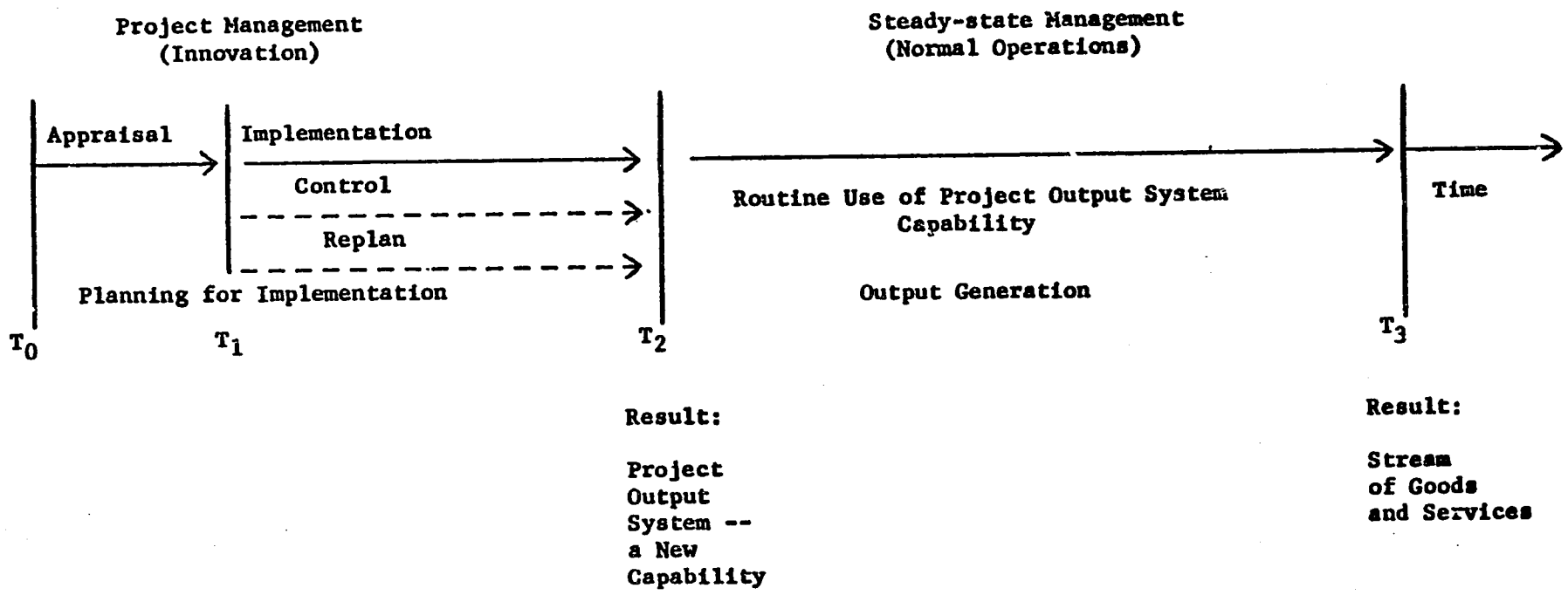
6. An excellent treatment of the aspects of appraisal, as the term is used here, is contained in J. Price Gittinger, Economic Analysis of Agriculture Projects (Baltimore: John Hopkins University Press, 1972.



Capability Components

Human	Physical	Technology	Social Structure
Managerial Professional Labor	Funds Facilities Raw Materials Energy	Knowledge Applications	Relationships Values & Attitudes Norms

Figure 1 The relationship of project management and steady-state management.

In Figure 1, the time period from T_0 to T_1 is spent on appraisal -- analysis of development needs, preliminary specification of the project output system, and generation of feasibility studies -- of the elements that constitute the potential value of the increased capability resulting from successful implementation of the project. This is the period often referred to as planning the project (as was discussed earlier). This, however, does not constitute all of project planning. It provides an initial configuration of the project output -- a configuration that will most probably change considerably during project "implementation." Comprehensive planning of a project involves the design of a set of activities as well as of the output system. Thus, project planning in addition to determining the configuration of the output system, involves analysis for the acquisition of project inputs, organization and scheduling of resources, and methods of transferring project results. The latter kinds of analysis can be initiated during the latter part of the appraisal period. But, even the addition of this type of analysis does not complete planning for implementation. Planning for implementation continues throughout the period from time T_1 until time T_2 as well.

Because development projects have an element of novelty or uniqueness, no previous management experience is exactly pertinent; in other words, because the project is not a replication of activities that are exactly similar to those that occurred in the past, managers are not able to anticipate all of the factors that eventually will influence the success of the project.[7] For this reason, as implementation of the project is initiated, unanticipated problems occur. Scarcity of human or physical resources or the inapplicability of technology cause delays or changes in the configuration of the final project output system.

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7. Some development projects are more novel than others. See the explanation of the differences between experimental, pilot, demonstration and capacity expansion projects in the project management overview volume.

After control processes direct managerial attention to these unanticipated problems, analysis may reveal that initial plans must be modified. Specifications must be changed, schedules adjusted, and new sources of project inputs sought.[8] The ramifications of these managerial corrective actions must be examined in terms of their effect upon project plans, particularly budgets (human and financial) and schedules. Replanning is necessary to assure proper coordination as project implementation activities are changed; and project supporters must be advised of the problems and remedial actions.

Planning follows a certain logic or series of steps. The appropriate logic depends upon many considerations including the managerial style, organizational structure, environmental dynamics, and general culture. Whatever logic is chosen, however, planning does not progress in a serial fashion from one step to another without considerable iteration or retracing of "loops." This is particularly true of development project planning which is done in an environment of uncertainty and novelty.

Sometimes project planning recycles over steps that were previously done because of unanticipated events, either internal or external to the project. In this case, re-planning accommodates a different set of environmental conditions or planning assumptions. Even if a project is so fortunate as to encounter few major unanticipated "shocks" however, there is usually a number of iterations through the planning logic. The logic may change somewhat through each iteration, but the major difference between iterations is the addition of detail. The project planning process that is described by the flowchart of Figure 2 demonstrates a number of iterations through basically the same logic in steps one through four.

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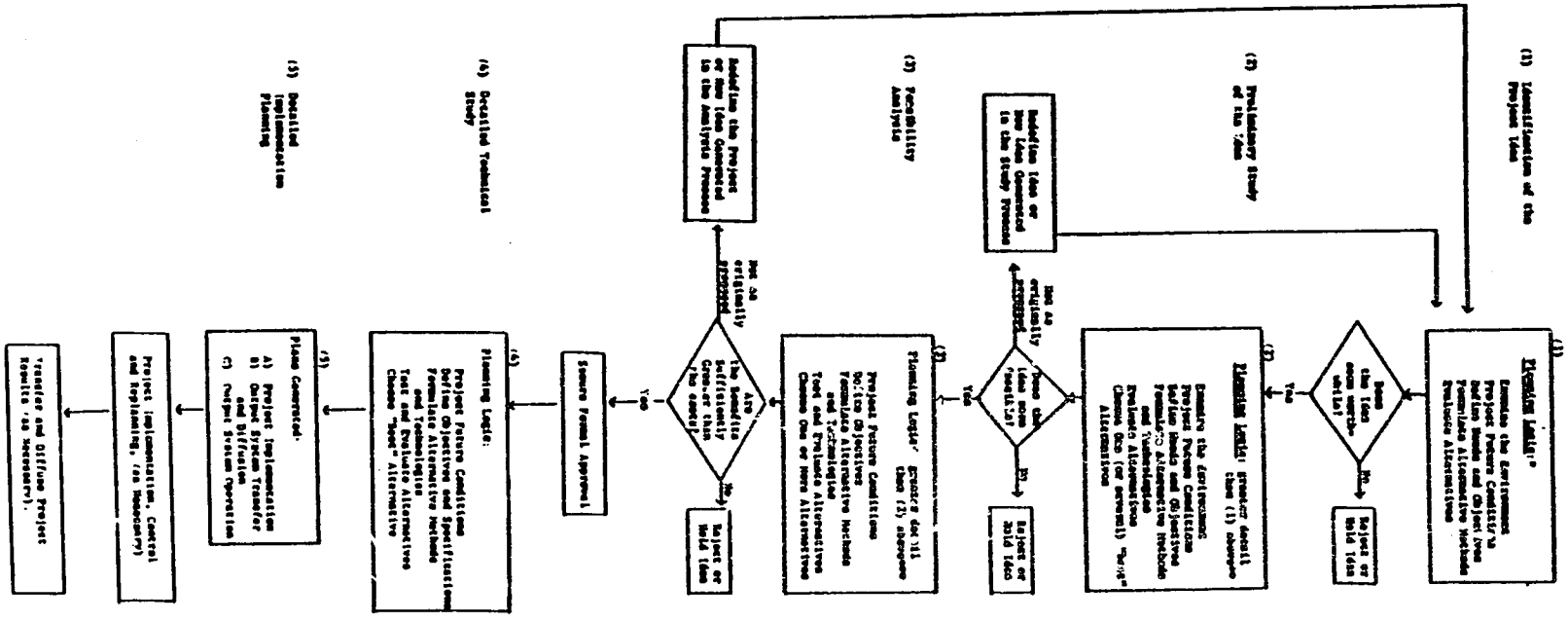
8. This is not intended to imply that the performance of the final output system will always be degraded, that costs will always be higher than anticipated, or that schedules will necessarily be slipped. Project management can often find a creative solution to the problem. See the learning package on project management problem solving.

There are a number of reasons why project planning recycles over the same logic or series of steps several times. One reason is that the process is frequently fragmented and transferred as it progresses between several organizations and individuals. Thus, the project may be identified by a central planning agency or a local action group and the first iteration would provide only a summary definition. Most likely this first iteration, to the extent that any detail is added, would concentrate on identifying the project results -- the output and needs that will be met for potential users and beneficiaries. As steps two through four are performed, a project proposal is generated and may be passed through several assistance or government agencies, private firms, consultants, and development banks. A second reason for the number of iterations is based on the innovative nature of projects. Many ideas for development projects are generated which prove, after varying degrees of analysis and study, to be impractical or infeasible. Some of these ideas can be deleted from consideration with only a cursory run through the logic. If each were analyzed in great detail, progressing through the planning logic one step at a time, considerable effort would be wasted. In addition, projects are new entities; when they are born, there are no resources immediately assigned to perform tasks. They grow in size and resource commitment over time as they demonstrate worth and feasibility. They grow in increments when funds or managerial staff are added to elaborate their definition. When one of these growth increments occurs, the capability in terms of managerial time and knowledge is increased so that another planning iteration can be performed in considerably more detail. Given the definition of implementation planning that is used here, this refinement and modification of plans continues throughout almost all of the project life.

Figure 2: The Iterative Nature of Project Planning



* Planning detail is sufficient to determine project output, beneficiaries and levels of usage.

** Planning detail is sufficient to determine required resources flows for project activities and output system operations.

*** Planning detail is sufficient to compare output flows (benefits) to resource flows (costs).

In summary, planning is a necessary analytical function that must be performed to identify and define a project proposal, but one that must also continue throughout the implementation phase. Planning, implementation, and control of projects must be a continuous and highly integrated cycle, if projects are to be managed effectively.

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* For Discussion Questions and Recommended Readings for this section see pages 68 and 69.

Elaborating the Logic of Project Planning *

Although project planning (as defined in the last section) is frequently fragmented among institutions and separated artificially into phases and disciplines, a logic or decision flow can be used by project management to assure that decisions are made and communicated at each phase of project planning and execution. In those less developed countries in which project planning is particularly fragmented between ministries or performed primarily by external assistance organizations, a general logic or framework for planning is critical to project success. If project management does not select a logic and monitor the actual planning process to assure its conformity to the logic, important steps or constituencies may be left out of the actual process. If much of the planning is done by multinational assistance organizations to identify, appraise, and prepare projects for loan-approval, the planning may be heavily oriented toward economic and financial analysis and the planning assistance may cease after the loan approval.[9] Project management must then augment this assistance by using some logic to assure a comprehensive planning process.

When a project management organization is charged with the responsibility for the project, one of its first tasks should be the review of the planning sequence that has previously been accomplished. A checklist of logical steps

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9. The reader should examine the following sources to determine the portions of the planning process that are frequently included in the economic and financial analyses performed by multilateral assistance organizations:
   1) J. Price Gittinger, Economic Analysis of Agricultural Projects, The Economic Development Institute, International Bank for Reconstruction and Development (Baltimore: The Johns Hopkins University Press, 1972).
   2) Ian M. D. Little and James A. Mirrlees, Manual of Industrial Project Analysis in Developing Countries (Paris: Development Center of the Organization for Economic Co-operation and Development, 1968).

*For outline of cognitive learning outcomes expected from this section see page 70.

in the planning sequence can assist management in identifying the types of planning already done and in determining that which remains to be performed. Definition of a sequence of planning steps does not imply that planning progresses straight through the sequence without backtracking or looping over a subset of steps. Figure 2, in the previous section, depicted the project planning process as highly iterative. A few of the logic steps may be repeated in greater detail as the project progresses from identification to approval. One of several available checklists of the project planning sequence is provided below; to be useful, however, any logic must be modified to fit local conditions (such as the availability of planning information).[10]

Step 1. Assessment of the Project Environment

Before beginning the analysis to determine the feasibility of objectives and the alternative methods that can be employed, an assessment of the project environment is essential. Environmental assessment identifies the individuals and institutions, and the general environmental conditions and trends that may significantly influence the project. This activity is often ignored in project management or is performed informally and unsystematically at an intuitive level.[11] An exception to this is the comprehensive sectoral analyses performed by multinational assistance organizations such as UNESCO, the World Bank, or WHO as a preliminary step in the identification of new projects. At the invitation of the host country, a study team from one of these organizations will visit, analyze, and report the general environmental conditions of a sector such as education, nutrition, or population.

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10. A different description of the project planning tasks is provided by John Baumgartner, Project Management, (Homewood, Illinois: Richard D. Irwin, Inc., 1963), pp. 19ff.

11. For this reason, a separate learning package has been designed to increase knowledge and skills in "Managing the Project Environment."

The opportunities and constraints to the project represented by the identified environmental factors become major assumptions that govern the direction and content of future planning. In other words, planning assumes, either either explicitly or implicitly, that certain key environmental conditions exist at the start of the project and that those conditions will change in a known manner during project implementation. Project planning (including implementation planning) can be greatly improved by:

1. comprehensively assessing the project environment to identify key factors,
2. projecting these factors into descriptions of future environmental conditions that will significantly impact upon the project, and
3. stating these "planning assumptions" explicitly.

If planning assumptions are left implicit, as is usually the case, evalution and control at a later stage become difficult, if not impossible. Determining why actual results varied from intended results (plans) requires greater documentation of the assumptions upon which the plans were initially based.

Step 2. Definition of Objectives and Output Specification

During the process of assessing the environment, project managers will undoubtedly spend a large proportion of the time studying the market for project outputs -- the stream of goods and services provided by the project output system. These studies should include two distinct elements. One identifies those organizations, agencies, or individuals, to whom the project output system will be transferred upon completion of the project, that is, those organizations that will be charged with managing routine production operations of the project output system. An example is the early identification of the proper authority or agency to operate a hydroelectric facility or irrigation

system once the project (the construction of a dam) is completed.[12] If an existing agency is not a logical choice, a new "steady-state" management organization must be created and designed as part of the development project activities.

The second type of market study involves identification of the number and types of users of project outputs during the period of routine operation. Needs analysis performed during project appraisal establishes who the potential buyer or client is (client characteristics and market size) and what the client wants (product or service specifications in terms of performance, quality and price).[13] In the case of social programs and projects, not only must services be provided but social change must be generated that results in socio-economic development. Defining the who and the what in the needs analysis of a social project presents unique difficulties for project planning.[14]

Once both types of market studies have been performed, the initial specification of the project output system can be generated, hopefully with the involvement of both types of users. This is the first step in defining broad project objectives. Other dimensions of objective definition, such as time and cost, are developed in order to identify and evaluate alternative methods of producing the project output system. More detailed objectives are developed as project work activities are defined with greater specificity during the evolution of the project plan.

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12. For those readers interested in the elaboration of this example in a real situation, see the description of the formation of the Damodar Valley Corporation in India as described by Albert O. Hirschman, Development Projects Observed, (Washington, D.C.: The Brookings Institution, 1967).

13. For a detailed prescription on how to perform this type of study, see the Manual on Economic Development Projects, (New York: United Nations, 1958), pp. 11-28.

14. The unique aspects of "needs analysis" for social change projects are well described by Egbert de Vries, Administration of Development Programmes and Projects: Some Major Issues (New York: United Nations, 1971), pp. 15-17 and pp. 36-39.

At this stage of project planning it is not possible to specify project objectives with great detail and accuracy. Subsequent planning steps will provide the analysis and information that are necessary to attain specificity and evaluate feasibility. At this stage, however, the proper dimensions of the objectives must be articulated to assure that later analysis will provide necessary detail. Project managers know, for example, that the project plan must eventually be submitted to a funding authority for approval. Approval will be made on the basis of specific criteria. The proposal must be formulated with sufficient analysis and data to facilitate evaluation in terms of those criteria. It is therefore essential that project managers define objectives in terms of dimensions that translate directly into these evaluation criteria in order to direct properly further planning and analysis. These criteria should also provide guidance in the next planning step, which is the identification and evaluation of alternate methods of pursuing the project objectives.

It is difficult to generalize across sectors and countries in developing a universal list of criteria, but those noted below (see Figure 2) are essential for consideration. It is obvious from inspection of this list that many of these criteria are contradictory in the sense that improving one dimension may only be accomplished by the sacrifice of one or more of the others. The effect of conflicting objectives on the planning process is discussed more thoroughly below.

Figure 3: Planning objectives/evaluation criteria

1. Maximize direct benefits to users
2. Maximize return to investors
3. Minimize cost/quality ratios
4. Minimize time until introduction

Figure 3: Planning objectives/evaluation criteria (continued)

5. Maximize indirect effects to the development process
   - reduce unemployment or underemployment
   - increase income and wealth redistribution
   - increase favorable balance of payments
   - reduce inflation
   - increase economic growth rates
   - increase national savings
   - promote further development and other projects frequently considered in development projects
6. Employ maximum use of indigenous under-utilized resources
7. Diversify the economy
8. Concentrate effort in least developed regions.
9. Promote national integration of disparate cultures.

At this point in project planning, only the general or broad objectives have been defined along appropriate dimensions. In later stages of planning, the objectives must be assigned priorities or weights to facilitate appraisal. Project managers must realize that priorities will depend upon the desires, power, and influence of different constituencies who support the project.[15] Priorities are

15. Establishment of the priorities affects the design of the project output system more than project management usually realizes. For example, if the criterion of income redistribution is of high priority in securing funding from a multinational donor, certain considerations should be added to the analysis that clearly delineate the effects of the project on income redistribution. This analysis may well change the design of the project. A case to illustrate this point is the selection of a site for an airport construction project described by V. C. Nwaneri, "Income Distribution and Project Selection," Finance and Development, Vol. 10, No. 3, September, 1973, pages 27ff. To elaborate this point in terms of the criteria of reducing unemployment or underemployment, see the project design considerations contained in "Administrative Requirements for Labor-Intensive Development," presented by the Development Administration Panel Seminar, Southeast Asia Advisory Development Group (SEADAG), Singapore, July 23-27, 1973.

almost certain to change -- sometimes drastically -- during project implementation. Project managers must be sensitive to these changes and reflect them in plan modification. Moreover, as project planning evolves, and analysis generates the ability to plan in greater detail, the objectives of the project must be broken into time-phased subobjectives, particularly if the project extends across several budgetary cycles, contract time horizons, or changes in key supporters. Each of these subobjectives must be translated into criteria for evaluation that are highly measureable and related to key events (milestones) in the progress of the project. This topic is discussed in greater detail later in the section on project scheduling.

Step 3. Identification and Evaluation of Alternative Methods

In most projects, a variety of methods or solution logics can be employed to develop the desired project output system. The most common source of variation is technology.[16] In the sense that technology is used here, for example, a family planning project output system may include different methods of contraception. A project to contruct a new industrial facility to produce glass products may choose a floatation process technology or a mold technology. For a given project output, different kinds and combinations of inputs may define alternate methods of reaching the project objectives.[17] The most common example of this is the different degrees of automation (combinations of labor and capital) that could be built into the project output system.

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16. For this reason, project management must be able to assess available technologies (both indigenous and foreign) that can be applied. This subject is treated in a separate learning package on technology assessment, transfer and implementation.

17. Least cost alternative studies, as performed by organizations such as the World Bank, frequently consider alternate technologies, economies of scale, and combinations of inputs.

In order to define alternate methods in sufficient detail to permit evaluation of their relative merits, it is usually necessary to define activities for each method. The appropriate degree of specificity indicates major differences among alternate methods in terms of both benefits and costs. Differences in benefits are usually reflected in performance of the goods or services produced by the project output system. In the family planning, example, birth control pills would be likely to exhibit greater reliability than prophylactics if the client is properly trained by the dispensing agency. If the time for project completion is a critical factor, it may also be beneficial for project management to develop a schedule of milestones (major intermediary events) and primary activities for each feasible alternative method. (The evaluations may use summary CPM networks or simpler scheduling methods to determine the elapsed time necessary to complete the project, given each alternative). To the extent that project managers plan each alternative with sufficient detail, the eventual choice will be made on the basis of knowledgeable tradeoffs among time, resource consumption, and final performance levels of the output system.

Step 4. Choice of Appropriate Method or Methods

For those projects that employ well-known technologies and use abundant local raw materials and labor, the evaluation of alternate methods can be made accurately with a fairly high degree of certainty in the predicted results. In this case, the planning performed in the previous step may specify an alternative that is clearly superior in terms of all or at least the most important objectives. The decision process is then rather simple and often choices can be made directly by the project manager.

In most cases, however, more than one alternative proves to be superior on the basis of a least one important criterion. The decision process becomes more complex as the number of conflicting objectives increases. Defining weights for the various dimensions is difficult because of differences in quantifiability and measureability and because the different constituencies that are affected by the project will have substantially different preferences. In many instances of this sort, project managers should avoid trying to aggregate dissimilar measures. When higher-level decision makers or a variety of constituencies are involved in the choice process, aggregation can hide real conflicts and tradeoffs that are better resolved before the project enters the implementation stage. Frequently meetings that include representatives of different constituencies, such as supporters and beneficiaries, will induce sufficient participation to assure that the final choice represents a negotiated position acceptable to all influential parties.

Another important factor affects the process of choosing between alternative methods: the degree of uncertainty may be so high for all known alternatives, and the success of the project may be so important, that no single alternative can be chosen. Rather a strategy of pursuing several alternative methods simultaneously must be adopted in spite of the obvious disadvantage of increased costs. This condition is particularly common among experimental projects in which success depends on discovery of appropriate technology. The pursuance of parallel methods is equally justifiable if the sources of uncertainty are political instabilities or vagaries of funding sources.

If several parallel methods are adopted simultaneously at this stage of planning, the net effect is to delay choice. When this is done, project management must establish frequent control check points at which the relative uncertainties

of each method are reassessed. In this manner, the choice of the "best" method will not be delayed beyond the point where uncertainty has been reduced to tolerable limits.

Step 5. Elaboration of Project Activities: Defining the Project Work (Task) Structure

In order to develop schedules and budgets in later stages of planning, the chosen method (or methods) of pursuing project objectives must be transformed into specific activities that will be performed by the project organization. To the extent that project managers have been involved in similar projects in the past (which is most likely to be true for demonstration projects), management can define the activities in considerable detail without external assistance. The appropriate level of detail for activity specification at this point in time depends upon two factors: 1) the budgetary money, personnel, facilities, scarce materials) accuracy that is required for funding decision making and 2) the required articulation of important relationships between activities to ensure coordination.

Defining the work structure of the project requires first the establishment of the logical bases for dividing the total work into specific activities, tasks and subtasks in a hierarchical fashion. A common basis for division is the items in the project output system. Thus a simple irrigation system project might be divided, on the first level, into construction of a pumping station, digging of flow channels, and establishment of the administrative authority. Another related common basis divides the project work into the functions of items described above (hardware, service, operations). Other bases include the required skills of labor for the project or geographic divisions. Different bases may be used for dividing the work at each level of the work structure. Since budgets and schedules are defined, in later planning steps, on the basis

of the work structure, analysis and proper choice of the structure can save considerable replanning at later stages. For example, if the work is first divided on a geographic basis (which it might be for a transportation project), budgets and schedules will be prepared for each region. In contrast, a division by item may call for separate budgets, etc., for the bridges, roadways, and signs and support systems. The implications of the choice of this first breakdown level are frequently substantial for the selection of further breakdowns into tasks and subtasks.

In many experimental projects, personnel will include a high proportion of professionals such as engineers, physicians, or agronomists. It may be necessary for project managers to solicit the consultation of members to these professions in order to define activities in sufficient detail. If possible, those professionals eventually selected to staff the project should be used in this earlier stage of planning. The exact specification of how tasks are to be performed should be left to individual professionals responsible for task performance during implementation. Activity planning can become overly detailed prematurely, thereby confining and demotivating professional staff members.

Step 6. Obtain forecasts

Estimates must be provided to forecast potential performance levels of the output system (the number of patients processed by a health clinic with certain quality standards or the number and grade of pineapples per hectare), costs for operating the output system, capital investments during and after the project, time for project completion and operating horizons for the output system. For each of those activities defined during the planning step, time and cost schedules should be obtained, preferably from those individuals who will be responsible for implementation.

Step 7. Calculation and Review of Output, Cost, and Time Schedules

After individual project activities are budgeted and scheduled, aggregate budgets and schedules can be calculated for the project. In this first attempt, the total cost or scheduled time may often turn out to be excessive. Reviews of "critical paths" or inordinately expensive activities frequently reveal sources of tradeoffs that may be made to reduce budgets and schedules to feasible proportions.

Step 8. Securing Approvals: Summary Plans and Proposals

Securing the approval of a project proposal and assuring the dispersion of funds may occur at quite different points in the project planning process depending upon several factors. One such factor is the source of the funds. If private capital is used, internal approval will often be granted by top management in stages as the potential returns from the project become more evident from market surveys, prototype testing, and pilot plant operations. If funding is to be provided by indigenous governmental agencies or development banks, credit worthiness may be less of a problem than if a multinational assistance organization provides a loan. In the latter case, substantially more financial and economic analysis may be required before a loan will be granted. Even within a specific assistance agency, differences in approval requirements and timing may exist. For example, loans from the World Bank are frequently approved at an earlier stage for projects that are primarily in "social" sectors such as education, population, or nutrition as compared to more traditional "bricks and mortar" projects such as are usually found in the transportation or industrial sectors.

Securing approval of the project proposal is the first step in securing formal commitment of resources. If project managers have been properly interacting with important constituencies to formulate plans in earlier stages, then the

approval process can be more readily expedited. A formal "chain of command" often exists in public sector project approval processes to secure legal ratification, political legitimization, and the allocation of funds. However, project managers cannot ignore those constituencies that are not part of the formal review and approval process but who can influence the success of the project. In some instances, the project approval process can be influenced by encouraging beneficiaries to form power groups and lobby for necessary legislation, funding, and support. In the private sector, development banks are frequently influenced in funding decisions (especially on loans to small and medium-sized firms) if advance orders or commitments can be secured from future clients or customers.

Step 9. Communication of Aggregate Plans; Elaboration of Activity and Task Plans

Once approval and funding is secured, project managers can begin organizing the project.[18] As management begins staffing, it adds additional managers and staff specialists for large projects. As the work force, professionals, and additional managers join the project, the aggregate plan must be amplified to determine how and when elementary tasks and subtasks will be performed. If the project is large enough to require more than an individual project manager and his immediate staff, a project management organization must be formed. As this organization grows in size, the importance of formal planning increases rapidly. For each manager to develop plans for that portion of the project under his responsibility, he must understand aggregate objectives, assumptions, and policies. Thus formal planning not only assures that the individual project manager develops plans in a complete and logical manner, but it facilitates communication and coordination with others working on the project.

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18. This extensive subject, the organizing of projects, is covered in another learning package.

In some instances project activities are programmable; that is, decisions concerning specific use of methods and tools, and resource allocation can be better made by top management than by the individual performing the work. Lower level project managers provide supervision to low-skilled laborers by providing detailed descriptions (plans) of tasks and subtasks. The participation of the individual or group in task planning will be lower if management has greater expertise for deciding how it is to be done. This form of planning is sometimes referred to as <u>procedural planning</u> because management spells out the detailed procedures to be used; task performers have few decisions to make. If, however, the majority of the tasks are not programmable but rather require considerable skill, professional knowledge and judgment on the part of the performers, then project management must seek their participation in task and activity planning. Management must than use a form of participative planning sometimes referred to as <u>declarative planning</u>. Using declarative planning, management specifies what is to be accomplished as well as the time and other resources available to perform the task. How the task is to be accomplished and the methods and approaches that are most appropriate are decided by the task performers. Figure 4 summarizes the main advantages of each form of planning. The respective advantages will suggest to project management whether elaboration of specific tasks should be more declarative or procedural.

Just as different forms of planning are appropriate for various project task situations, so are different methods of communicating plans. If a plan is complex or involves considerable technical knowledge and language, accurate communication may be difficult if a <u>noninteractive</u> form of communication is chosen. Noninteractive communication is one-way communication -- as in the distribution of written memoranda or a message over a loudspeaker -- in which the receiver of the

Procedural Planning: specification, in a detailed step-by-step sequence, of a set of actions which will result in the accomplishment of a desired outcome.

Advantages:
1. efficiency in imparting expertise to less trained or skilled subunits.
2. may be communicated quickly in a non-interactive mode to large audiences.

Declarative Planning: specification of a desired outcome and organizational resources available to accomplish it. The actions for achieving it are to be determined by subunits responsible for implementation.

Advantages:
1. greater involvement in the planning process usually means higher motivation to accomplish desired outcome.
2. novel and creative methods may be discovered to accomplish the outcome.
3. better matching of capabilities to methods (if desired outcomes are reasonable given the resources available).

Figure 4: Advantages of procedural and declarative planning processes

plan has no opportunity to test his understanding by interacting with the sender. Interactive communication allows the receiver to question or paraphrase the message to test his understanding with the sender. Each of these forms of communication has its respective advantages (as shown in Figure 5) for the transmission of plans.

Thus as project implementation begins with staffing and structuring of the project organization, planning continues with the elaboration of aggregate planning into project tasks and subtasks. As the organization grows, the planning process expands to include the intentions and actions of new members and groups. For those new groups with substantial responsibility for planning their own activities, a similar sequence to that described above for project management must be performed at the appropriate organizational level.

- Advantages of Interactive
  - Greater message content transmission accuracy
  - Receivers more satisfied, can test for errors
- Advantages of Noninteractive
  - Faster
  - Transmitters more satisfied, not under attack for poor communication

Figure 5: Advantages of interactive and noninteractive forms of communication

Step 10. Development of Progress Monitoring and Control[19]

Step 11. Monitoring of Internal Progress and Environmental Change[19]

Step 12. Measurement of Progress[19]

Step 13. Identification of Problems and Obstacles[19]

Step 14. Replanning of Project Activities and Resource Reallocation

In almost all development projects, progress deviates considerably from plans. Most plans turn out to be overly ambitious, and tend to understate resource constraints, delays and capability to accomplish activities. Some of this ambition is necessary to provide motivation and secure approval. However, as obstacles and schedule slippages are identified by control processes, project managers must respond positively to the situation by seeking solutions to specific problems and replanning schedules, resource allocations and final outputs. So many sources of unanticipated problems exist for development projects that

19. These elements are normally considered "control" functions but are included here in order to emphasize their close relationship to the planning logic. They are described in detail in the learning package entitled Project Management Control Processes.

implementation planning frequently requires creative problem solving on an almost continual basis by both project managers and technical experts.[20] Much of this replanning takes place at the task or activity level, but frequently no solution can be found that does not require modifications of schedules and budgets. If the ramifications of plan modifications are known early enough, resources can sometimes be reallocated from activities containing slack or be augmented by additional funding. Scheduling techniques can be incorporated in the planning process to facilitate plan modifications and operational changes. These are discussed in a later section.

Step 15. Termination Planning and Preparation for Transfer of Project Results

Many development projects are not terminated at the proper time or in an effective manner. Because projects are limited in scope with specific output and performed by temporary organizational arrangements, managers must design project termination well in advance. This is a form of planning rarely done by those who manage ongoing organizations and hence, few managers have adequate skills or experience in planning for project termination. To improve the process, termination planning must begin at the outset of a project. In defining resource requirements, for example, the expected life of the project should not be considerably less than the life of physical equipment unless management plans for the transfer of this equipment to the project output system, to another project, or to a market where it can be resold. If bulldozers, for example, are purchased and maintained with the intent of securing ten years of service, but the life of a dam building project is only three years, then project managers must plan to transfer the unused portion of these resources to another activity.

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20. This subject is elaborated in the learning package on project management problem solving.

Management must also plan for termination before the expected completion date because many development projects should be terminated for reasons other than successful attainment of objectives. These reasons include the discovery of more effective alternatives, shifts in client or donor support, unsatisfactory progress or proven infeasibility, or the loss of critical capabilities such as key personnel. Although these reasons may be fairly obvious to the objective observer, projects are unlikely to be terminated unless management accepts this as one of its primary responsibilities and, thus, plans appropriately. Without proper planning and control processes, managers may overlook unsatisfactory progress. The process of planning for termination, whether the project is successfully completed or not, should include the experts who are providing professional inputs to the design of the project output system. Often they resist termination of unsuccessful projects for fear of damage to their professional reputation. They may also resist termination when objectives have been accomplished for fear of a premature "design freeze;" they may wish to increase quality or reliability beyond a point that is economically justifiable. Providing participation in early termination planning and providing other opportunities for their professional involvement may overcome some of this resistance.

Planning for termination means more than preparation of a final report. As discussed earlier, the project output system must be designed in such a manner that it can be transferred easily to those who are responsible for its routine operations. This may include training and development of the "acquisition system." Reallocation of unconsumed project resources must be planned, particularly for project personnel because they will often have improved capabilities as a result of the project experience.

In summary, following the logic of project planning described above (or some similar process), a series of planning documents will be generated including statements of project objectives and output system specifications, a project proposal, schedules, budgets, and diffusion plans. These documents may be prepared with inputs from a variety of sources but it is the responsibility of the project managers to ensure that they are consistent and that no major gaps occur in the planning process. *

* For Discussion Questions and Recommended for this section see pages 71-72.

Project Scheduling *

In the last decade, a wide variety of scheduling techniques have been developed for the management of projects. Use of these techniques has spread rapidly to all levels of management and combinations of the techniques are used to assist in many different functions and phases of project management. Summary or milestone charts are used by top management to plan and coordinate the activities of lower-level projects. These projects often use scheduling techniques to provide detailed descriptions of activities within the project and activities requiring coordination with other projects or with project subcontractors. The techniques are used to formalize many of the planning, control, and implementation functions of management. At the inception of a program or project, the definition of the logic of the network or chart requires planning of activities to the level that facilitates the selection of technical problem solving approaches. At this stage, alternate plans may be generated using these techniques in order to judge the cost and schedule implications for different methods of performing project activities. After the selection of one method, time and cost tradeoffs are made to affect the scheduled completion date or by introducing additional planning factors (such as the use of scarce human or physical resources). This may be accomplished through the use of additional scheduling techniques, such as resource reallocation, manpower loading, and responsibility charting methods.

Control techniques are used to monitor progress and issue reports to management for corrective planning, if necessary.[21] In the highly uncertain environment

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[21]The process of control and its relationship to planning is elaborated in the learning package entitled "Project Management Control."

*For outline of cognitive learning outcomes expected from this section see page 73.

of program and project management, schedule and budget slippages occur fairly frequently within some of the activities. Management can use the scheduling techniques as tools for determining what managerial actions are appropriate. In other words, if the slippage is minor and does not affect the completion of other activities, management can deal directly with the implementation problems of the work group responsible for that activity. Perhaps staffing is insufficient or delinquent materials can be expedited. Technical problems might be solved by holding problem solving meetings with the work group or providing expertise and consultation from outside the work group. Problems of leadership or morale within the work group might also be alleviated in an analogous fashion. The scheduling techniques may, in fact, indicate that even with slippage, the project will be completed on time if the activity is not critical in the schedule. In such a case management may simply choose to ignore the slippage (using the exception principle) thereby directing its attention to areas which are more important to the success of the program or project.

If the slippage indicates a major problem in terms of completion within the scheduled time or budget, the techniques may be employed again to facilitate replanning efforts to reallocate and redirect project resources. It may even be necessary to change the previous planning process. For example, different scheduling techniques might be used to improve the management functions that are most needed to correct problems encountered in implementing the project. As an illustration, if Gantt charts, because of their simplicitly, were used as the major planning device, and if the project appears to be suffering from a lack of communication and coordination between activity work groups, a network scheduling technique might be used to introduce greater recognition of the relationships between activities.

In this discussion, the work scheduling is used in a special context. In the most common context (the scheduling of the repetitive production and distribution of current goods and services), the required activities are well known and the available resources are also well defined. Scheduling is then a relatively simple process of assigning the activities to the facilities and other resources. Because program and project activities generally involve more unique, novel, and perhaps even highly creative kinds of activities, little is known in advance about the specific work to be performed and the resources that will be required. For that reason, scheduling involves a great deal of planning which defines the necessary activities for successfully reaching the objectives of the program or project. This initial planning effort of defining the activities is often done in a highly iterative and participative mode, particularly involving those experts who will be performing work activities that generate novel, creative results.

Because many of the scheduling techniques may be used in a variety of ways with great differences in detail, both program and project managers should understand the purposes of the techniques, the potential benefits from their use and the costs associated with their implementation. Program and project managers must not only select the proper combination of scheduling methods but also educate and motivate the project team to use them. This must be accomplished not only for the initial planning but also throughout the implementation and control phases during the life of the project. To do this, management must be actively involved in the following four functions:

1. Selection of appropriate scheduling techniques. This implies an understanding on the part of the management of the diversity of the techniques and the benefits and costs associated with the use of each.

2. Education of personnel in the use of the techniques.

3. Assurance of uniform use of the techniques by project personnel to develop a coordinated plan of sufficient detail for identification of major points of coordination and potential technical difficulties. Management must motivate the program and project teams to plan, in order to avoid the false starts that are encountered when development projects proceed without adequate planning.

4. Establishment of progress monitoring and reporting procedures using the techniques to facilitate replanning as technical and/or administrative problems are encountered.

In addition, project managers must be perceived as using and supporting the planning and control activities. In the control process, project management must be perceived to react in a positive manner. Correction of schedule or budget slippages should be the purpose of control, rather than an emphasis on fault finding and punishment. Unless the control function is perceived as being fair and objective, activity progress and other information will not be reported accurately and the control system will be ineffective. This does not imply that incompetence should be tolerated but rather that project management should demonstrate the proper tolerance for project uncertainties and events that are outside of the control of those whose performance is being evaluated.

To assist in the selection process, a set of criteria are described in Figure 6 and the various techniques as they are discussed will be evaluated on the basis of these criteria.

When considering the costs and benefits of using any scheduling technique, one must <u>be careful to specify how it will be used and the detail which is needed at each level of management</u>. A common error of project management is to try to use the scheduling documents, charts, and reports with the same level of detail that is needed for lower levels of activity management. In addition

Benefits

The technique facilitates:

1. derivation of output specification
2. delineation of required activities
3. coordination and communication between work groups and levels of management
4. determination of type, amount, and timing of necessary resources
5. recognition of high-risk elements and assessment of uncertainties.
6. suggestion of alternate courses of action
7. delineation of effects of resource level changes on schedules and output performance
8. assurance of coupling between planning and control

Costs

The technique requires:

1. new forms of information from additional sources and incremental processing (managerial time, staff time, professional time, computer expenses)
2. additional staff or smaller spans of control to free managerial time for planning tasks (increased managerial overhead)
3. special studies and analyses or services by external consultants or staff (salaries or consulting expenditures)
4. training of the project team in the use of the technique (cost of training time and materials)
5. time for preparation and review of reports (professional, staff, and managerial time)
6. development of new systems to support the technique (budgeting, cost accumulation, information, computer software.

Figure 6 Criteria for Project Planning Technique Selection

to incurring excessive costs, the detail obscures the most pertinent issues from the attention of top management. Different levels of management may require different combinations of techniques. For example, the highest level may require use of CPM because of the problems of coordinating many subcontractors while a task leader may find a form of Gantt chart to be sufficient because his small group works closely together and frequent modifications are made in their plans.*

*For Discussion Questions and Recommended Readings for this section see pages 74 and 75.

Charts as representations of schedules

Scheduling techniques facilitate the review of project plans and progress through the use of charts and graphs to depict activities, their relationships to each other and to time schedules. The kind of chart or graph constructed depends upon the specific technique being used; the procedures for generating the different forms of charts or graphs are described below.

Regardless of the technique, generating the visual display which represents the plan is an integral part of the planning process. To plan, coordinate, and control the tasks of each work group, the project must be divided into work activities which, when completed, will assure achievement of the objectives. The detail which must be used in defining these activities depends upon the level of management and the purposes of the plan. Thus, at top levels of program administration, summary, milestone, or integrating charts consisting of a dozen or two activities may be adequate. At the lowest operating levels, a single activity on a summary chart may be elaborated into an operations chart of 50, 100, or even more tasks depending upon the complexity of the project. Usually the summary graphs or charts are developed first in planning processes by top planning officials or project administrators. As projects are organized to initiate implementation, the people responsible for subactivities can develop more detailed charts for their work or join management in adding detail and expanding the summary charts.

In deciding how to break the efforts of the program or project into activities to be charted, a first attempt should concentrate on operationally defining objectives and sub-objectives. Top management should meet with functional specialists, consultants, and other experts in deciding the best approach to reach the goals. The methodology or approach should be summarized by working backwards from objectives to determine the activities that must be

performed before objectives can be attained. This summary logic can then be detailed by other planning teams to whatever level is necessary. (This establishment of the project work structure was previously described in the discussion of the project planning logic.) Enough detail must be evident in the summary chart itself to depict the points where coordination is necessary. Expansion of the charts for operating detail should involve the participation of those responsible for the implementation of activities.

A project can be divided into smaller activities according to a variety of criteria:

1. The nature of work involved (when the activity groups need different types of resources for their accomplishment);
2. Place and time of work (when work undertaken at different locations or at different times may be considered as different activities);
3. Supervision or responsibility for work;
4. Method of financing the project (when a project is financed by several agencies);
5. The physical items or output subsystems upon which work is being performed.

In the preliminary stages of planning the logic, the times for completion of activities should be ignored until the sequencing, relationships of activities and significant events or milestones can be incorporated Once this logic is developed, the activity leaders or experts should participate in estimating the time and resources necessary to complete each activity. Wherever possible, the checkpoints or milestones should be defined in terms of measurable, specific criteria which leave no doubt of degree of accomplishment during the control process. This is most easily attained if the events can be

defined in terms of some observable, physical output such as a machine, a new school, a plot of ground cultivated, or a written report of test results.

Gantt Charts

Gantt charting is the simplest scheduling technique. On a Gantt chart, the activities are listed by name and the estimated time for completion of each activity is represented by a time-scaled bar. The bar is positioned on a time-dimensioned axis so that the start of the bar is at the earliest possible start date. The format is illustrated in the example shown in Figure 7. Gantt charting is most commonly used in the scheduling of repetitive operations, where the activities breakdown has been performed as a routine. Applied to non-repetitive operations such as project tasks, the Gantt charting technique provides less assistance in planning and directing activities because it neither allows for expression of uncertainty nor reveals relationships among activities in a project. If relationships are not explicitly revealed by the scheduling technique, project management is unaware of the degree of flexibility that is allowable in scheduling each activity without affecting other activities. In the example below, is activity A a prerequisite for B? Does activity C require the partial completion of B? If any event affects the start of C, how does that affect the whole project? These types of questions are unanswerable by simple Gantt charts. However, because of their simplicity, Gantt charts are very useful in those types of projects in which the inherent uncertainty is so great that almost constant replanning is required. Activities can be added or dropped from the chart or rescheduled with a minimum of paperwork. Gantt charts are therefore particularly helpful on small, experimental projects.

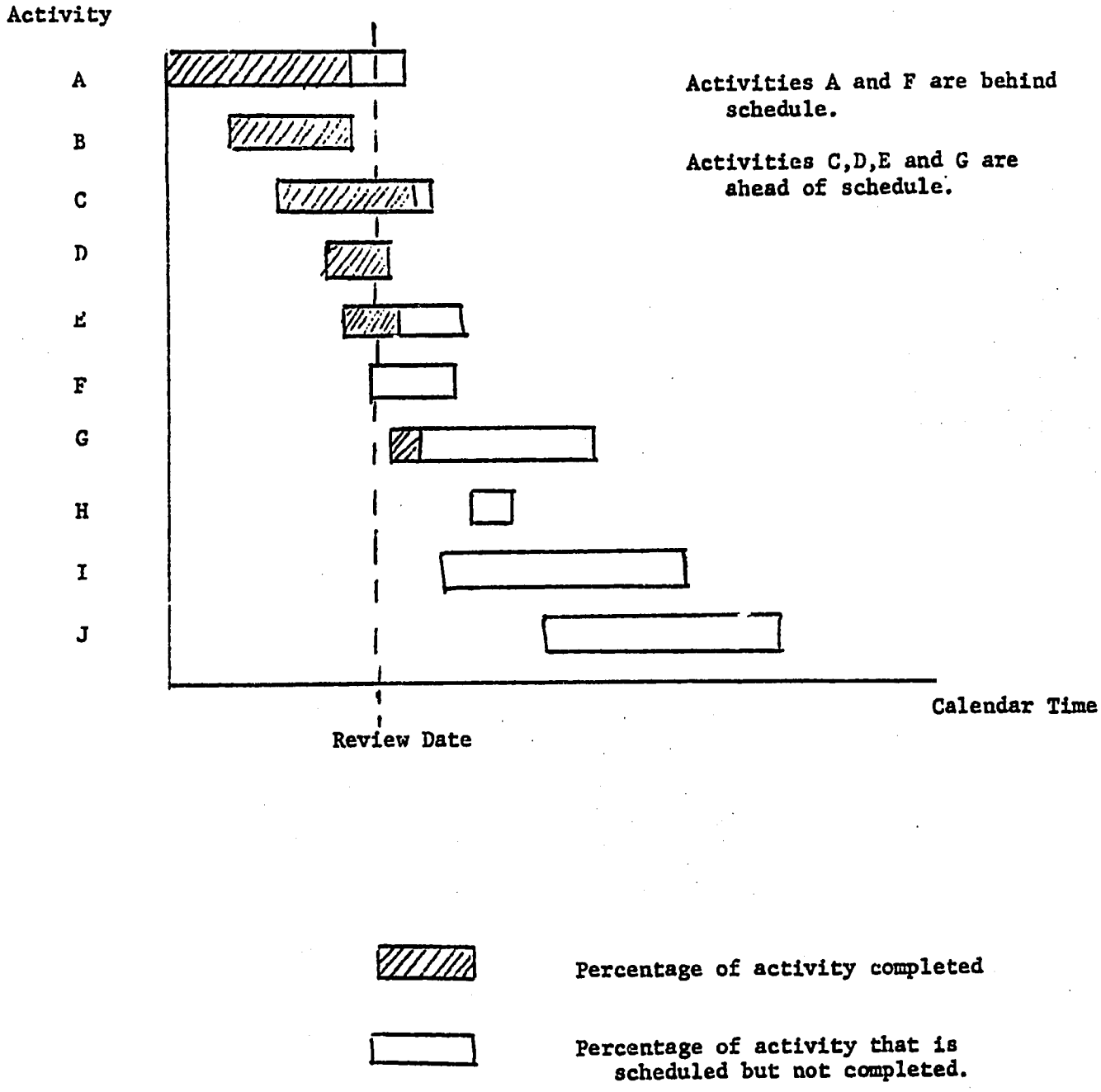


Figure 7 An example of a Gantt chart

Summary: Gantt Charting

DATA REQUIREMENTS: -- number and type of activities

-- activity duration (best estimate)

-- activity schedule date

-- activity progress to date

OUTPUT INFORMATION: -- activity status -- delayed, on time, ahead of schedule

ADVANTAGES: -- simple: easy to understand, easy to change

-- minimal data required for construction of chart and updating.

DISADVANTAGES: -- doesn't show interrelationships of activities: has little predictive value

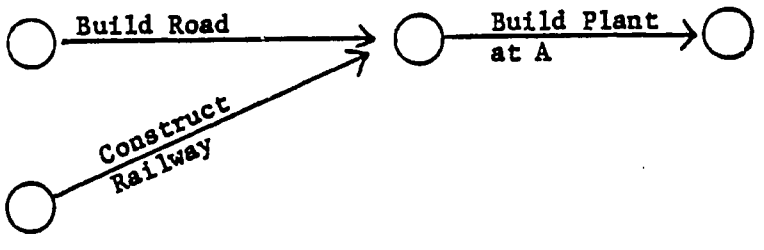
-- no opportunity for sensitivity analysis

-- no explicit recognition of uncertainty

Network Analysis

A number of scheduling techniques which rely on network models have been developed and widely used in program and project management over the last decade. Before examining the specifics of each technique, several general aspects of network models will be discussed.

The models in network diagrams are composed of arrows and nodes. The meaning of the arrows and nodes differ from one method to the other but they represent mainly the activities and their relationships. In this example, the arrows represent the activities and the nodes represent the events.



It is important at this point to clarify the distinction between activities and events. Activities are subdivisions of the project work that consume resources such as time and money. An activity for a land reclamation project may be the construction of a dike. This activity may take four months and cost $70,000. An event is a particular point in time when something significant is scheduled to happen; an event is associated with the beginning or the end of an activity. The completion of the dike is an event. There are no resources associated with events. There exist two types of network diagramming: arrow diagramming and precedence diagramming.

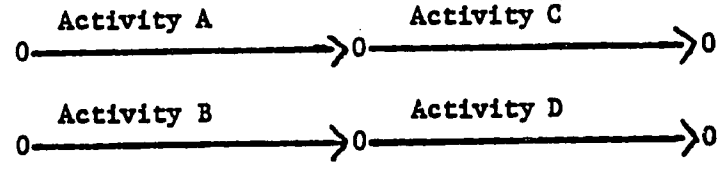
1. Arrow diagramming.

   The activities are represented by arrows.

   The nodes represent events.

   This is the case for PERT

In this method, it is sometimes necessary to introduce <u>dummy arrows</u> in order to indicate activities that have no physical significance, zero time duration, and require no resources. The dummy arrows are used to show the correct relationships when this cannot be done by bringing the terminals of the arrows involved together at a common node.

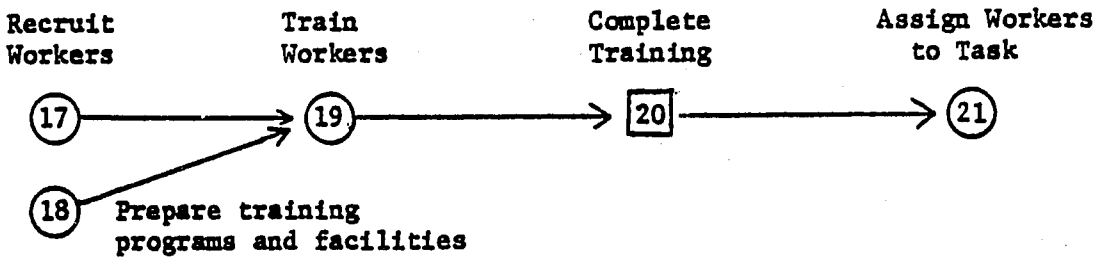


Activities A and B must be completed before C could begin but Activity D does not depend on the completion of A.

2. Precedence diagramming.

   The nodes of the network represent activities rather than events.

The events are sometimes described on the chart in terms of measurable happenings that are particularly important in the project implementation. The key activities are identified by a special notation such as the square indicating activity 20 below.



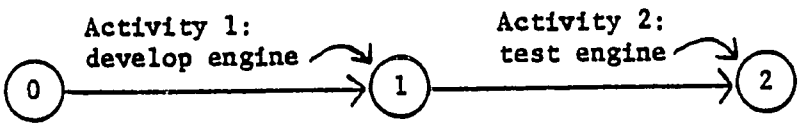
The first procedures for CPM were precedence diagramming but now CPM is commonly considered the same as deterministic PERT which is arrow diagramming.

Critical Path Method (CPM)

The basic elements in CPM are: 1) the flow diagram or network, 2) critical paths, and 3) slack or float. There are two basic versions of CPM. The earliest version was based on precedence diagramming. Later versions are based on arrow diagramming and are treated essentially as a form of deterministic PERT.[22] Since PERT is discussed below, precedence diagramming form of CPM is explained here. An example summary network for a project designed to introduce a new project is given below as a precedence diagram.

The Network

Events are depicted by arrows. Activities are represented by nodes:



A grouping of activities and events form a network. No looping is allowed. The direction of the arrow indicates the precedence relationship between events.

[22] For a description of arrow diagramming CPM and example networks applied to development projects, see Kenneth F. Smith, Project Management Systems for Economic Development (Washington:AID).

In the above example, activity one must occur before the activity "test engine" can start. The length of the arrow may or may not be time-scaled; it usually is not because of the difficulty of redrawing the network at each progress reporting review date. An example of a time-scaled network for a development project is provided in Figure 8.

The Critical Time Paths

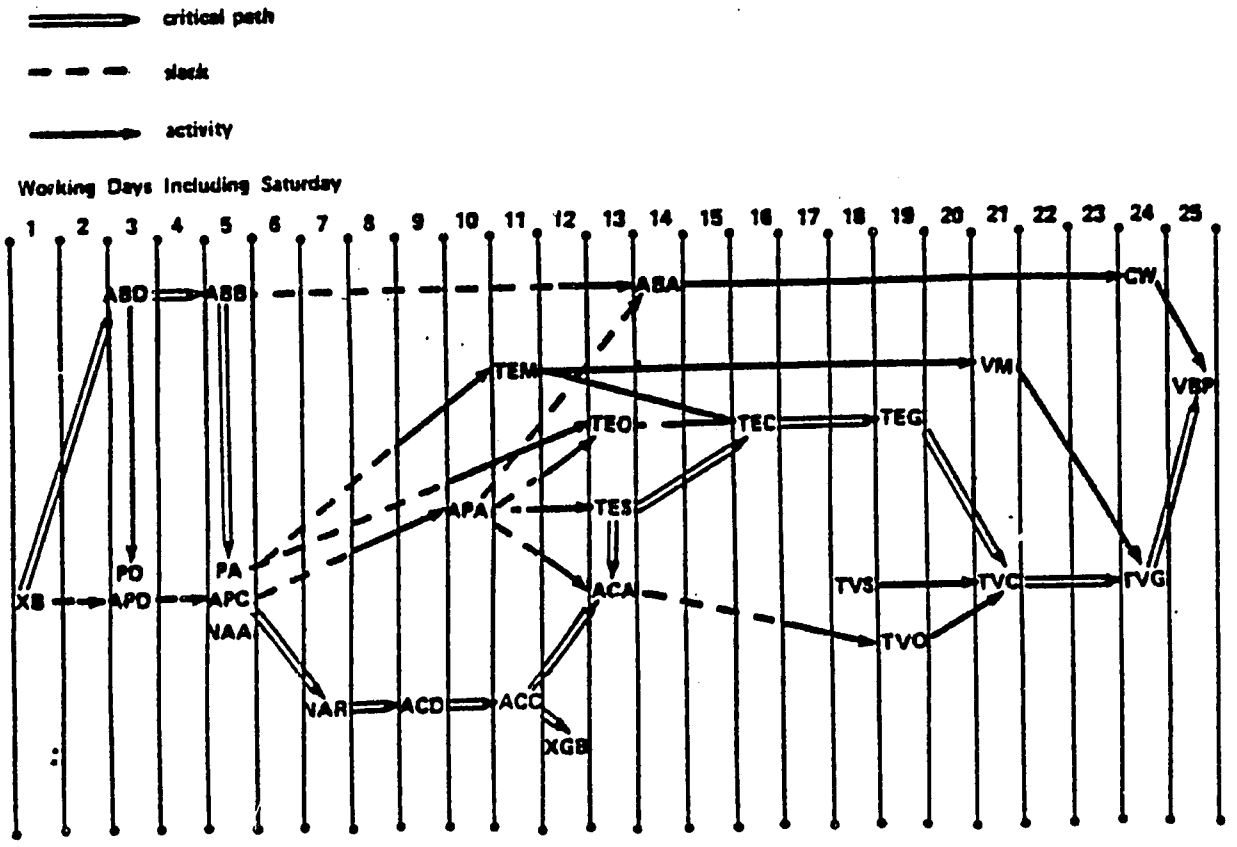
The critical path is the path requiring the longest time from the start to the finish of the network. In the initial planning, management should devote resources along the path to reduce the time requirement necessary to complete the overall project. In the implementation and control stages, management should continually scrutinize the activities on the critical path.

Slack

Some leeway exists for scheduling the start of activities that are not on the critical path; that is, the non-critical activities can be delayed some amount of time without causing a completion delay for the entire project. The amount of slippage is called "slack." (The term "float" is more commonly used in CPM and "slack" in PERT but since the concepts are similar, the single term "slack" is used here.

There are several forms of slack associated with each activity. Total slack (also called "primary" or "path" slack) is the amount of delay which is possible without delaying the completion of the project. Free slack (also called "secondary" or "activity" slack) is the amount of delay which can be tolerated before the start of the next activity will be delayed. To calculate these slack values for a given network, four time values must be computed for each activity. The calculations are illustrated for a simple CPM network in Figure 9. The first two time values for each activity, the early start (ES)

THAILAND
PREPARATIONS FOR CREDIT FERTILIZER CAMPAIGN
. . . PERT TIME CHART



AB Agreement With Banks & Businesses
ABA Approved
ABD Drafted
ABB Bilateral Preliminary Approval

AC ARD-Changwad Agreement
ACA Approved
ACD Drafted
ACC Originator (governor) Approval

AP Project Agreement
APA All Signed Off
APC Committee (ARD Agbus.) Approval
APD Drafted

CW Commodities In Warehouse

NA Notification By ARD
NAA Approved
NAR Received

P Plans & Procedures
PD Drafted
PA Approved

TE Training Of Extension Ofrs. (incl. CD)
TEC Course Begins
TEG Graduation
TEM Materials Ready
TEO Organization Complete
TVS Selection of Participants

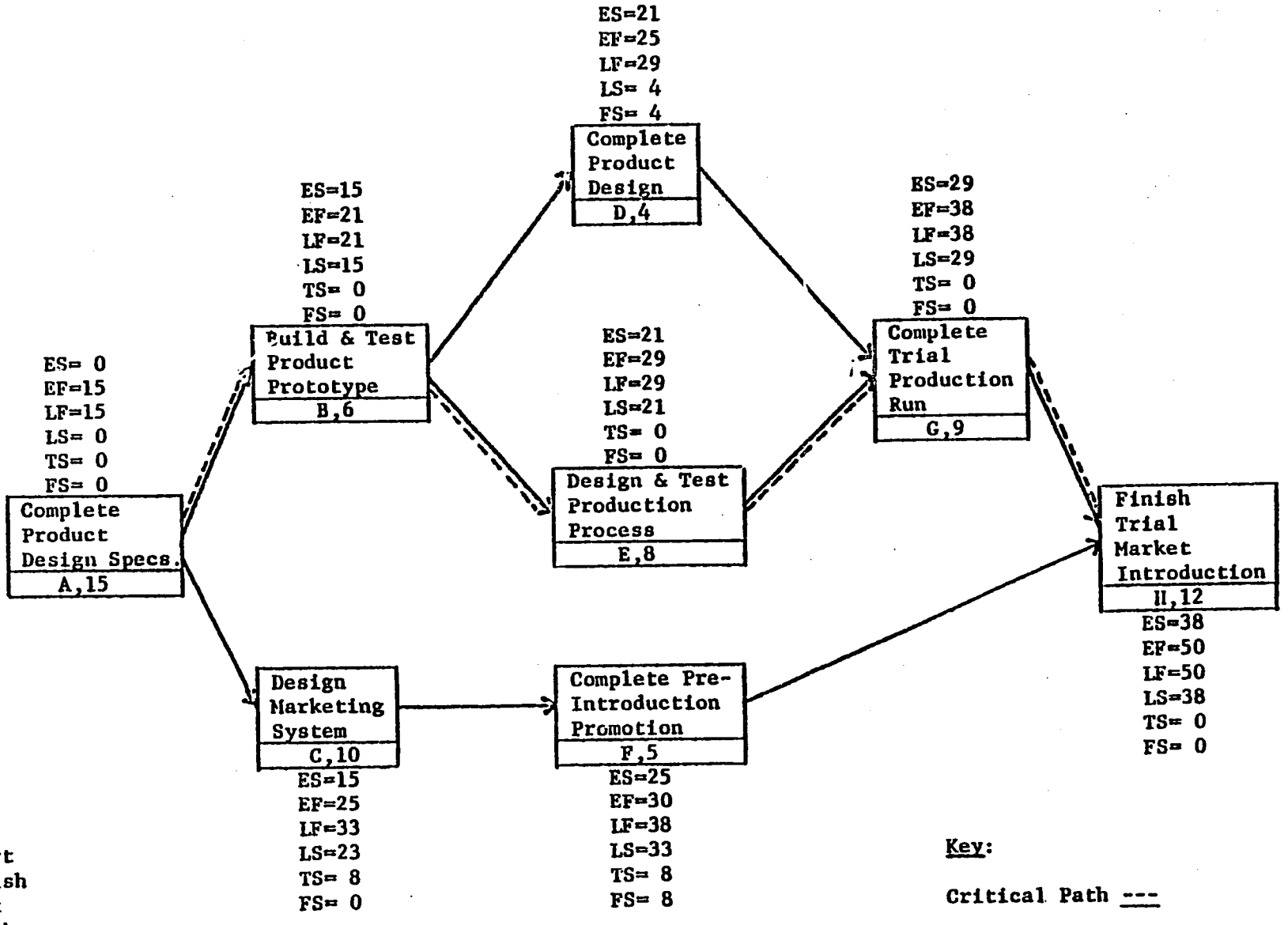
TV Training of Volunteers
TVC Course Begins
TVG Graduation
TVS Selection Of Participants

V Village Campaign
VBP Presentation In Beginning Village
VM Materials Ready

X Externally Determined Dates
XB Begin
XGB Governors Conference Begins

Figure 8 A time-scaled PERT chart[23]

[23]Reproduced from Kenneth F. Smith, Project Management Systems for Economic Development. (Washington, D.C.: AID), p. 41.



ES: Early Start
EF: Early Finish
LS: Late Start
LF: Late Finish
TS: Total Slack - delays greater than this will delay the project completion
FS: Free Slack - delays greater than this will delay the start of the next activity

Key:

Critical Path ---

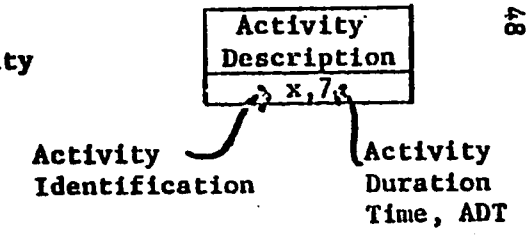


Figure 9 An example CPM network

and early finish (EF), are calculated by a "forward pass" through the network. That is, starting at the left of the network (the first project activity), these times are computed for each activity such that all predecessor activities must have these values associated with them before they can be calculated for a given activity. The early start time is the earliest possible time that an activity can begin given that all its predecessors also began at their ES times. The early finish time is simply the ES time plus the time it takes to accomplish the activity, the activity duration time, ADT. These two values are calculated on the forward pass using the following rules:

Forward Network Pass, activity i

$$ES_i = \text{Maximum: } \{\text{Predecessors' EFs}\}$$
$$EF_i = ES_i + ADT_i$$

In the example network, activity G has two predecessors, D and E. The EF of D is 25 and the EF of E is 29. Thus the ES of G is the maximum of these predecessors' EFs, that is 29. The EF of G is the ES, 29, plus the ADT of G, 9, for a total of 38.

The second two time values associated with each activity, the late start (LS) and the late finish (LF), are calculated on a "backward network pass" using the following rules:

Backward Network Pass, activity i

$$LF_i = \text{Minimum: } \{\text{Successors' LSs}\}$$
$$LS_i = LF_i - ADT_i$$

The backward pass starts at the right, the last activity in the project, and proceeds to the left, towards the first activity. To start the backward pass, the LF of the last activity is set equal to the EF so that the slack on the critical path will be zero (as shown by the example calculations). In the example network, activity B has two successor activities, D and E. The LS of D is 25 and the LS of E is 21. Therefore the LF of B is the minimum of these LSs or 21. The LS of B is the LF, 21, minus the ADT of B, 6, for a value of 15.

The total slack for each activity is calculated using the following rule:

$$TS_i = LS_i - ES_i$$

In the example network, the total slack of activity F is 33 - 25 = 8. The free slack is computed using the following rule:

$$FS_i = \text{Minimum: Successors' ESs} - EF_i$$

Thus in the example network for activity B, the ES of successor activity D is 21 and the ES of successor activity E is also 21; the minimum of these two ESs is the same, 21, so that the FS of B is 21 minus the EF or B which is also 21 so that the FS of B is zero.

Sometimes another kind of slack, called schedule slack, is used if the scheduled time for completion is not set by calculating the early finish of the last activity. Perhaps for reasons beyond the control of the project, the scheduled completion time, SCT, is set in advance of planning the project. The scheduled time for completion will then most likely be larger or smaller than the EF of LF of the last activity. Schedule slack may then be computed using the rule for total slack except that the backward pass must be redone with a change in the first computation step. Instead of setting the LF of the last activity equal to its EF, the LF is set equal to the scheduled completion time, SCT. Thus, if the SCT is less than the EF computed on the forward pass, the LFs, and LSs of all activities will be less than when computed using the EF rather than the SCT. In this case the critical path will initially have negative schedule slack. In an analogous manner, if the SCT is greater than the computed EF, the schedule slack for activities on the critical path will be positive.

Because CPM shows the relationships between activities and presents the planning information that is necessary for reallocating resources between activities, it is a very useful planning tool for projects that require careful coordination. Thus, if the activities are performed by a diverse group of subcontractors or governmental agencies, CPM can help project management communicate

the role of each subcontractor or agency to its management. Care must be taken to define activities so that the work to be performed in each includes only that for which the separate subcontractor is responsible. Although replanning requires substantial work for the revision of a large network, this effort can be minimized by the proper development of a hierarchy of planning networks for larger projects. If top management develops only a summary, integrative network and the major activities on it are expanded to subnetworks by lower levels of management, only the affected portions of the plans must be revised during planning changes. Thus very large projects such as construction of hydroelectric systems, or extensive irrigation or transportation systems may profit considerably by the use of CPM.

Summary: Critical Path Method

Data Requirements:	- number, type, and relationship of activities - activity duration (best estimate) - activity progress during operating phase
Output Information:	- project expected completion time - critical activities - delays here will delay the project - activity slack - the amount of delay possible before other activities or the project schedule is affected
Advantages:	- explicitly depicted relationships aid project coordination - output information is vital to project management resource reallocation decisions
Disadvantages:	- complexity adds to implementation problems - fairly extensive data requirements - change in activity relationships require an entire new graph drawing - no explicit recognition of uncertainty

Program Evaluation Review Technique*

The Concept

PERT is a network technique. It is designed for planning and control of activities in a wide variety of program and project environments. Like CPM, it identifies critical paths and slack but it is more sophisticated than CPM because it introduces the notion of uncertainty in estimating the time.

Use in Initial Planning Phase

1. Develop the network. This is done in a manner analogous to that described previously for CPM except here the nodes represent events instead of activities.

2. Develop three time estimates for each activity in the network:

a = optimistic time (the shortest time for which there is a one-in-ten chance of completing the activity)

m = most likely time

b = pessimistic time (the longest time for which there is a one-in-ten chance)

These three estimates should be made in conjunction with the personnel who are responsible for performing the work in the activity.

3. The β distribution is used in the PERT estimation process. The time, t_e, is the estimated mean of the distribution of possible elapsed times that may be required to complete a given activity.

$$t_e = \frac{a + 4m + b}{6}$$

The mean, t_e, is computed for each activity in the network. For calculations of slack and expected start and finish times, t_e is substituted for the Activity Duration Time (ADT) used with CPM. With the exception of this substitution, the calculation rules are the same. The critical path is the longest path of expected times through the network.

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*Authorities in networking with experience in developing countries do not recommend PERT with 3 time estimates. Many of them feel that it complicates the task unduly and also provides an excuse for non-performance.

4. Calculate the slacks associated with each activity. The different forms of slack are computed for PERT in the same manner as was used above for CPM, with the exception that slack is now associated with the arrows rather than the nodes. Instead of the one time estimate for CPM, the activity duration time (ADT), the t_e computed in the above step is used in the formulas.

5. Compute the probability of meeting the schedule. First a variance is calculated for the random variables, the times to complete each of the activities, using the following formula:

$$VAR(t) = \frac{(b-a)^2}{36}$$

The probability calculations in PERT assume independence between all the t's, and thus the variance of the time to complete any path in the network is simply the sum of the variances of all the activity times on the path. Using the mean times to calculate the critical path expected total time, T_E, to completion and summing the variances of the activities times in the critical path, provides the mean and the standard deviation (the square root of the total variance) of a normal distribution. This normal distribution is completely defined by the mean and the standard deviation and thus may be used to calculate the probability of completion by any scheduled time, T_S. For example, if the critical path has an expected total completion time of 140 days and the variance is 100, one might wish to know how certain the completion of the project is by the end of 150 days. The standardized normal probability table could be used by calculating the Z value,

$$Z = \frac{T_S - T_E}{\sigma_{T_E}} = \frac{150-140}{\sqrt{100}} = \frac{10}{10} = 1.$$

From a normal table, the probability is 0.84 of being completed on schedule.

Computer programs may be used which calculate the probabilities associated with different paths through the network. The big advantage of PERT over CPM

is that it directs project managers' attention to highly uncertain areas of the project (paths having relatively large variances) as well as the longest paths. Thus the sequence of activities on the critical path may have a slightly longer expected time for completion but a much lower variance than another path with some very risky activities on it. The probabilities of completing by some scheduled date may actually be lower for the non-critical path and thus more managerial attention is warranted for these "non-critical" activities.

Summary: Program Evaluation and Review Technique (PERT)

Data Requirements: CPM plus the following

- three time estimates by activity experts - most likely, pessimistic, and optimistic
- project scheduled completion date
- activity schedule dates

Output Information: CPM plus the following

- the probability of completing on time and the variability in the possible completion dates
- the probabilities of meeting activity schedule dates

Advantages: CPM plus the following

- a knowledge of the likelihood of completion times

Disadvantages:

- additional complexity
- additional data requirements
- high cost of replanning - new activities or changes in relationships necessitate constructing new graph and getting new estimates

Line of Balance (LOB)

Line of balance is a technique using a time scaled network to predict the effect on end-item delivery of delays in components or subsystems. As such it is used when there is repetitive production of physical goods or service

systems such as test models or prototypes at the end of a demonstration project. It pinpoints production problems by predicting delays in the final product which result from slippages in the components and subassembly stages. With this knowledge of eventual delays, the program or project managers can expedite late items in sufficient time to recover the schedule. Application of the technique requires the generation of four charts:

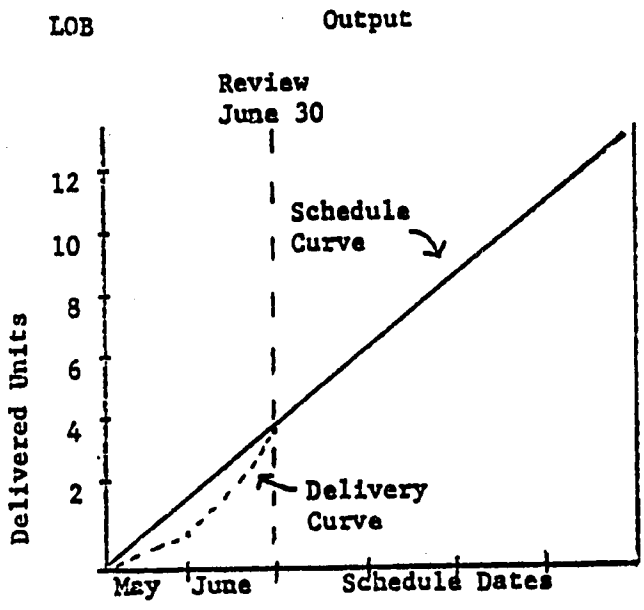
1. the objectives chart or output delivery schedule,
2. the project plan and control point network,
3. the physical inventory progress chart, and
4. the line of balance chart.

Example of each of these charts is shown in Figure 10 and explained below.

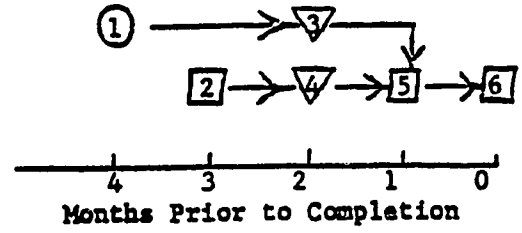
The objectives chart simply plots the scheduled dates of delivery objectives in terms of the number of units of production planned. The solid line represents the planned delivery schedule. The actual deliveries are plotted and compared to the planned deliveries on each review date. The example shows the status of the chart as of the June 30 review. At the end of May, one unit was behind schedule but by the end of June, deliveries were back on schedule.

The control point network is time scaled to show the key operations or activities to be performed on each unit. The symbol for each activity is placed on the network in such a position as to illustrate the lead time necessary to accomplish the remaining activities if a unit is to be completed on schedule. Completion of each key activity is a control point which will be used on the remaining two charts for examination of progress.

The progress chart shows the actual physical inventory as of the review date at each of the control points. The inventory is not a numerical count of items but given instead in terms of completed fabrication of a type of component for which three are required in the final product, and if thirty components

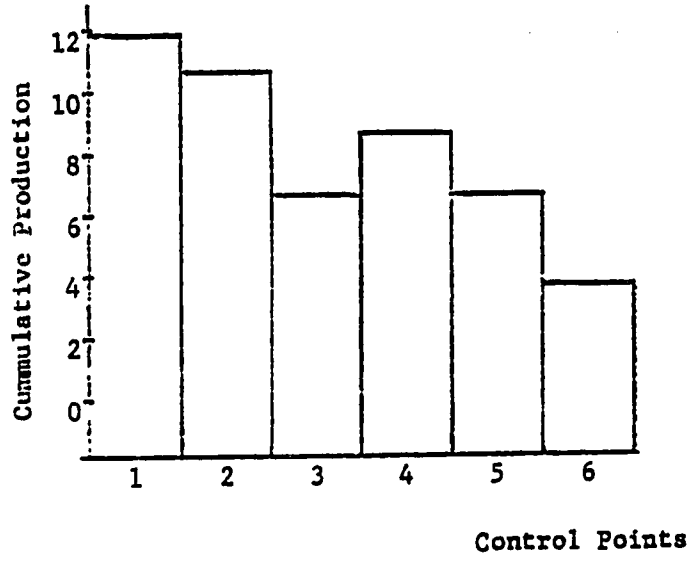


I. Objectives Chart

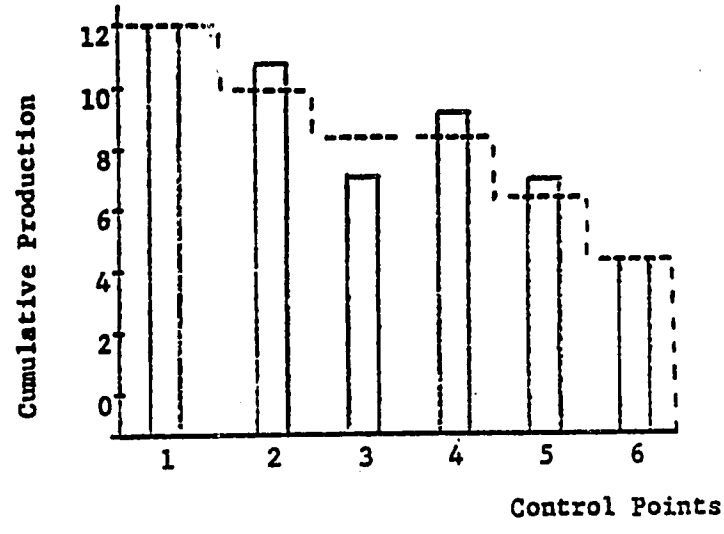


1. Purchase order placed, subsystem A.
2. Fabrication completed, subsystem B.
3. Testing completed, subsystem A.
4. Testing completed, subsystem B.
5. System Assemply completed.
6. Installed at customer.

II. Control Point Network



III. Physical Inventory
Progress Chart, June 30



IV. Line of Balance Chart,
June 30

Figure 10 Example line of balance charts

are available or shipped at the review date, the cumulative production units shown on the chart for control point three would be ten.

The line of balance chart translates the cumulative production requirements at each control point from the objectives chart and superimposes this line of balance on the progress chart. To construct the line of balance, the quantities required to support the delivery objectives are determined from the objectives chart and the control point network. In the example shown below for the June 30 review date, cumulative production of four completed units is needed to be on schedule. At control point four, a lead time of two months is needed to finish processing equivalent units at that stage. By August 31, eight units must be completed so on June 30 there must be the equivalent of eight units at or past control point four for the necessary two months lead time. The line of balance translates the scheduled production into the requirements at each control point. As can be seen in the example, when progress is compared to planned production, progress at control point three is behind schedule and will result in a slippage on one unit by August 31, unless corrective action is taken. Since progress at control points two, four, and five is ahead of schedule, resources may be taken from the activities associated with these control points if their use will expedite progress at the third control point.

Summary: Line of Balance (LOB)

Data Requirements:
- Output delivery schedule
- Program plan and control network
- Physical inventory progress information

Output Information:
- A line of balance or the production quantities needed at each subsystem control point to support the output delivery schedule.
- At each review point, the effect of subsystem slippages on the final schedule is determined.

Advantages:

- Pinpoints production bottlenecks and potential slippages for prototypes and demonstration or replication programs
- Predicts effect on production quotas of delays in subsystem development
- Simpler than other network techniques to understand and implement

Disadvantages:

- Useful in its present form for repetitive activities within projects, particularly with physical output involved
- Considerably more complex with greater information requirements than Gantt charts

PERT/Cost

Planning and controlling projects so that time schedules are met may not be enough to assure successful completion in terms of budgets. Frequently schedules are compressed to avoid slippages by allocating more resources and overrunning the budget. Some sort of formal system is needed to relate the time schedule to the budget. One such method is PERT/cost.

The need for formalizing project budgetary control varies considerably depending upon the budgetary procedures and practices of the organization in which the project is housed. In many instances, projects are defined as part of the activities of organizations or governmental agencies where budgetary and cost accounting systems are based on fixed time period planning and reviewing. Project budgets should be reviewed against activity progress rather than expenditures in a fixed, budgeted time period. For this reason, special budgeting and cost control techniques, such as PERT/Cost, may be required.

Once a network has been defined in enough detail so that the work involved in each activity is known, estimates of time and cost may be made in collaboration with the people responsible for accomplishing the activity. In most cases, resources required for the activity will be translated into monetary values for

the budgetary process. Sometimes special scarce resources such as personnel are budgeted separately in terms of an additional measure, such as man-hours. This is discussed below in terms of the manpower loading technique. Once a monetary value is budgeted for the resources necessary to complete a project activity, that monetary value must be "loaded" or assigned against a time schedule during the time span when that activity is expected to be in progress. This is done by using the activity scheduled time from the PERT schedule.

There are several ways of doing this. One computer program simply assigns the activity budget in a linear manner over the expected activity duration starting at the earliest start time for the activity. Other programs use non-linear functions and may assign the budget starting at some schedule point between the earliest and the latest start dates. One program requires a weekly cost estimate for each week that the activity is expected to be in progress. The output of all of these methods, however, presents the budgeted cost on a time schedule associated with activity progress. Thus during the progress reviews, expenditures to date are compared to progress to date, not some artificial budgetary period. In this manner, projects whose expenditures are considerably over the projected budget will be happily accepted as well managed, if accomplishment is commensurately ahead of schedule.

Summary: PERT/Cost

Data Requirements:
- PERT plus
- activity budgets (planning)
- expenditures by activity by cost account (control)

Output Information:
- PERT plus
- cash flows and budget schedules (planning)
- actual-budgeted expenditures (control)

Advantages:

- PERT plus
- cost control information - ties expenditures to schedule progress

Disadvantages:

- PERT plus
- additional data requirements may be unreasonable unless simplified cost accounts are established

Manpower Loading

If a development project is being implemented by an organization or agency which is responsible for other projects as well (perhaps in a matrix-type structure), it may be very helpful to management in the organization or agency to have a detailed schedule of requirements for particularly scarce resources from project management. This is particularly true if the larger organization is functionally structured and each functional area must make temporary assignment of its resources to different project organizations. One technique which may be applied is called manpower loading although it may be adapted to other kinds of resources than personnel, such as scarce facilities.

This technique requires gathering estimates of resource consumption (specifically the number of man-hours per week) for each activity for each kind of resource which is not interchangeable with another kind of resource. In many cases where resources are generally available or interchangeable it is sufficient to control monetary expenditures. If not, then the critical skills should be "loaded" against a time schedule by adding the resource requirements for each of the activities in the project in the same manner as monetary values were assigned using PERT/Cost. A computer program can be used to summarize by each skill class (if human resources are the scarcity being loaded), the requirements for all activities in each week when they are scheduled to be in progress using either CPM or PERT. An example output is shown in Figure 11 for the network illustration provided in the section on CPM. From the example, it can be seen

Project X Total Manpower Requirements by Skill

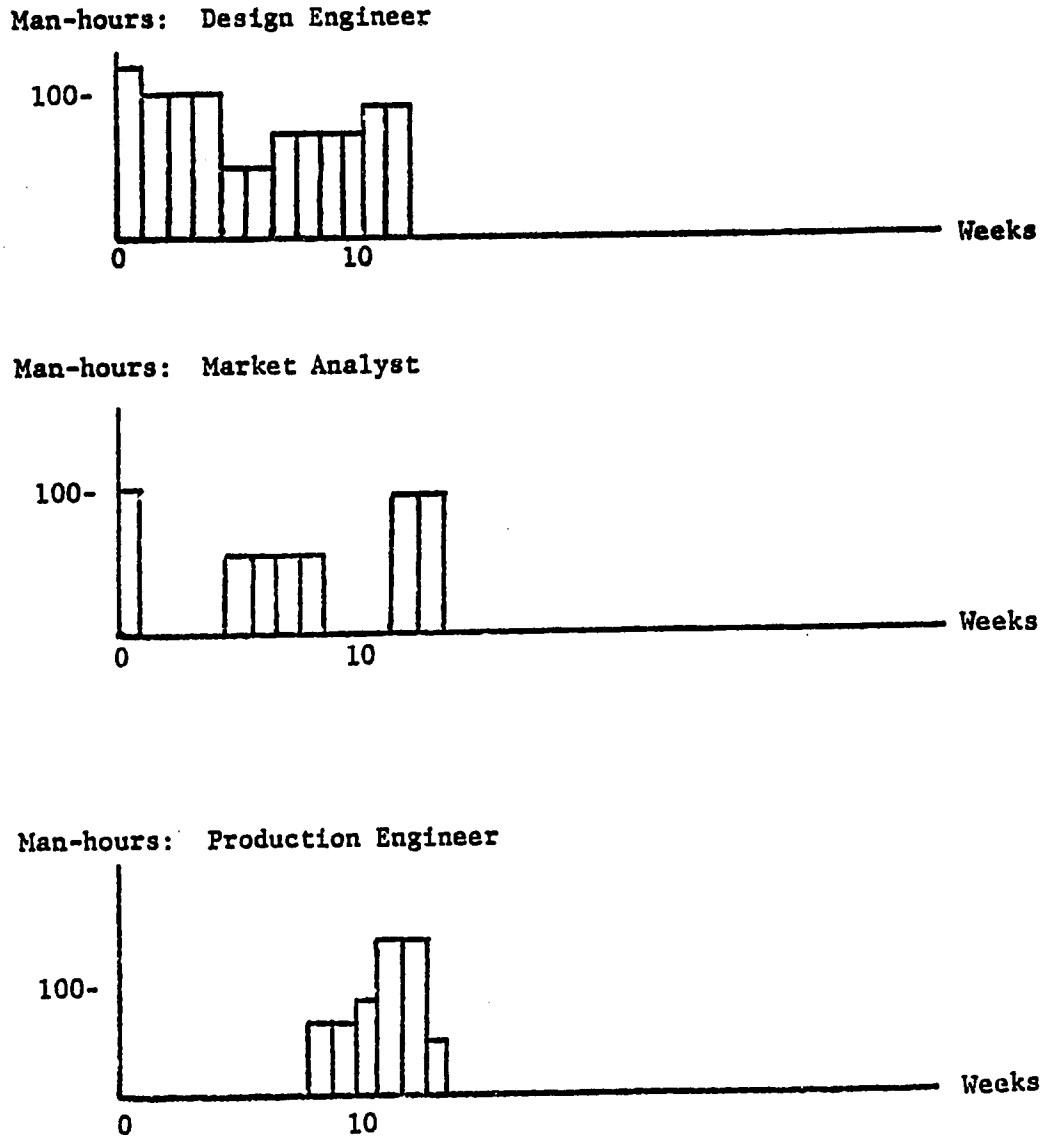


Figure 11 Example manpower loading output charts

how helpful this type of information would be for heads of the functional areas, such as design engineering, if they were required to support a number of projects simultaneously.

Summary: Manpower Loading

Data Requirements:	- CPM or PERT plus - the required man-hours for each activity by skill categories
Output Information:	- CPM or PERT plus - schedules or required manpower inventories for each skill by week for the duration of the time schedule
Advantages:	- CPM or PERT plus - information for personnel recruiting and assignment (particular valuable in matrix organizations).
Disadvantages:	- CPM or PERT plus - even greater data requirements - project replanning necessitates functional department replanning

CPM or PERT Resource Reallocation

As was noted in the sections describing CPM and PERT, knowledge of the slack associated with each activity can be of tremendous assistance in directing managerial and project resources to potential problem areas. Formal procedures can be used to analyze a network and switch funding resources from activities which have a great deal of slack to more critical activities. To use these techniques, two assumptions must be valid. First, the resources must be reasonably interchangeable between activities. Secondly, some of the activities must have an inverse relationship between time and cost and it must be possible to extend

or reduce the time which would normally be required by assigning fewer or more resources, respectively.

If these assumptions are valid and a formal procedure is desired, three time estimates and three cost estimates must be generated for each activity to be involved in reallocating resources. (Some procedures use only two estimates - "normal" pace and a "crash" pace.) One set of estimates pertains only to the normal time and budget as used by PERT/Cost. Two additional sets of estimates are needed. One set is the shortest possible time for completion of the activity on a "crash" basis and an associated higher cost. The other set assumes that if more tasks in the activity were done in a sequential manner rather than in parallel with more resources or capacity, then the cost could be reduced by extending the time by some amount. An alternate method of presenting these estimates is to give an incremental cost per week (or some other time period) and the limit on the number of weeks which the normal time could be shortened by assigning more resources. The extended time and associated savings could be presented in a similar manner.

Once the reallocation data are estimated, the network is searched for opportunities to switch resources. This reallocation may be done by visual inspection of the network and trial and error switching or it may be done by computer using one of the several heuristic programs available. If the budget for the project can not be increased, a first pass is usually made to extend the noncritical activities and see how much savings can be made. Care must be taken in this step not to extend these activities to the point of causing them to become critical schedule items. Once the savings are known, they may be applied to activities on the critical path starting with those activities with the lowest incremental cost per unit time period saved. This search continues until the savings are depleted or some sort of budget constraint is met or until the schedule is shortened to a satisfactory time frame.

Summary: CPM and PERT Resource Reallocation

Data Requirements:

- CPM plus
- for each activity: normal pace and cost, collapsed time and cost, extended time and cost

Output Information:

- CPM plus
- the allocation of resources to minimize costs for a given scheduled completion date

Advantages:

- CPM plus
- greater knowledge of tradeoff between completion dates and project costs by trying a number of runs with different schedule dates

Disadvantages:

- CPM plus
- more data again
- computation costs may become significant.

PROJECT PLANNING BIBLIOGRAPHY

deVries, Egbert. Administration of Development Programs and Projects: Some Major Issues. (New York: United Nations, 1971).

Haq, Mahbub ul. "Annual Planning in Pakistan," Journal of Development Planning, No. 2, 1970, pp. 81-113.

Il, Lee Hee. "Project Selection and Evaluation: Formulation of an Investment Program," in Irma Adelman (ed.), Practical Approaches to Development Planning (Baltimore: John Hopkins Press, 1969).

Melnick, Julio. Manual on Economic Development Projects (New York: United Nations, 1958).

Millikan, Max F. "Comments on Methods of Reporting and Evaluating Progress Under Plan Implementation," in United Nations, Planning and Plan Implementation. (New York: United Nations, 1967).

Peart, Alan T. Design of Project Management Systems and Records. (Boston: Cahners Books, 1971.

Smith, Kenneth F. Project Management Systems for Economic Development. (Washington: Agency for International Development).

Southeast Asia Development Advisory Group, Development Administration Panel Seminar, "Administrative Requirements for Labor-Intensive Development" Singapore, July 23-27, 1973.

United Nations. Manual on Economic Development Projects. (New York: United Nations, 1958).

Recommended Readings

Baumgartner, John Stanley, Project Management (Homewood, Illinois: Richard D. Irwin, Inc., 1963). Chapter 2

Lebell, Don. "Entrepreneurial Planning for the Small Scale Project," Interfaces, Volume 4, Number 2, February, 1974, pp. 53-59.

Nwaneri, V. C. "Income Distribution and Project Selection," Finance and Development, International Monetary Fund and World Bank Group, Vol. 10, No. 3, September, 1973, pp. 27 ff.

Additional Readings

Gittinger, J. Price. Economic Analysis of Agricultural Projects. Baltimore: Johns Hopkins University Press, 1972.

Hirschman, Albert O. Development Projects Observed. Washington, D.C.: The Brookings Institution, 1967.

Packard, Philip C. Critical Path Analysis for Development Administration. Paris: The Hague, 1972.

Tinbergen, Jan. Central Planning, New Haven: Yale University Press, 1964.

United Nations Industrial Development Organization. Programming and Control of Implementation of Industrial Projects in Developing Countries. New York: United Nations, 1970.

Waterston, Albert. "An Operational Approach to Development Planning, International Development Review, September, 1969, pp. 6-12.

Planning Processes for Development Project Management

Planning for Implementation

Cognitive Learning Outcomes include:

1. expanding the concept of project planning beyond a priori appraisal of the project worth to include planning for and during implementation,

2. recognizing the artificiality of separating planning and implementation,

3. identifying organizational mechanisms and planning processes which may enhance the integration of planning and implementation,

4. examining the role changes required for project managers who participate in planning for implementation.

Planning for Implementation

Discussion Questions

If learners using these materials have experience in managing projects and knowledge of the indigenous planning process, these questions should be directed toward the specifics of their own country, sector of experience, and current projects. If not, the concepts of the paper could best be discussed in the context of a "case" situation. It is suggested that one or more guest "lecturers" who can describe the current project planning processes be invited to give brief presentations and to become involved in the discussion.

1. Give a comprehensive description of a planning process which integrates a priori analysis and planning with implementation.

2. List and note the major differences between the current planning processes and the description provided above.

3. What organizational changes would be necessary to eliminate some of the differences noted above?

4. How would the role of the typical project manager be changed if he were to become actively involved in integrating planning and implementation?

5. Can project managers be supplied to perform this new role? How is a project manager typically selected for important development sectors? How scarce is the supply? Are current project managers adequately trained in project management to guide comprehensive project planning processes? Is a special training program needed locally to develop this body of project managers? Where and how might such a program be established if it were necessary?

Planning for Implementation

Recommended Readings

In order to increase the learner's understanding of the relationship of project planning to the more highly aggregated planning of national, regional, or sectoral development, the following articles are recommended for their reading.

Haq, Mahbul ul. "Annual Planning in Pakistan," Journal of Development Planning, Number 2, 1970, pp. 81-113.

Il, Lee Hee. "Project Selection and Evaluation: Formulation of an Investment Program," Irma Adelman (Ed.), Practical Approaches to Development Planning (Baltimore: Johns Hopkins Press, 1969).

Millikan, Max F. "Comments on Methods of Reporting and Evaluating Progress under Plan Implementation," in United Nations, Planning and Plan Implementation (New York: United Nations, 1967).

Planning Processes for Development Project Management

Elaborating the Logic of Project Planning

The desired cognitive learning outcomes of this section of the paper include:

1. a conceptual development which promotes the readers' view of project planning as an integrated, continuous process. In this conceptualization, the reader should see the role of project management as coordinating all of the individuals and institutions who provide managerial and technical assistance by contributing to the project planning process.

2. knowledge of one prescribed sequence of steps for the development of a comprehensive plan for project implementation. This knowledge would include an elaboration of the project management role within each of these steps.

3. a conceptualization of the primary factors to be considered in the development of an individualized planning sequence which addresses the particular needs of the country, sector, and management style of the trainee. In other words, this conceptualization will help the reader plan the planning process before planning the project.

Planning Processes for Development Project Management

Elaborating the Logic of Project Planning

Discussion Questions

Learners should discuss the following questions and issues after reading this section. The discussion can best be directed toward their knowledge and experience in a given sector or project. If the learners have little experience with development project management, an invited speaker should describe the usual planning process for one or several development sectors.

1. Check off those steps of the planning sequence described in the paper if they are commonly accomplished comprehensively in the learners' situations and experience.

2. Add steps or elaborate the logic derived from the above exercise if it does not fully describe the typical planning process as experienced by the learners.

3. For each step, describe the involvement of various organizations and groups such as ministries (planning and other), special interest groups, multinational assistance organization, et cetera.

4. How might the process described in the above steps be improved (for example, would increased participation of various groups be desirable)?

5. What value might be derived by using such a set of planning steps as a checklist?

Elaborating the Logic of Project Planning

Recommended Readings

To increase the learner's knowledge of the project planning process and the varieties of plans that are generated in that process, the following articles are recommended for their reading.

Baumgartner, John Stanley. Project Management. (Homewood, Illinois: Richard D. Irwin, Inc., 1963), Chapter II.

Nwaneri, V. C. "Income Distribution and Project Selection," Finance and Development, International Monetary Fund and World Bank Group, Volume 10, Number 3, September, 1973, pp. 27ff.

Lebell, Don. "Entrepreneurial Planning for the Small-Scale Project, Interfaces, Volume 4, Number 2, February, 1974, pp. 53-59.

Additional Readings

de Vries, Egbert. Administration of Development Programmes and Projects: Some Major Issues. (New York: United Nations, 1971), pp. 15-17 and pp. 36-39.

United Nations. Manual on Economic Development Projects. (New York: United Nations, 1958), pp. 11-28.

Planning Processes for Development Project Management

Project Scheduling

This section of the paper is provided for the purpose of accomplishing the following cognitive learning outcomes for the trainee:

1. A conceptual development which assures that the trainee will consider both the costs and the benefits of project scheduling as this portion of the planning process is designed.

2. Knowledge of the variety of techniques and methods of scheduling and an appreciation of the need for careful selection and use.

3. General knowledge of techniques and methods most frequently used. This general knowledge emphasizes what each technique does (and does not do) and its advantages and disadvantages for assisting in the project management process.

4. Preliminary knowledge that is necessary to use the techniques (for example, what informational inputs are required). Additional knowledge is necessary for the actual use of the techniques is provided in the accompanying exercises.

Planning Processes for Development Project Management

Project Scheduling

Discussion Questions

The learners should discuss the following questions and issues in the context of a project with which he has intimate familiarity. If this is not possible, an outside resource such as a project manager of an existing project should be scheduled to describe his project and join the discussion. Another alternative is the use of an extensive case if such exists for the appropriate sector and culture.

1. For a given project, choose three possible scheduling techniques. For each level of project management, define the effort and detail that would be appropriate for the techniques. List the benefits (in terms of improved decision making) and the costs associated with the technique. Which seems to be the most appropriate?

2. How widely used are the various techniques in the experience of the participants?

3. What assistance (in terms of planning staff, computers and software, etc.) is available to managers who want to make greater use of formal planning techniques?

Planning Processes for Development Project Management

Project Scheduling

Recommended Readings

In order to increase the knowledge of the learner in the detailed use of network planning techniques, the following readings are recommended.

Packard, Philip C. Critical Path Analysis for Development Administration (Paris: The Hague, 1972).

Peart, Alan T. Design of Project Management Systems and Records (Boston: Cahners Books, 1971), Chapter 2.

United Nations Industrial Development Organization, Programming and Control of Implementation of Industrial Projects in Development Countries (New York: United Nations, 1970).

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Introduction to the Exercise Section

This section contains several exercises and cases. They are included here as material which can be used to simulate some of the planning process and related issues. It is expected that use of this material will assist the participants in the development of their project planning knowledge and skills.

Each of the exercises contain detailed instructions of the procedure for using them. The "Hollow Square" exercise can be an excellent simulation of the dynamics which can occur when planning is separated from implementation. "Preparing the Network" allows the participant the opportunity to apply networking to some activities with which he is very familiar. The "Communication of Plans" exercise can be used to illustrate the differences in the processes and results of interactive and non-interactive planning. The "Role Analysis Technique" is a tool that can be utilized during and after the training session to clarify role responsibilities on the project.

The case discussion exercises are preceded by a suggested procedure for their use which is applicable to all the cases. The major utility of each case is presented in the summary preceding the cases.

All of the exercises, including case discussions, are presented here as supplementary material for use by trainers in project management workshops and training sessions. It is the trainer's responsibility to decide which of the exercises are most appropriate for his workshop and particular learning objectives. Those exercises not used can be added to the backlog of training material which will be available for use in future training sessions. These exercises can be best used by assisting the participants work through them, continually helping the participants to relate what they discover and learn to their own experiences in project management.

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Introduction to the "Hollow Square" Exercise

The "Hollow Square" exercise is a very good tool for illustrating the dynamics that occur when 1) one group attempts to plan some activities for others to implement, and 2) a second group attempts to implement plans made by another. The task used in the exercise is relatively simple compared to developmental project tasks. The construction of the hollow square is a programmable, finite task with a clear point of termination. Yet the task is sufficiently novel and complex to stimulate a very good simulation of what happens when the planning and operating groups are separate groups.

The planning group many times assumes the existence of numerous constraints on their freedom to interact with the operating group. These assumptions greatly inhibit creative, effective responses to the problem. The plan resulting from the planning group's activities is generally not clear enough for the operating group to implement without interactive communication.

This exercise usually stimulates a great deal of interaction among the participants. The excited involvement of the participants in the exercise is very productive but it can detract from the value of the exercise without some facilitation on the part of the trainer. It is important that the group devote some time at the end of the exercise to a discussion of how the dynamics of this particular exercise occur in their work situations on the project. What is the significance of what they've learned here to their work?

The "Hollow Square" Experiment*

Goals

I. To become aware of the dynamics involved in planning for the accomplishment of a task which will be carried out by others.

II. To become aware of the dynamics involved in carrying out the planned instructions of others in accomplishing a task.

III. To become aware of the crucial role of communications when giving or receiving instructions for carrying out a task.

Group Size

No more than twenty-three members in a single experimental group. Two or more groups of up to twenty-three members each may be used if a competition situation is desired.

Time Required

Approximately one hour.

Materials Utilized

[I.] Observation Team Briefing Sheets and Observer Notes for each individual on an observing team.

II. Planning Team Briefing Sheets for each individual on a planning team.

III. Hollow Square Patterns for each individual on a planning team.

IV. Hollow Square Key for each individual on a planning team.

V. Envelope containing four of sixteen puzzle pieces for each individual on a planning team.

VI. Operating Team Briefing Sheets for each individual on an operating team.

VII. Pencils for all group members

VIII. Small table...for each experimental group.

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*J. W. Pfeiffer and J. E. Jones, Structured Experiences for Human Relations Training, Volume II, (Iowa City, Iowa: University Association Press, 1970), pp. 35-38.

Physical Setting

Room large enough to accommodate the experimental groups comfortably with access to other rooms where the planning and operating teams can be isolated. If two or more experimental groups are competing, choose the size of the room in proportion to the number of participants. Tables should be set up to become the center of activity; individuals should be able to move freely around them.

Process

I. The facilitator selects four people for the planning team and sends them out of the room to be isolated.

II. The facilitator selects four people for the operating team and sends them to another room. This room should be comfortable, since this team will have a waiting period.

III. The facilitator designates those members left (up to fifteen) as the observing team. He gives each individual a copy of the Observing Team Briefing Sheet and allows them time to read it. Each member of the observing team chooses one member of each of the other teams to observe.

IV. The facilitator explains to the observing team that they will gather around the table where the planning and operating teams will be working, and that their job will be to observe, take notes, and be ready to discuss the results of the experiment after the operating team has finished.

V. The facilitator then brings in the planning team, gathers them around the table, and distributes puzzle pieces envelopes, Planning Team Briefing Sheets, Hollow Square Patterns, and Keys to each individual on the team.

VI. Following this distribution of materials, the facilitator explains to the planning team that all the necessary instructions are on the Briefing Sheet....The facilitator answers all questions, if raised, with the phrase, "All you need to know is on the Briefing Sheet."

VII. The facilitator then cautions the observing team to remain silent and not to offer clues.

VIII. The experiment proceeds of its own accord, including summoning of the operating team without further instructions from the facilitator. If a competition situation has been established, the facilitator has the responsibility of timing the experimental groups from the moment Step Seven has been completed until the experimental groups have completed the assembly of the hollow squares.

IX. Following the completion of the experiment, the facilitator organizes a discussion around the points illustrated by the experiment. He calls on the observers for comments, raises questions himself, and gradually includes the planning and operating teams as they gain insight into their functioning.

An example of a discussion point lies in an evaluation of the Planning Team Briefing Sheet. The rules established are by exclusion, i.e., all other actions by the planning team are acceptable, such as drawing a detailed design on the Hollow Square Pattern, drawing a template on the table, or on another sheet of paper, numbering the pieces of the puzzle, etc. Has the planning team restricted its efficiency by setting up artificial constraints not prescribed by the formal rules? Have they called in the operating team early in the planning phase, an option which they are free to choose?

If there has been a competition between or among experimental groups, the elements involved which led to the winning team's efficiency may be discussed.

X. The facilitator may wish to summarize with all the important points raised during the discussion period.

HOLLOW SQUARE OBSERVING TEAM BRIEFING SHEET

You will be observing a situation in which a planning team decides how to solve a problem and gives instructions to an operating team for implementation. The problem consists of assembling seventeen pieces of cardboard into the form of a hollow square. The planning team is supplied with the general layout of the pieces. This team is not to assemble the parts itself but is to instruct the operating team on how to assemble the parts in a minimum amount of time. You will be silent observers throughout the process.

SUGGESTIONS:

1. Each member of the observing team should watch the general pattern of communication but give special attention to one member of the planning team (during the planning phase) and one member of the operating team (during the assembling period).

2. During the planning period watch for the following behaviors:

   a. Is there balanced participation among planning team members?

   b. What kinds of behavior block or facilitate the process?

   c. How does the planning team divide its time between planning and instructing? (How early does it invite the operating team to come in?)

3. During the instructing period watch for the following behaviors:

   a. Which member of the planning team gives the instructions? How was this decided?

   b. What strategy was employed in orienting the operating team to the task?

   c. What assumptions made by the planning team are not communicated to the operating team?

   d. How effective were the instructions?

   e. Did the operating team appear to feel free to ask questions of the planners?

4. During the assembly period, watch for the following behaviors:

   a. What evidence do the operating team illustrate that instructions were clearly understood or misunderstood?

   b. What non-verbal reactions did planning team members exhibit as they watched their plans being implemented or distorted?

OBSERVER'S NOTES

	This Helped	This Hindered
Phase I - Planning		
Phase II - Instructing		
Phase III - Assembly		

HOLLOW SQUARE PLANNING TEAM BRIEFING SHEET

Each of you will be given a packet containing four cardboard pieces which, when properly assembled with the other pieces held by members of your team, will make a hollow square design.

Your Task

During a period of 35 minutes you are to do the following:

1. Plan how the seventeen pieces distributed among you should be assembled to make the design.

2. Instruct your OPERATING TEAM on how to implement your plan (you may begin instructing your OPERATING TEAM at any time during the planning period--but no later than five minutes before they are to begin the assembling process).

General Rules

1. You must keep all pieces you have in front of you at all times.

2. You may not touch or trade pieces with other members of your team during the planning or instructing phase.

3. You may not show the KEY at any time.

4. You may not assemble the entire square at any time (this is to be left to your operating team).

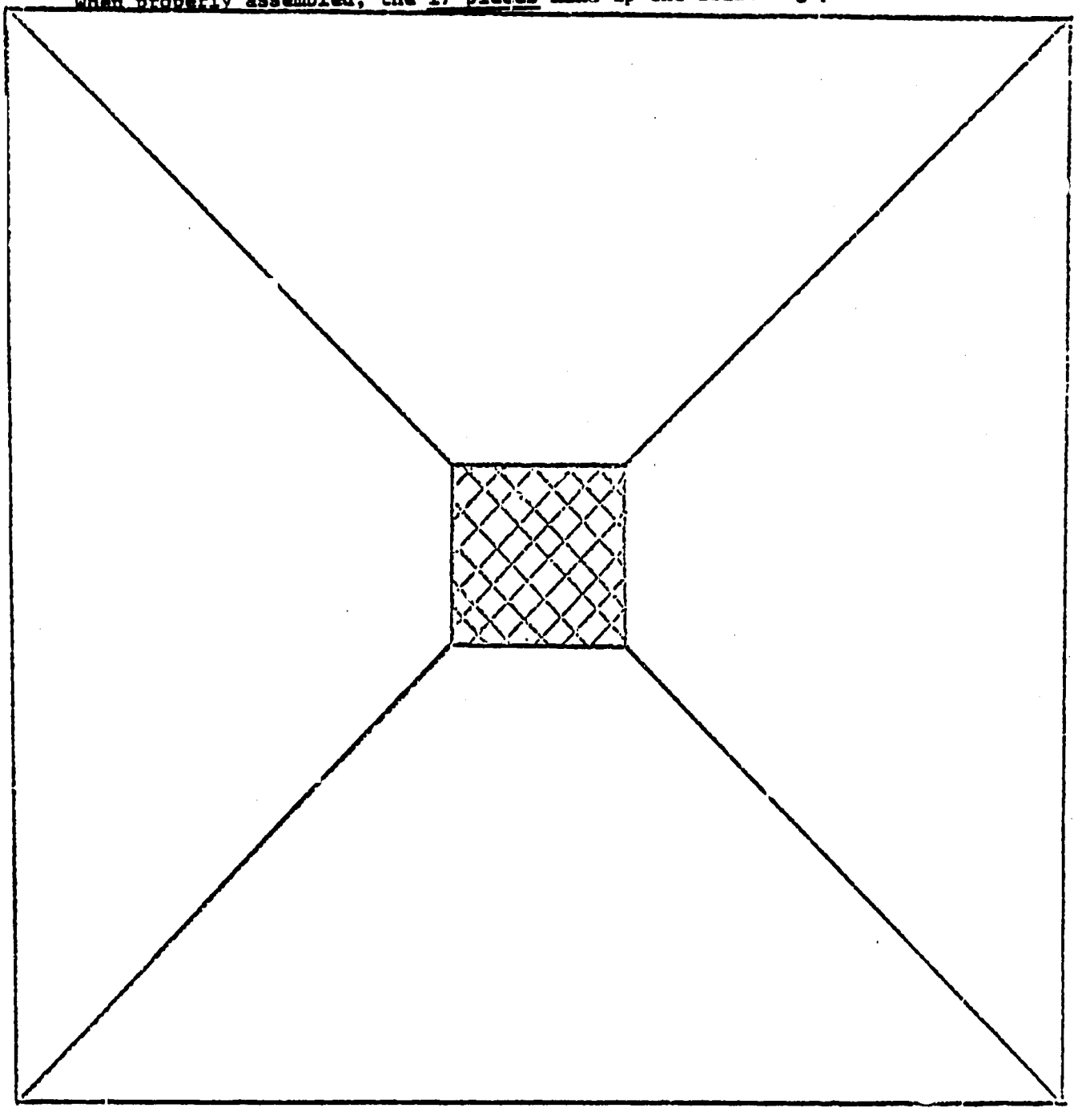
5. You are not to mark on any of the pieces.

6. Members of your operating team must also observe the above rules.

7. When time is called for your team to begin assembling the pieces, you may give no further instructions, but you are to observe the operation.

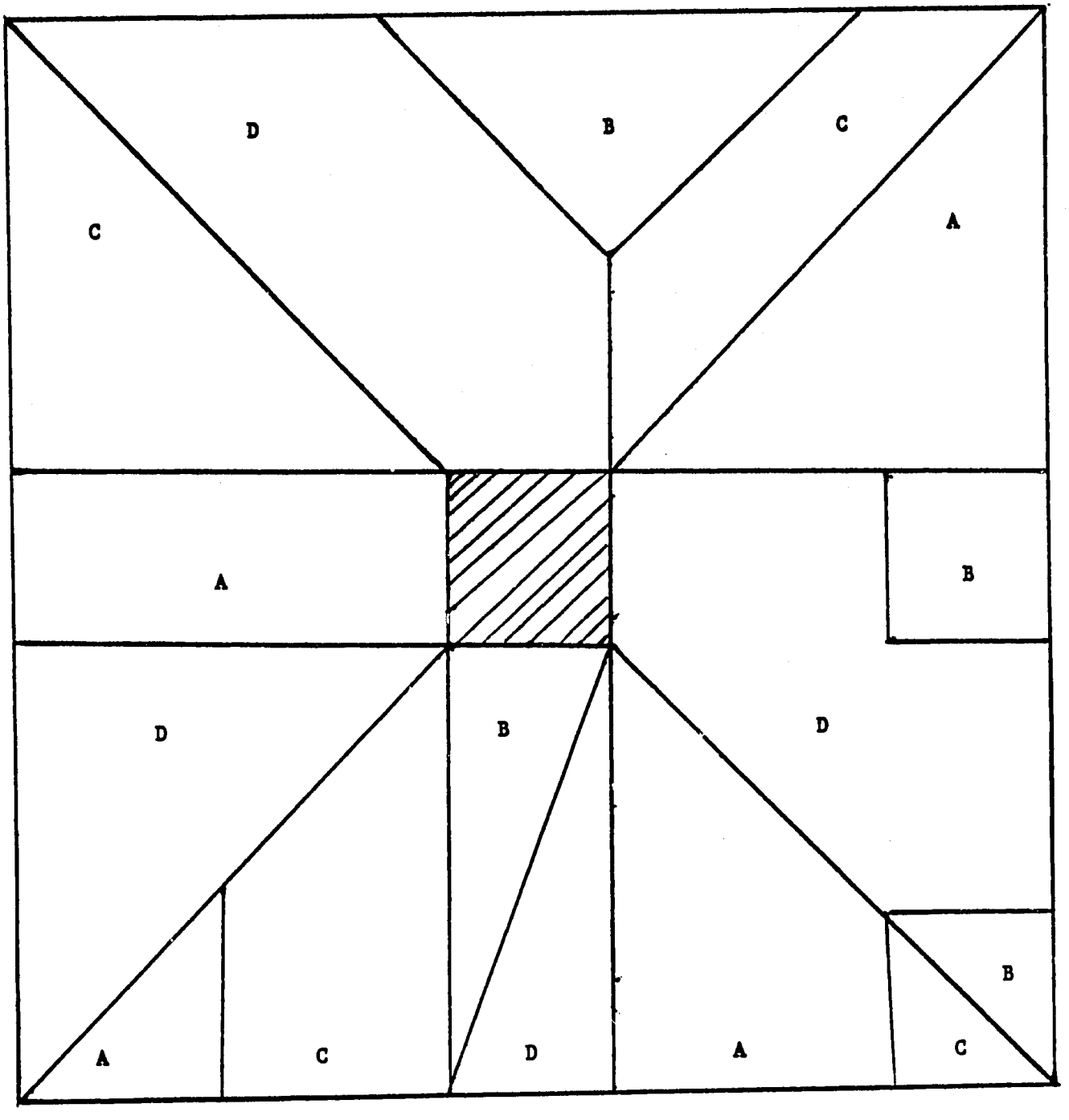
HOLLOW SQUARE PATTERN

When properly assembled, the 17 pieces make up the following pattern:



HOLLOW SQUARE KEY

(the 17 assembled pieces:)



HOLLOW SQUARE OPERATING TEAM BRIEFING SHEET

1. You will have responsibility for carrying out a task for four people according to instructions given by your planning team. Your planning team may call you in for instructions at any time. If they do not summon you, you are to report to them anyway. Your task is scheduled to begin exactly thirty minutes from now. After that, no further instructions will be permitted.

2. You are to finish the assigned task as rapidly as possible.

3. During the period when you are waiting for a call from your planning team, it is suggested that you discuss and make notes on the following

   a. What feelings and concerns do you experience while waiting for instructions for the unknown task?

   b. How can the four of you organize as a team?

4. The notes recorded on the above will be helpful during the discussion following the completion of the task.

Introduction to the Preparing a Network Exercise

Network construction is an important aspect of effective project planning and implementation. The following exercise is designed to provide individuals with the opportunity to increase their understanding of and skills for network construction. The exercise requires that participants develop a network of a series of activities with which they are familiar; those they engage in between getting up in the morning and leaving their home.

The general outline of the exercise can be modified where necessary and used for constructing networks of other activities. This flexibility makes this a very useful exercise.

Preparing a Network

Purposes

To provide participants with the opportunity to further develop their understanding of the network construction process.

To provide participants with the opportunity to develop their networking skills by constructing a network of a life activity with which they are already familiar.

To reinforce the lecture material through an experience-based learning exercise.

Group Size

Any size group will be appropriate for this is an individual level exercise.

Time Required

Approximately 45 minutes

Materials

Paper and pencils are required for each participating individual.

Physical Setting

A room sufficiently large for the group size is appropriate. A chair and writing space for each individual will be needed.

Process

I. The facilitator should explain the general purpose of the exercise and review the concept of a network if necessary. He should inform the individuals that they will work alone and construct a precedence network of activities that each person performs in the morning between rising and leaving for work. Start with the last activity, "leaving the door" and work backwards.

II. The first step is to list all of the major activities that take place between leaving the door and rising.

III. Once all seem to be finished, the facilitator instructs them to construct the network of these activities.

IV. Each person should add to the activities listed those of the other members of his household with whom he interacts.

V. These activities that are performed by others should be indicated with a double line bordering the activity box. The interactions should be noted.

VI. Times for the activities should be estimated. The critical path and slack should be calculated.

VII. Once all are finished, the participants may wish to have a discussion session on network construction. The facilitator should be available to answer all questions raised by the participants.

NOTE: It may be necessary for the facilitator to clarify each step in the process by giving an example.

Planning Exercise

by William M. O'Keefe
Vanderbilt University

Communication of Plans: Interactive and Non-interactive Modes*

The following communication exercise is included to provide participants the opportunity of experiencing non-interactive and interactive communication for a relatively simple problem. It is expected that through this experience they will develop a better understanding of the value of both of the communication modes. It is important they they relate this understanding to the process of planning in projects. Through discussion, it is hoped that the participants will also develop a better understanding of the role of communication in both declarative and procedural planning.

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*Adapted and significantly modified from "One-way and Two-Way Communication" in Structured Experiences for Human Relations Training by J. W. Pfeiffer and J. E. Jones, Iowa City, Iowa: University Associates Press, 1969.

Purpose:

I. To demonstrate the strengths and weaknesses of non-interactive and interactive communication.

II. To provide an experience upon which to base a discussion of non-interactive and interactive communication in procedural and declarative planning.

Group Size: eight or more participants

Time Required: as much time as the trainers think is useful (minimum of 45 minutes)

Materials:

I. Chalkboard, chalk, and eraser or newspring and marking pen.

II. Two sheets of paper and a pen or pencil for each participant.

III. Copies of Charts 1 and 2.

IV. Two or more copies each of Observer's Handout, Chart 1 and Observer's Handout, Chart 2.

V. Copies of Tables 1, 2, and 3.

Physical Setting: The participants should be seated so that they are facing the demonstrator of the chart. It is helpful if the participants are seated in such a way that it is difficult, if not impossible, for them to see each other's drawings.

Process:

I. The trainer may wish to start with a discussion of the differences between Procedural and Declarative Planning, which were presented in the paper on Planning. He should then discuss the issue that just as different forms of planning are appropriate for various project task situations, so are different methods of communicating plans. Non-interactive communication is one-way communication: the receiver of the plan has no opportunity to test his understanding by interacting with the sender. Interactive communication is two-way communication: the receiver of the plan has the opportunity to question or paraphrase the message to test his understanding with the sender.

II. Phase One: Non-interactive Communication

The trainer should indicate that the participants will experiment with the two different types of communication by participating in the following exercise.

1. The trainer selects one person to demonstrate one-way communication and one or two others to act as observers. Each of the participants is supplied with a pencil and two pieces of paper, one labeled Chart 1 and the second piece labeled Chart 2.

   During this phase, the demonstrator stands with his back to the group or stands behind a screen so that the participants cannot see his face.

2. The trainer tells the group that the demonstrator will give them directions to draw a series of squares. He instructs the participants to draw the squares exactly as they are told by the demonstrator on the paper labeled Chart 1. The participants are told that they may neither ask questions nor talk with each other.

   a. The trainer gives the demonstrator Chart 1, Non-Interactive Communication, and asks him to study the diagram of squares for a period of two minutes.

   b. The trainer gives the observers their Observers' Handout -- Chart 1 -- and asks them to take notes on the behavior and reactions of the demonstrator and the participants.

   c. The trainer places the three tables on the chalkboard or on newsprint in full view of the participants. (It is more efficient to prepare the tables before the exercise and have them ready for use.)

TABLE 1

MEDIANS	1	2
Time Elapsed		
Guess Accuracy		
Actual Accuracy		

TABLE 2

Number Correct	Guess	Actual
5		
4		
3		
2		
1		
0		

TABLE 3

Number Correct	Guess	Actual
5		
4		
3		
2		
1		
0		

d. The facilitator tells the demonstrator to start after the two minute period finishes. He reminds the demonstrator to tell the participants to draw the squares as quickly and as accurately as he can. The trainer should again remind the participants that they should not ask questions or make any noise.

e. The trainer keeps track of the time it takes the demonstrator to complete his instructions and records this time in Table 1, column 1 under Time Elapsed.

f. Then each participant is asked to estimate the number of squares he has drawn correctly in relation to the other squares. He then writes the number in the upper right hand corner of the page.

Phase Two: Interactive Communication

g. Repeat the experience but make the following changes: a second demonstrator is selected and he uses Chart 2. He stands facing the group. He seeks and responds to questions from the group. There is a great deal of interaction.

h. Once the demonstrator is finished, the trainer asks the participants to guess the number they have correct for Chart 2. In Table 2 he will fill in the GUESS column with the number of squares the people think they have correct from Chart 1. In Table 3, he will place the number of guesses about Chart 2. He will then add each of the sets of guesses and put the average guess in Table 1 just below the Time Elapsed for each exercise.

i. He then shows the participants the original copies of Chart 1 and Chart 2 and asks them to determine their actual accuracy. He totals up the scores for each Chart and gets the average number of correct scores for each participant. He then places the average results in Table 1.

III. The discussion of the results should be concerned with the following questions:

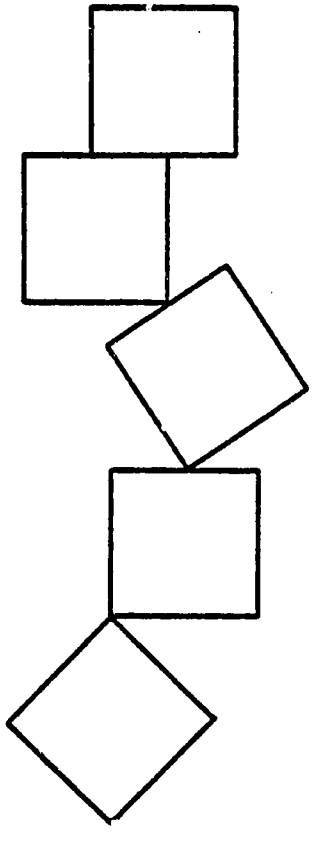
Which type of communication was fastest?
Which type was more accurate?
Which type was more difficult for the sender? For the receiver?
Which type of communication appeared to be more orderly and controlled?

It will be helpful to have the observers of both exercises share their observations with the participants.

IV. During the final phase of the discussion, the trainer should facilitate the process of the participants' relating this experience to their planning and communication experiences in their work.

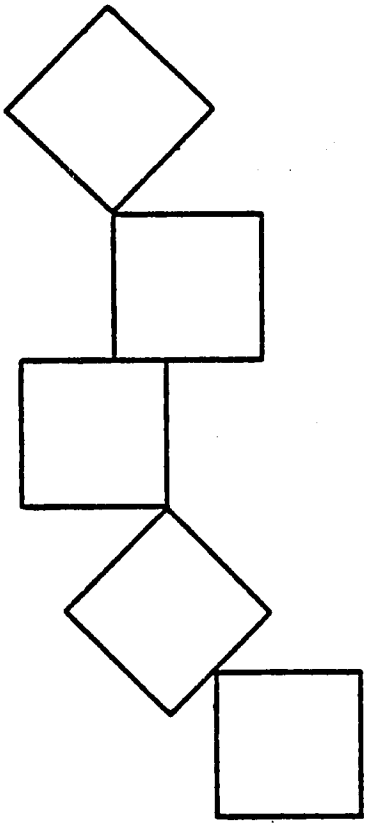
The trainer should emphasize the fact that interactive communication contributes considerably less to accuracy after a problem has become more programmable and routine. He should also emphasize the fact that interactive communication is even more important in Declarative Planning than in Procedural Planning because the task situations are less well defined and need more clarification.

Chart I. Non-Interactive Communication
(To be given to first demonstrator)



Directions: The person selected to present non-interactive communication should study the figure above. When finished, he should stand with his back to the group and instruct the participants how to draw these figures. He should begin with the top square, describe it and then describe the second one, and then the third, etc. It is important that the person describing the figures emphasize the relationship of the lower ones to the upper ones. No questions are allowed.

Chart 2. Interactive Communication
(To be given to second demonstrator)



Directions: The person selected to present Interactive Communication should study the figure above. When finished, he should stand facing the group and instruct the participants how to draw the figure. He should begin with the top square, describe it and then describe the second one, etc. It is important that the person describing the figures emphasize the relationship of the lower ones to the upper ones. Encourage people to ask questions. Answer all questions from participants and repeat information if it is necessary.

(To Be Handed To The Participants For Non-Interactive Communication)

Chart 1

_____Guess Correct

_____Actual Correct

(To Be Handed To The Participants For Interactive Communication)

Chart 2

_____ Guess Correct

_____ Actual Correct

Observer's Handout - Chart 1

1. Observe the demonstrator.
   Does he appear confident and sure of his presentation?

   Does he indicate through his behavior that he is making any mistakes?

   Does the demonstrator appear to be aware of any hostility?

2. Observe the participants.
   Do they appear confident about the content of the message they are receiving?

   How do they behave?

   Do they display any hostility toward the demonstrator? How do they do this?

3. Observe the general environment.
   What is the general noise level in the room?

   How fast is the exercise being conducted?

   Do you think the participants are receiving the message correctly?

4. What other observations do you have?

Observer's Handout - Chart 2

1. Observe the demonstrator.
   Does he appear confident and sure of his presentation?

   Does he indicate through his behavior that he is making any mistakes?

   Does he appear to be aware of any hostility from the participants?

   How does he respond when people ask him questions?

2. Observe the participants.
   Do they appear confident that they are receiving the message accurately?

   Do many ask questions?

   Do they appear more frustrated or less frustrated than before?

   Do they display any hostility toward the demonstrator?

3. Observe the general environment.
   Is it noisier now than before?

   Is the exercise going slower or faster than before?

   Does there appear to be any signs of frustration in the room?

4. What other observations do you have?

Introduction to Role Analysis Technique (R.A.T.) Exercise

Developmental projects can be characterized by a great deal of role ambiguity and conflict. Many times project personnel do not clearly understand their role or the set of behaviors and activities that are associated with a particular project position. Personnel are not clear as to what is expected of them in their role and others do not understand or they misinterpret an individual's perception of his role obligations. Role ambiguity is associated with the complexity of the task, the rapid rate of change in the project, and the required high degree of interdependence among the personnel.

Conflict can result from the interactions of project participants in part because of the stress coming from the requirement for innovative solutions to non-routine problems. Conflict also arises when one or more people are held responsible for the work of others. Some of this role ambiguity and conflict can be diminished if attention is paid to more clearly defining the roles of individuals at the early stages of the project. It is also helpful to define roles when new personnel join an on-going project.

The role analysis technique (R.A.T.) outlined in the accompanying exercise can be of great use when elaborating the project activities. It is important to define more clearly what kinds of performances are expected from the different individuals involved when elaborating project activities. Greater role clarity helps people understand and develop greater consensus for individual roles. This can reduce ambiguity and diminish the potential for conflict.

The purpose of the R.A.T. is to help individuals develop a better understanding of the purpose of various people's roles and how they contribute to the project. R.A.T. can also contribute to the development of interdependence in the project through better communication and a clearer understanding of mutual obligations and responsibilities.

The R.A.T. should not be used to describe exactly what an individual's authority and responsibility are in highly non-routine developmental projects. Too much detail at a premature point in the project can be disruptive to the task by increasing conflict and demotivating personnel. Role definitions are usually very general in the early design stages of a project but become more specific as the project develops.

The role definitions developed with the R.A.T. are temporary and need periodic updating and reformulation as the project task activities change. The purpose of role definition is to facilitate problem solving through a clearer understanding of and consensus for a particular role's obligations and expectations. It can assist in the identification of special conpetencies and can result in greater individual role flexibility by influencing individuals to define their roles in sufficient depth and breadth to meet the special demands of development projects.

Role Analysis Technique*

Purposes:

- To assist project personnel in developing a better understanding of the purposes of each individual position and how each contributes to the project.
- To contribute to the development of interdependence through better communication and a clearer understanding of mutual obligations and responsibilities.
- To minimize future misunderstanding and conflict through a clarification of roles.

Staff Size: One staff person for each group is desirable.

Group Size: Groups of up to eight or nine individuals can be utilized.

Time Required: Approximately one hour or more depending upon the interests and needs of the group.

Materials:

A pencil and some paper are needed for each person. There should be a sufficiently large amount of newsprint, masking tape and at least one marking pen for each group. In addition, there should be an easel or blank wall on which to hang the sheets of newsprint.

Setting:

A chair is needed for each participant. Tables may be used by each group. If the room is very large, two or more groups may share the same room as long as they do not interfere with each other while working.

Special Note:

Use of the R.A.T. can be dysfunctional if too much detail is sought prematurely. The trainer needs to assist the group in determining what an appropriate amount of detail is for the analysis of a role. For example, in experimental projects, the role definitions would be relatively general when compared to demonstration projects. This is because the tasks cannot be as well defined in an experimental project because there is less experience that is directly applicable to the experimental tasks than in the demonstration.

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*This exercise was developed by William O'Keefe of Vanderbilt University with partial support of the Brazilian Government. The exercise is reproduced here with the permission of the Government. The exercise is originally based on the work of Ishwar Dayal and J. M. Thoman, "Operation KPE: Developing a New Organization," Journal of Applied Behavioral Science, Volume 4, Number 4, 1968.

Process:

1. The facilitators ask each group to be seated in its work area. The groups must be comprised of people who normally work together in a project. It is very useful to have the leader of the group or of the project present in the group. Once the groups are seated, the facilitators distribute the materials to each group.

2. One of the trainers should explain the purpose of the Role Analysis Technique. Each group should then pick a person whose position in the project will be the focal role for purposes of the exercise. It is best to start with an individual in a leadership position.

3. The group is asked to think a few minutes in silence about the purpose of the focal role they've selected. How does this role relate to the objectives of the project? What activities are required of the person? What activities can he choose to do or not to do? What is the relationship of this role to other roles in the project?

4. The facilitator asks each group member to write the title of the focal role at the top of his paper, e.g. Project Leader, Design Engineer, etc. He requests that the group members write statements of their expectations of the focal role's performance. What do the members expect the focal role person to do on the project? The facilitator instructs the focal role person to write statements about what he perceives his obligations to be in his role. What does the individual perceive he is obliged to do in his role?

5. When all have finished writing, the facilitator instructs the group to select a secretary or recorder who will write down the statements read by each person from his individual list. The recorder will place two sheets of newsprint on the wall. On one he will write "Obligations" and on the other, "Expectations."

6. The focal role person will start the process by reading one statement of a perceived obligation. The recorder will write this on the large sheet marked "Obligation." Then the person sitting to the right of the focal role person will read a statement of an expectation he has for the focal role. The recorder will write this on the "Expectation" sheet. The next person will read a statement which in turn will be recorded on the "Expectations" sheet. When all have made one statement, the focal role person makes his second statement and it is recorded on the "Obligations" sheet. Each member makes his second expectations statement which is recorded on the "Expectations" sheet. The group continues in this manner until all the members' expectations statements are recorded on the "Expectations" sheet and all of the perceived obligations of the focal role person are recorded on the "Obligations" sheets.

   During this process there should be no discussion of the role. Individuals may ask clarifying questions such as "I don't understand what you mean; please explain." They may not disagree at this point or argue for some other viewpoint.

7. After all the statements have been recorded, the group reads them in silence. Once they have finished reading them, the facilitator encourages the members to discuss the obligations and expectations.

8. There should be a great deal of overlap between the expectations and obligations. After clarification of the points in common, the group should then discuss the important expectations that are different from the person's perceived obligations in the project. Discussion of these differences should be pursued until the focal role person and the group member reach some acceptable degree of agreement.

9. The exercise should end with the focal role person agreeing to write a role description that summarizes the information discussed by the group.

10. The group may wish to continue the exercise at a later point in time by selecting additional group members and developing their role analyses.

BIBLIOGRAPHY

Dayal, I. "Organization of Work," in H. Baumgartel, W. Bennis, and N. De (Eds.). Readings in Group Development for Managers and Trainers. Bombay: Asia Publishing House, 1967.

Dayal, I. and J. M. Thoman. "Operation KPE: Developing A New Organization," Journal of Applied Behavioral Science, Volume 4, Number 4, 1968.

Kahn, R. and R. Rosenthal. Organization Stress. New York: John Wiley and Sons, Inc., 1964.

Leavitt, Harold J. Managerial Psychology. Chicago: University of Chicago Press, 1958.

Pfeiffer, J. W. and J. E. Jones. "One-Way and Two-Way Communication," Structural Experiences for Human Relations Training, Iowa City, Iowa: University Associates Press, 1968.

Case Discussion Exercises

Outline of Case Discussion Procedure

The trainers are encouraged to utilize the cases for discussion of the issues on project planning. Below is an outline of a suggested procedure which the trainer may use, or modify, to fit his particular circumstances, when discussing the cases.

I. After selecting the appropriate case, distribute it sufficiently in advance of the time that the case will be discussed.

II. Review with the group the main reasons for utilizing the case. For example, "We will discuss the 'Preliminary Study of Tractor Demand' case because it illustrates the type of study which must be done in the early stages of the project to estimate the worth of the project."

To encourage good case preparation, do not assign more than one or two cases per session.

III. The issues covered in the case can later be referred to in appropriate lectures or other discussion sessions. Participants can be encouraged to present brief case discussions which relate to problems they've had in their project work.

If the trainer asks the participants to prepare for a case discussion, it is important that the group devote sufficient time to the case. If the participants prepare for a case discussion and do not have sufficient opportunity to discuss it, they may become demotivated. The lack of motivation will inhibit good case preparation for future discussions.

IV. The types of questions that may be asked by the trainer during a case discussion include the following:

What are the main points illustrated by this case?
How do they relate to project management planning?
What kinds of experiences have you had on projects that similar to those presented in the case?

The last question is particularly important. The material in the cases can be made more valuable to the participants and enhance their understanding of project planning if they have the opportunity to relate the case to their own experiences on projects.

Planning Processes for Development Project Management

Exercises: Case Discussions

Preliminary Study of Tractor Demand: this case illustrates the type of study which must be made at an early stage of project planning in order to determine how much the project will contribute to development goals (i.e., a preliminary estimate of the worth of the project.) In this case, a market study is made to estimate the size of the national market for tractors.

Choice of Technical Alternatives in the Chilean Electrification Programme: this case illustrates the types of dimensions upon which comparisons of technological alternatives are based. Each alternative not only employs different technical approaches but must also be appraised on the basis of the effect upon demand, ecology, capital requirements, operating costs, et cetera.

Influence of the Change of Fuel and of the Source of Raw Materials on Production Costs and Steel Quality in an Iron and Steel Mill: this case provides an excellent example of the kinds of changes that can occur between the formulation and implementation of a project. Each of these changes, if they have a major impact on the project output as it was originally conceived, can become projects in their own right. At a minimum, replanning of the original project is required to accomodate the changes as illustrated in this case.

Size and Location in a Project for a Beet-Sugar Mill: this case illustrates two factors (size or economies of scale and location) which frequently offer alternative project formulations. These two factors, particularly size, are often closely associated with technological alternatives, but even when independent of the technical methods present important considerations in defining the project output system.

Iran: Dez Multipurpose Project: this case illustrates a common occurrence in physical infrastructure development projects -- the multipurpose design which necessitates planning coordination between several ministries, agencies, and organizations. Many projects which are not justifiable on the basis of the primary purpose become inordinately worthwhile when slightly replanned to simultaneously accomplish ancillary purposes.

Preliminary Study of Tractor Demand-

This case (Case 6) was taken from the Manual on Economic Development Projects, United Nations Publication E/CN.12/426/Add.1/Rev.1/ TAA/LAT/12/Rev.1

Case 6

PRELIMINARY STUDY OF TRACTOR DEMAND

The case below corresponds to a study made for the Chilean Agricultural and Transport Development Plan (*Plan de Desarrollo Agrícola y de Transportes en Chile*). This time it was not made from the point of view of a project to install an assembly industry or for the integral manufacture of tractors in the country, but rather for the balance-of-payments projection used in formulating the Plan. The same figures will naturally serve as a first estimate on the order of magnitude of the national market for these capital goods, and it is being used in that sense. Details that might vary from one country to another are omitted, in order to stress simply the method followed.

1. *Basis of projection*

The basis used was the total number of tractors imported into the country between 1939 and 1953 inclusive, subtracting from this amount those which have finished their useful life (calculated at 10 years according to a previous survey) and those not used in agricultural work. Hence it was concluded that at the time of the study there were 10 400 tractors working in Chilean fields. It may be observed that in the absence of an agricultural census or of direct statistical information, an indirect estimate had to be made. As the import figures recorded statistically make no difference between agricultural and non-agricultural tractors, an additional estimate had to be made concerning the number of the former.

2. *Projection*

The projection was made according to the results shown in table 18.

Column B of the table indicates the number of tractors that completed their useful life each year, according to the import statistics for previous years. Column C refers to tractor demand derived from increases in the area under cultivation, in accordance with the objectives of the Agricultural Development Plan. Column D refers to demand derived from a higher degree of mechanization, that is, from the substitution of other forms of traction—differing from that achieved with tractors—and has also been estimated in terms of the Plan's objectives. Column E represents total annual demand.

Average annual demand for the different periods would be the following:

Periods	*Tractors per year*
1954-57	1 400
1958-61	2 337
1954-61	1 868

The corresponding average annual imports were:

Periods	*Tractors per year*
1946-53	1 276
1949-53	1 438

The figures in the last column of table 18 reflect the upward trend in the demand component represented by replacement. It can also be seen that the growth in the replacement percentage is not uniform, as shown by the demand points in columns B and E. This is due to irregularity in the historic series of tractor imports, undoubtedly affected by the war. That is why, in spite of an assumed future uniform growth of agricultural production, peak demands are recorded in some years of the projection period.

3. *Other data*

The market study for tractors cannot be confined to obtaining the figures indicated in table 18. Other data must also be known, such as those relating to trading and technical services, for instance. In the annex on agricultural mechanization, the Plan explains that in 1950 the *Corporación de Fomento* undertook a survey designed to discover various features of the market. Some of them are given below.

The average tractor in Chile is of 32.3 h.p. at the traction bar and replaces or is equivalent to 24 traction units.[19] These equivalences make it possible to estimate that the number of tractors needed for total mechanization of the country's cultivated area would be 26 000. Another calculation, carried out on the basis of farm sizes, reached a similar figure (almost 27 000). Approximately 1 tractor is used for every 100 hectares under cultivation, a ratio which can be used as an index of the degree of mechanization. On the basis of this index the additional demand for tractors can be calculated when an increased degree of mechanization is attempted.

Table 18

CASE 6. PROJECTION OF TOTAL DEMAND FOR TRACTORS

Year	Tractors in use (A)	Annual demand for tractors: For replacement (B)	Through increases in the cultivated area (C)	Through improved mechanization (D)	Annual total (E)	Percentage of replacements within total demand (100 B/E)
1954	10 400	199	820	156	1 175	17
1955	11 376	482	652	156	1 290	37
1956	12 184	761	701	156	1 618	47
1957	13 041	560	799	156	1 515	37
1958	13 996	1 703	809	156	2 668	64
1959	14 961	1 157	785	156	2 098	56
1960	15 902	775	796	156	1 727	45
1961	16 854	1 915	784	156	2 835	67
1962	17 794					

Source: Development Corporation (*Corporación de Fomento de la Producción*) Chilean Agricultural and Transport Development Plan, 1954.

19. The traction unit is a horse or its equivalent in oxen.

Choice of Technical Alternatives in The Chilean Electrification Programme To Meet Demand in The Third Geographical Region (1953 - 1964)

This case (Case 15) was taken from the Manual On Economic Delelopment Projects, United Nations Publication E/CN.12/426/Add.1/Rev.1/ TAA/LAT/12/Rev.1

Case 15

CHOICE OF TECHNICAL ALTERNATIVES IN THE CHILEAN ELECTRIFICATION PROGRAMME TO MEET DEMAND IN THE THIRD GEOGRAPHICAL REGION (1953-1964)

1. *Present deficit*

The forecasts of maximum demand for electrical energy in the third Chilean geographical region were explained earlier.[4] A summary is given here of the technical analysis which was made to choose the best alternative between the possible power stations in the region. An appendix is added to simplify the text for those readers who are not familiar with the technical aspects. The region is divided into two zones, north and south of the River Maipo, shown as A and B.

In 1953, when the programme was formulated, the peak hourly demand in winter in zone A was 311 000 kW, and 30 000 in zone B, giving a total of 341 000 for the region. The total installed capacity to meet this demand was 338 000 kW, of which the winter base load was estimated at only 289 000 kW, so that there was an initial deficit.

All the existing installed power stations in the region were listed, excluding only those not connected to the distribution grid. Of the latter, it is assumed that industrial stand-by stations would not operate if power were available from the grid. The power station of a mining enterprise operating in the region was omitted, since this mine's demand was also excluded from the consumption.

The list of plants included details of the type (hydroelectric or thermal), the date of installation and power (specifying the number of units and the installed capacity of each plant, total installed power and winter maximum base load, i.e., the maximum power available in winter during periods of maximum demand).

The installation dates show that many of these plants were old. During the project period (1953-1964) they would reach the age of 50 years. Others are uneconomic, and many should be taken out of service when the supply is adequate. For hydrological reasons, others cannot produce the total of installed power in winter (glacier system of rivers). To sum up, of an installed power of 338 000 kW, 289 000 kW of firm power will be available only if no plant goes out of service for major repairs, assuming that there will be a certain minimum flow simultaneously in the different rivers.[5]

2. *Comparison of availability and demand*

The total availability has been divided into the area supplied under a concession to a private company, and the remainder (zones A and B respectively).

Comparing available power with the demand in the zones, it may be seen that zone B has a surplus, while A has a considerable deficit. The magnitude of this deficit has not been felt to its full extent, since a plant in zone B delivers part of its output to zone A.

The base load available in zone A in 1952 came from the private enterprise (154 800 kW) and the interconnected plants of the system (estimated at 41 100 kW). The available total was therefore some 195 000 kW, to which may be added the surplus in zone B. In 1953, the following was the situation in zone A: the transfer of 63 000 surplus kW from zone B was added to the available 195 000 kW, giving a total availability of 260 000 kW against an anticipated demand of 311 000 kW. A deficit of 50 000 KW was therefore foreseen, which could only be reduced in part by the private industrial plants (totalling some 9 500 kW).

The deficit in installed power is only part of the problem; the deficit in energy must also be considered. The latter deficit is caused by periods of extreme drought, when the regulating reservoirs do not accumulate sufficient water to meet the daily peak load and the winter peak power and available energy, which depends upon the flow, are thus reduced.[6]

In zone B new plants are being constructed, which, in addition to ensuring the supply, will deliver their surplus to zone A as previously explained. Including these surpluses, the availability for zone A, consisting of the 195 000 kW produced by the private enterprise plus the inter-connected industrial plants and the surpluses from zone B, will be as shown in table 41.

[4] See case 3.

3. *Capacity to be installed*

The availability shown in table 41 includes all plants, existing and under construction, except the small plants belonging to industries which cannot be connected to the system. As from 1958, the availability will be definitely insufficient, and between 1956 and 1964 a minimum of 300 000 kW must be put into service.

4. *Basic criteria for choosing alternatives*

Three general types of alternatives were discussed to provide the necessary 300 000 kW, using the water and coal resources of the region: possible small and medium-sized hydroelectric plants, and thermal ones. The general criterion adopted for selection may be summarized as follows:

(*a*) Construct first a medium-sized hydroelectric plant, since the absolute increases in demand are less during the first stage, as may be seen from table 41;

(*b*) Towards the end of the period, when the annual increases in demand are greater, construct a large hydroelectric plant;

(*c*) During the intermediate years, construct thermal plants to meet the demand and add flexibility to the system.

[6] In plants without a reservoir, the power depends entirely on the volume of water flowing (see the technical appendix which follows this example).

[7] Explanations of technical terms are given in the technical appendices at the end of case 3 and of this case.

Table 41

CASE 15. DEMAND AND AVAILABILITY OF ELECTRIC ENERGY IN CHILE, ZONE A OF THE THIRD GEOGRAPHICAL REGION, 1951-64

(Thousands of kW)

Year	Peak hourly demand	Present availability including works under construction in zone B[a]
1951	268.9	263.6
1952	291.3	261.2
1953	310.8	268.8
1954	331.8	266.4
1955	354.1	356.2
1956	378.0	343.2
1957	403.6	339.9
1958	431.0	345.5
1959	460.3	378.8
1960	491.7	374.7
1961	525.3	370.2
1962	561.2	365.4
1963	599.8	360 2
1964	641.0	354.4

[a] The availability decreased because the surpluses of zone B, which are transferred to zone A, are declining. The word "present" refers to the date of the study.

5. *Discussion of alternatives for the medium-sized plant*

The discussion began with an analysis of the alternatives offered by two power stations (called here I and II), which together could have an installed capacity of 50 000 to 70 000 kW, the maximum base load in winter being some 35 000 kW. Although these plants were interesting, since they would be near the largest consumer centre, the idea was discarded since their construction was linked to the execution of certain water supply works, regarding which no firm decision had yet been reached. In addition, because of the length and situation of the conduit, the construction period would be too great. The analysis then examined possible alternatives III and IV (13 000 and 14 500 kW, respectively, of winter maximum base load). These plants were not considered capable of construction immediately because the base load and winter output were too small; the region already had a deficit and urgently required greater power.

Alternatives V and VI were examined later, but considered to be of little importance. Finally, alternatives VII and VIII were analysed; these were possible plants whose water was made available to a private enterprise under a concession. Alternative VII could be developed to up to 58 000 kW and VIII up to 22 000 kW; VII was preferred and it was included in the programme, because of its greater power, although its construction was more difficult. Its winter maximum base load would be 40 000 kW and it would enter into service in 1960.

It will be appreciated that size and urgency were the predominant factors in this case, but no choice would have been possible without previous studies which showed the general characteristics of the alternatives.

6. *Decision between large hydroelectric plants*

The following four alternatives of over 120 000 kW were examined for the large plant.[7]

A: Plant with 180 metres head, 130 000 kW.

B: Storage plant, 125 000 kW.

C: Storage plant (different river), 130 000 kW installed.

D: Storage plant (different river), minimum power 165 000 kW.

Alternative D (on the River Rapel) was adopted for the following reasons:

(*a*) Because of the present level of electrical development in the zone to be served, a plant was advisable which could supply both the winter output and the power required regardless of the hydrological conditions of the year for the run-of-the-river plants already existing or projected. This double flexibility could only be achieved with storage or thermal plants. In the case of Chile, taking into account the minimum number of kWh which this plant must supply, the storage alternative is preferable.[8]

In addition to the general preference for the storage

7. The capital letters refer to plants at particular sites.

8. The "case of Chile" implies abundant water resources in relation to demand; tight coal supplies; acute balance-of-payments difficulties. The fact that hydroelectric plants are preferable to thermal ones does not imply that the latter method should be discarded out of hand.

Table 42

CASE 15. POWER AVAILABLE IN CHILE, ZONE A OF THE THIRD GEOGRAPHICAL REGION[a]

(Thousands of kW)

Year	Peak winter demand in zone A	Available power: From the private enterprise and industrial plants	Available power: Surpluses from zone B and other works under construction or planned	Total	Deficit
1951	268.9	195.9	67.7	263.6	5.3
1952	291.3	195.9	65.3	261.2	30.1
1953	310.8	195.9	62.9	258.8	52.0
1954	331.8	195.9	60.5	256.4	75.4
1955	354.1	195.9	150.3	346.2	7.9
1956	378.0	195.9	147.3	343.3	34.8
1957	403.6	195.9	144.0	339.9	63.7
1958	431.0	195.9	149.6	345.5	85.5
1959	460.3	195.5	182.9	378.8	81.5
1960	491.7	195.9	218.8	414.7	77.0
1961	525.3	195.9	214.3	410.2	115.1
1962	561.2	195.9	264.5	460.4	100.8
1963	599.8	195.9	314.1	510.0	89.8
1964	641.0	195.9	363.5	559.4	81.6

[a] Including works under construction in 1952 and the two new hydroelectric plants contemplated for this region in the programme (1955-1964).

alternative, plant A, which is run-of-the river, was discarded for other reasons: it cannot produce more than 290 million kWh in winter (against 400 million with plant D); and it depends greatly upon the future operating conditions of a projected irrigation reservoir in its river, which cannot be sufficiently appreciated until it has been in operation for some years. This eliminates A for the period under consideration.

(*b*) Past studies of alternative C show that the construction of a dam on the bed of this river would be extremely costly and would limit the height of the reservoir. It would also have little advantage as a source of electricity supply, since the rises in the river are very irregular over a period of years, and the capacity of the reservoir would be insufficient to give complete control.

(*c*) Plant B would obtain its water from the damming of a lake for irrigation purposes, which is at present under way, and depends on the completion of that work.[9] The probable power of 125 000 kW is estimated from extrapolated hydrological statistics based on observations over relatively short periods. It is therefore not known precisely how much water will be available in the reservoir for generating electricity in winter. It was considered better to wait until some years after the completion of the reservoir, during which period hydrological observations would provide reliable data on which to base studies of alternative B.

(*d*) Plant B, although it has a reservoir, is a mountain plant. If this were to be built first, the supply to the main consumer centre in the capital of the country would depend on three mountain plants, all in the same area, which would supply more than half the power required and which would be linked to the consumer area by 320 km of transmission lines, including 100 km through mountainous country. This would be most unwise from the point of view of possible interruptions of the supply.

(*e*) Alternative D (the River Rapel) has the following advantages over the others:

9. A water administration agreement was reached.

Table 43

CASE 15. AVAILABLE WINTER BASIC LOAD IN CHILE, ZONE A OF THE THIRD GEOGRAPHICAL REGION, FOR THE PERIOD 1953-64

(Thousands of kW)

Year	Peak winter demand	Existing plant			New works under construction or planned						Type of plant				
		Cia. Chilena de Electricidad	ENDESA Sauzal Ciprises	Others*	3rd Unit Laguna Verde	Sausalito	Isla	Thermo-electric	Tinoco	Rapel	Thermal	Hydro-electric	Total	Deficit	Reserve
1951	268.9	154.8	67.7	41.1	—	—	—	—	—	—	82.9	180.7	263.6	5.3	—
1952	291.3	154.8	65.3	41.1	—	—	—	—	—	—	82.9	178.3	261.2	30.1	—
1953	310.8	154.8	62.9	41.1	—	—	—	—	—	—	82.9	175.9	258.8	52.0	—
1954	331.8	154.8	60.5	41.1	—	—	—	—	—	—	82.9	173.5	256.4	75.4	—
1955	354.1	154.8	150.3	41.1	—	—	—	—	—	—	82.9	263.3	346.2	7.9	—
1956	378.0	154.8	147.3	41.1	—	—	—	—	—	—	82.9	260.3	343.2	34.8	—
1957	403.6	154.8	144.0	41.1	40	—	—	—	—	—	122.9	257.0	379.9	23.7	—
1958	431.0	154.8	140.6	41.1	40	9	—	—	—	—	122.9	262.6	385.5	45.5	—
1959	460.3	154.8	136.9	41.1	40	9	37	40	—	—	162.9	295.9	458.8	1.5	—
1960	491.7	154.8	132.8	41.1	40	9	37	40	40	—	162.9	331.8	494.7	—	3.0
1961	525.3	154.8	128.3	41.1	40	9	37	80	40	—	202.9	327.3	530.2	—	4.9
1962	561.2	154.8	123.5	41.1	40	9	37	80	40	55	202.9	377.5	580.4	—	19.2
1963	599.8	154.8	118.1	41.1	40	9	37	80	40	110	202.9	427.1	630.0	—	30.2
1964	641.0	154.8	112.5	41.1	40	9	37	80	40	165	202.9	476.5	679.4	—	38.4

* The 4 000 kW which the Carena plant supplies to zone B have been deducted.

(i) The possibility of building a large reservoir, with a dam on solid foundations, which would be low in cost and ensure an ample supply of power.
(ii) Greater capacity. (It has been seen that the size of the anticipated deficit calls for large capacity).
(iii) The transmission lines to the two most important consumer centres would be only about 100 km long, and the power could be transmitted at 154 000 volts.

Alternative D would provide almost complete control of the river, but it has the disadvantage that 27 000 hectares of land would be flooded, of which 8 300 are of first quality. Economic studies were therefore undertaken to find the optimum solution. Until such time as these are completed, a minimum height of 86 metres has been estimated, which would mean flooding only 6 400 hectares, 2 300 of which have no agricultural value (river bed).

The plant would have 165 000 kW installed power and would be capable of generating 600 million kWh per year. It would be installed in three units of 55 000 kW each.

Allowing for power availability from works under construction and from the new hydroelectric plants selected on the basis of the criteria described above, the situation in zone A during the period 1953-1964 will be as shown in table 42.

It can be seen from table 42 that there will be a deficit of 52 000 kW in 1953, and 75 400 kW in 1954. This will fall in 1955 to 7 900 kW, when one of the plants under construction enters into operation. After that year, the deficits will be increasingly greater until, in 1962-1963, the second hydroelectric plant of the programme begins operation. This will reduce, but not eliminate the deficit. Table 42 shows the deficit to be 115 000 kW in 1961 and 81 600 in 1964. To meet this, it would be necessary to build new generating plants to a total capacity of 120 000 kW, so as to allow a minimum reserve percentage.

It was decided that the majority of the plants should be thermal for the following reasons:

(*a*) In an extensive system, such as that in the example, with much of the output being generated by run-of-the-river power stations, it is advisable to maintain an adequate percentage of thermal plants for security and elasticity of supply. In 1952, the available power in zone A was 260 000 kW, of which 32 per cent (81 000 kW) was from thermal plants. If only the present plants were maintained, in 1964 (the final year of the programme) the thermoelectric availability would be 14.5 per cent (the same 81 000 kW, out of a total anticipated supply of 557 000.) It is true that by that time there would be two plants with reservoirs and that it would not be necessary to maintain as high a percentage of thermal plants as in 1952. Nevertheless, the chief storage plant (Rapel) would not be completed until 1960, and until then the thermal plant would be necessary, since it would be inadvisable to reduce the percentage so rapidly.

If the 120 000 kW deficit in zone A is made up with thermal units, the proportion of about 30 per cent would be re-established. If only 80 000 thermal and 40 000 hydraulic units are added, the proportion of thermal plants would be 23.7 per cent.

(*b*) Another reason is urgency. None of the hydroelectric plants studied could be in service before 1957, and any other project would require an even longer period. Meanwhile, the deficit situation is such that the 120 000 kW still lacking must be brought into service very soon, in 1956 if possible. This can only be achieved with a thermoelectric plant.

(*c*) A further reason for the urgency is the complete absence of reserves in the system, which is aggravated by the fact that most of the plants have old machinery, many of them having been in use for nearly 50 years.

This leads to the conclusion that the installation of at least 80 000 kW of thermoelectric power is justified, and it is estimated that this could reasonably be divided between two plants of 40 000 kW each. The remaining 40 000 kW would be required in 1960, and some of the hydroelectric plants mentioned above could be considered for this purpose.[10]

Finally, the forecasts of the demand for power and energy and the dates of entry into operation of the plants have been presented in figures, accompanied by tables showing the demand for power and energy and yearly availabilities according to the timing of the programme.

The entire electrical development programme planned for the region during the period 1953-1964, expressed in terms of winter maximum base load, is presented in table 43.

The study also contains figures which show the development in terms of energy. Finally, there is a figure showing hourly winter peak loads, annual consumption and availabilities.

In order to improve the supply to the third geographical region of the country during the first years of the period, it is proposed to utilize a transmission line which will carry up to 50 000 kW from the fourth geographical region.

Technical Appendix on the Engineering of Power Stations

1. *General considerations*

Whatever method may be used to project demand, the first task in the approach to the technical problem of supply is to express demand in terms of the installed capacity required. The difference between required and existing demand will show what new generating capacity has to be installed.

Having decided the amount of power which must be supplied and the capacity to be installed, the next problem is to decide between possible alternatives for the provision of this capacity. For this purpose the characteristics of the system and of each power station have to be defined. This calls for a study of investment and production costs, and an economic evaluation of these alternatives from various angles.

Power stations can be grouped into two general types according to the natural resources they transform into electric power. One type is the hydroelectric power station, which uses the energy provided by the watercourses of the country or region; the second is the thermoelectric plant, which transforms the thermal energy of fuels into electricity.

Therefore, considering the electrical system as a whole, the basic question is whether to use thermal or water resources to generate electricity. Three factors will affect the decision:

10. Provisionally, and only for programming purposes, these 40,000kW were also considered to be of thermal origin.

(*a*) The natural sources of energy available;

(*b*) The alternative uses of these resources, including the possible export of fuels;

(*c*) The facilities, limitations and technical combinations possible in the use of these sources of energy to meet the demand in question.

When an over-all energy programme has been completed for a country, a large part of these problems will have been solved. It will then be known what electric production capacity is to be installed, and which part of it will be thermal and which hydraulic. The project-maker's task will be to study specific plants within these points of reference.

2. *Hydroelectric power stations*

(a) *Hydroelectric power*

The energy utilized in hydroelectric power stations is represented by a combination of two basic factors: the volume of water available (also called the flow or discharge), generally measured in cubic metres per second, and the difference in levels between which this flow can be utilized (head).

The flow depends basically on the hydrological conditions of the area being studied, while the head depends on technical and economic limitations. The geological and climatic factors, in addition to topographical and hydrographical conditions, complete the basic picture of hydroelectric potential from the point of view of natural conditions.

Hydroelectric power stations can generate only according to the availability of water, which usually varies in the course of the day, season, and year, in cycles which depend upon the general hydrographical conditions of the area, hence the concept of "hydrological security", i.e., the likelihood of obtaining a guaranteed flow of water over a certain period of time. The two main types of hydroelectric power station and run-of-the-river storage plants depend on the possibility of controlling this flow-by pondage.

The technical study of a hydroelectric plant covers essentially the following aspects:

(i) Research into the water resources and the possibility of using them according to local topographical, geological and meteorological conditions and the nature of the watercourse;

(ii) Decision on the type of plant to be built and planning of the civil engineering works;

(iii) Planning the electrical engineering at the production, transmission and final distribution stages.

The very nature of the water resources, depending as they do on hydrological cycles, necessitates observations over a long period of years.

These three aspects are closely inter-connected, and, in order to arrive at the final solution, all of them will have to be considered in the light of the general programme and of the economic and technical elements of the problem. The electrical engineering of a power station includes the aspects relating to anticipated demand. Civil engineering must deal with the problem of utilizing the energy of the river, according to its natural characteristics, that is, utilizing the potential energy of the flowing water. Joint planning of these two aspects of engineering therefore implies co-ordination of the characteristics of the availability of useable energy and the demand for electricity. This co-ordination is represented physically by the common shaft of the turbine, through which the flow of water passes, and the electric generator, from whose terminals the electricity flows to the consumer.

In conventional language, therefore, in a power station there are a "supply" of energy and a "demand" for electricity. The former is represented by the source of energy employed and the installations for its utilization and transformation; the latter is equivalent to consumption requirements. The supply varies in hydroelectric plants according to the hydrological characteristics of the watercourse. Since the demand is also variable, according to its own characteristics, special synchronization problems arise in hydroelectric plants which do not occur in thermoelectric ones, where the supply of energy, represented by fuel, only depends on its procurement.

(b) *Storage basins*

The presence or absence of storage basins in hydroelectric plants constitutes the basic difference between the two types into which they were divided above: run-of-the-river and storage.

Run-of-the-river plants are characteristic of the upper or middle reaches of rivers, where the water is used without any large-scale prior storage (up to one day's control), or at best, with only a balancing tank.

Storage plants consist essentially of a dam or retaining wall for the water, at the most appropriate place, (narrow gorge) which will allow the accumulation of water upstream. The amount of water accumulated will depend partly on topographical conditions and the height of the dam and partly on filtration and evaporation (geological and meteorological conditions); its capacity may also be affected by the accumulation of silt carried down by the waters. Storage allows better distribution of the water, and consequently better utilization for generating electricity.

The storage cycle is the period between two dates when it is completely full; the length of these cycles is very important in defining the capacity of the plant and other characteristics. It may be a few hours, a day, a year or several years, depending on the hydrological conditions and the rate of discharge of water, which again depends on variations of demand. The balancing tank—defined later—is in fact a storage basin with a one-day cycle, which is often built in run-of-the-river plants, but some such plants do not have even this limited pondage. In the latter case, the minimum load which the plant should be designed to carry is that of minimum flow; on the other hand, when there is pondage the minimum load may be greater than the minimum flow of the watercourse, because water can be stored.

(c) *Flow control*

The difference between power and energy from the point of view of demand may also be expressed in terms of hydrological availability.

If the flow is controlled—daily, seasonally, or in cycles of several years—the possibility of synchronization between available natural energy and the energy demand, on one hand, and the maximum power available and demanded, on the other, will be greater.

In the case of daily control (balancing tank) the water

may be accumulated during the day to meet the peak demand at certain hours; at the same time, less flow can be used during periods of low demand, so that the difference between the water available and demand can be stored during these hours. In the case of seasonal variation, the possibility of control and synchronization with demand increases, since water can be accumulated not only during the day but during the year from one season to another. Surplus water during periods of low demand can be retained for the months of peak demand.

This explains why, in cases where there is control, the average flow of a river does not represent the maximum power demand which might be expected. During variable periods, depending upon whether the control is daily, annual or longer, greater power can be generated than that represented by the average flow, since, as just seen, the larger volumes of water used are compensated by the surpluses produced during hours or months when the demand requires a flow less than the average.

The above explanations may be summed up thus: given a certain head, the total energy available is proportional to the average flow and the maximum available power, which is maximum flow. Control enables the natural energy available to be distributed in such a manner that during certain periods greater power is produced than that which the average flow would provide, and less power in the remaining periods. Studies of hydrological conditions and control possibilities will show what power is utilizable with a given average flow, and this in turn must be synchronized with the peak demand for electricity. The capacity to be installed will therefore depend on a study of available utilizable energy combined with a study of the demand to be met. Storage plants with high control possibilities are similar in this respect to thermoelectric plants, which can work at full power over periods as desired.

The foregoing is very important in the case of networks where there is inter-connexion of run-of-the-river plants and thermal plants, or high-capacity storage plants. For instance, the run-of-the-river plants may be allowed to take the basic load, that is, the part which is always foreseeable and therefore less than the maximum. Thus the run-of-the-river plants would always work at the highest power which the flow would permit, with high load factor; the storage plants take the rest of the load, with all its variations, since their surplus water is never lost but retained to supply peak demand.

There are many possible dam designs and their height will be largely affected by economic considerations. The greater the height, the greater will be the flooded area and also the storage capacity, i.e., the control possibilities and peak power demands which can be met.

When the flooded areas include farm lands, economic calculations become specially important. The productive possibilities deriving from a greater availability of electricity must then be compared with the drop in farm production.

(d) *Natural resources*

The natural resources required by a hydroelectric plant depend on hydrological, geological, topographical and meteorological conditions. These factors are decisive in determining the sites and possible size of a plant and the characteristics of the turbine.

Hydrology. Hydraulic energy is directly related to the hydrological cycle of the area, and this in turn depends on solar energy. The latter produces the evaporation of small quantities of water from the planet, which, passing to the atmosphere in the form of vapour, then falls to earth as rain, snow, hail or dew. Part of the water which falls drains from the high land towards the sea because of slopes. From the sea, the water evaporates again, completing the cycle. It is possible to make use of that part of the cycle where the water drains and where the other natural conditions allow it to be accumulated and used economically.

Hydrographic basins—that is, areas where water is attracted towards specific watercourses—may depend fundamentally on snow or rain, which will affect the river cycles and the various possibilities of utilizing them so far as hydrological security allows.

In addition to the physical limitations to the utilization of water flows, there are also economic limitations, since the hydrological cycle has a decisive effect on other uses in fields such as irrigation, hygiene, transport and industry. In many cases these limitations necessitate the study of multiple projects to cover the various possibilities of use simultaneously.

It is therefore absolutely indispensable that hydrological studies should be made. They consist basically in flow measurement at various points of the river and of the hydrographic basin in general. Information on rainfall or snowfall is equally necessary. These data, obtained over a period of years, are tabulated, systematized and plotted on graphs for analysis according to certain specially developed techniques. The essential information is the average available flow during a year or a number of years, in varying degrees of probability, since the available energy is directly proportional to the flow and the head. The degree of certainty of each of these flows is called hydrological security and it is a factor of considerable influence in determining the size of the plant.[18]

The following are the functions of the hydrological service:

(i) Installation of limnometers and limnographs, rain gauges and recorders, snow recorders, snow drift indicators, evaporimeters and recorders, gauging stations, weirs, etc.
(ii) Checking instruments and the gauging stations mentioned above.
(iii) Selection and training of observers or instrument readers.
(iv) Reception and systematization of readings.
(v) Preparation of statistics of average daily and monthly flows.
(vi) Preparation of seasonal rating graphs for flows and other data.
(vii) Study and application of different methods of interpolation and extrapolation of flow statistics.
(viii) Special studies.

Topography. The formation of the terrain is important in determining the most suitable point for installing the water take-off or reservoir. It will affect the planning of the reservoirs as regards the size and height of the dams. Transport possibilities must also be remembered in the study, especially during the construction period.

18. There are two basic concepts of hydrological security; monthly, which refers to the percentage probability of a specific flow during a given month; and that which refers to the probability of a given flow at any time of the year.

Geology. This affects several factors: base for foundations; permeability of the soil (filtration losses); possibility of using earth dams, suitability for tunneling, etc.

Meteorology. This naturally affects the hydrological cycle (precipitation, flow cycle, evaporation). It is also connected with the construction and operating problems of the power station, which must be considered in the work schedule.

(e) *Civil engineering in hydroelectric power stations*

The fundamental aspects of a hydroelectric plant so far as civil engineering is concerned are as follows:

Catchment area. As the name indicates, this covers the works required for the retention of the waters to be used, so as to convey them to the site of the plant.

Sand and gravel removal. These works are often necessary to avoid the possibility of sand or gravel entering and damaging the turbines. Their inclusion in the work programme depends on local circumstances.

Conduits. These convey the water from the catchment area to the point of drop. They may be canals, flumes, pressure tunnels, etc.; siphons or other civil engineering works are sometimes necessary, all of which must be specified in the project. A problem of technical alternatives with considerable economic implications arises in connexion with the study of conduits. The object is to convey water from some point of the river, by means of conduits—canals, tunnels, etc.—whose gradient is less than that of the natural river-bed, so that differences in height are obtained between the level of the conduits and that of the river into which the water will be discharged after use. It has already been explained that the available energy depends on both the flow and the head of the water. The study on conduits takes this latter factor into account, and the decisions are reached by comparing the cost of the alternative methods with the amount of energy gained or lost with the different heights obtained according to the various alternatives. Other natural conditions play an important part. For instance, in order to obtain a given height, a canal may be very long compared to a possible tunnel, but the cost per metre of tunnel may be much greater and may depend very largely on geological conditions.

Balancing tank. When it is desired to control daily the water passing through the turbines and to ensure the volume required for the daily peak load period, balancing tanks are built to provide pondage for possible variations in the flow and demand during the day. Their inclusion or omission will depend on hydrographical and topographical conditions and on the type of plant. They will be unnecessary in the case of storage plants.

Surge tank. This also stores water, but on a smaller scale, to regulate the intake into the delivery piping; it is always installed. At times surge columns, which perform the same function, are drilled in the rocks.

Delivery piping. These are the pipes through which the water falls into the turbines. They may be of steel, reinforced concrete or concrete, and they lead from the surge tank to the power house. The difference in level between the two ends of the delivery piping provides the head or power drop of the water.

Power house. This is the building where the actual generating equipment is installed, the most important being the turbo-generators (combinations of one turbine and one generator). The turbines are normally of one of three types: Pelton or impulse wheel, suitable for large heads; Francis or reaction wheel, for medium heads; and Kaplan or propeller wheel, for low heads.

The generators are coupled direct to the turbine shaft. Their specifications appear under electrical engineering, since they depend on the characteristics of demand. The turbine specifications are a civil engineering matter and depend essentially on local hydrological and natural conditions in general, which determine the possibilities of reservoirs, heads, etc.

Tail race. This is the discharge of water from the turbines after use.

Other works. The specific conditions of any plant may require further works, which will vary in each case.

(f) *Electrical engineering of projects*

A distinction should be made between the aspects mentioned below, which will normally be the same for both thermal and hydraulic plants.

I. Production, divided into:

Generating. This is the installation of the generator, whose characteristics will depend on demand.

Switchboards. Control and instrument panels.

Switchgear. Includes costly elements, since it must be capable of breaking on-load circuits carrying considerable energy.

Protection. Lightning conductors, etc.

Auxiliary services. Batteries, pumps, local lighting, etc., for the power station.

Transformers for raising the voltage generated to that which will be carried over the transmission lines.

II. Transmission, consisting of the following:

Pylons, to carry the cables.

Conductors and insulators.

Substations. Transformers, switchgear and controls.

Voltage regulation and power factor correction equipment (condensers, transformers, boosters, etc.).

III. Distribution:

Substations

Distribution grids.

3. *Thermoelectric plants*

In these plants, thermal energy is obtained from various fuels. Until recently there were two general types: those where the motive power was a steam engine (generally turbine) and those with an internal combustion engine (diesel or other).

Progress in the utilization of atomic energy now heralds another type using nuclear fuel. A technical revolution is in progress, the outcome of which cannot be predicted and whose characteristics cannot yet be described, even broadly, in this *Manual.* The following explanations refer only to the two conventional types of thermoelectric plants.

From the point of view of generating electric power for public service networks, steam power stations are the most important. Diesel plants are used only in special cases and generally supply specific services, such as isolated mines or small townships distant from the more important networks, where transport is a fundamental problem and where hydroelectric possibilities do not exist. Freight is also an important item in thermoelectric plants.

The technical elements of the study—the installation and operation of a thermoelectric plant—are usually less complicated than for a hydroelectric plant. On the other hand, the equipment of a thermal plant is more complex.

Individual consideration of a thermal plant does not require a careful study of the hydrological, geographical and topographical features mentioned earlier.[14] It may be installed more quickly, which is an advantage in urgent cases.

The total cost of investment, transmission and distribution per kW installed is usually lower for thermal than for hydraulic plants, although favourable local conditions may reverse this. The foreign exchange component of the investment per kW is often higher for thermoelectric plants since the equipment is more complex. This point will be dealt with in more detail when investment is discussed.

A fundamental economic and technical problem in this type of plant is efficiency in the use of fuels, which is measured in terms of calories per kilowatt-hour generated. The equivalent amount of coal per kWh varies in relation to this efficiency and the quality of the fuel.[15] The efficiency of each project must be estimated on the basis of sound background data; in general efficiency will be higher with better quality equipment, which means a higher level of investment. The fixed expenses of depreciation increase in direct proportion to the initial costs of the equipment and tend to reduce the advantages of higher efficiency. This also depends to a great degree on the relationship between the annual production of energy (kWh per year) and the total rated capacity, i.e., the plant factor.

From this aspect local conditions determine the optimum points, which should also be considered in the light of their effects on the balance of payments. Spares and maintenance costs will generally be in foreign currency, while those of fuel may be in either national or foreign currency depending on local conditions. This type of analysis will therefore affect the technical specification of the equipment.

4. *Interconnexions*

The economic and technical conditions which determine the availability of energy in each case raise the problem mentioned earlier of seeking optimum combinations in the utilization of fuel sources to meet a given demand. The most common solution to such problems often consists in integrating thermal and hydraulic plants in systems which may be predominantly either thermal or hydraulic. In other words, there will be optimum combinations as regards the utilization of either type and there will also be optimum utilization as regards the combined use of both types. Flexibility in the use and control of electric power and the possibilities of interconnecting plants open a wide field for technico-economic analysis.

The desired solution is one where the base load is carried by a high-efficiency plant, which operates with a high load factor, while the additional power to meet peak loads is supplied by other plants which operate only part of the time. In general, the newer or more efficient installations carry the base load, since they work continuously; less efficient plants, or those with high operating costs, are usually left to carry the peak loads. It may thus be advisable to project a run-of-the-river installation with a high load factor, even though maximum utilization of the flow is sacrificed, leaving the peak loads to be carried by low-efficiency thermal plants. Conversely, it may be preferable to plan the project so that new thermoelectric plants carry the base load, leaving the peaks to the hydroelectric plants if hydrological conditions and demand characteristics make this desirable.

It is therefore advisable to consider power station projects not as individual plants but rather in relation to the possibilities of interconnexion with an electrical production, transmission and distribution grid or network. Except in special isolated cases—such as some mines—the normal procedure will be to examine the electrical situation of a region or a country as a whole and to project individual plants in a way which will lead to the greatest efficiency in the operation of the system.

The advantages of interconnexion are clearly seen when considering the installation of new plants in an area where there are old, small and inefficient plants, which often occurs in under-developed countries. Similar plants may have been installed by industries in order to supply their power needs from their own resources during the early stages of industrialization, but it must be pointed out that a number of small plants is always less efficient than one plant with equivalent power. When large power stations are installed, the older plants can often be utilized by connecting them to the common grid and using them only to meet the peak loads. In this case, the new installations would carry the base demand.

It must also be remembered that it is often possible to make use of electric power generated by using the hot gases or steam produced by many industrial processes. Much of this power is used for the operation of the same industry, but there may be surpluses which could be utilized by connexion to the general network.

To sum up, the technical possibilities of interconnexion will require sector programmes to be drawn up to satisfy electrical demand, if maximum utilization of each plant is to be achieved.

Finally, the possibilities of interconnexion are not limited by national frontiers and may be international in scope. These possibilities have been borne out by experience in Europe but have not yet been tried out in Latin America.

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14. In cases of interconnexion, hydrological cycles will also affect a thermal project thermal project.

15. Technical improvements in the design of boilers and the utilization of steam for generating electricity have led to a considerable improvement in efficiency. In the United States, fuel consumption per kWh (in kg of coal equivalent) decreased from 0.626 in 1939 to 0.562 in 1949 and 0.453 in 1954. These figures show that, in the period 1949-1954, efficiency increased more than during the previous ten years. Larger units have also influenced efficiency, and so has the use of higher steam temperatures and pressures. These latter, however, appear to have reached a stage of decreasing efficiency. Finally, the quality of the fuel used will also affect efficiency.

Influence Of The Change Of Fuel And Of The Source Of Raw Materials On Production Costs And Steel Quality In An Iron And Steel Mill

This case (Case 21) was taken from the Manual On Economic Development Projects, United Nations Publication E/CN.12/426/Add.1/Rev.1
TAA/LAT/12/Rev.1

Case 21

Influence of the change of fuel and of the source of raw materials on production costs and steel quality in an iron and steel mill

This case is taken from studies for the expansion of an iron and steel mill and shows the possible effects of technical changes on the evaluation of a project. It deals in a general way with the expansion of the production of a mill from 300 000 to 560 000 tons yearly, bearing in mind a probable further expansion to 1 million tons. In addition to the actual plant expansion, the project also anticipates a change in the source of fuel and iron ore in order to improve output quality and decrease production costs. Each of these changes is a project in itself, which, although related to the other studies, may be approached and presented separately.

It is proposed to replace the domestic fuel at present used by natural gas, also domestic. There is a project to begin working a new mine, owned by the enterprise, which would supply ore to replace that from the present supplier. The examples given below refer to these two supplementary projects and show the influence that technical changes may have on a project.

1. *Change of fuel*

The conversion process in the steel plant was complicated by the high sulphur content of the fuel oil (average 4 per cent) to the point where it became necessary for a time to import fuel.

After many tests, it was found possible to begin the conversion process by using a low-calory light oil to melt the charge in the open hearth furnace and afterwards to use the higher-calory, high sulphur oil. In this way a steel of satisfactory quality could be made, although with a loss of output, which meant lower tonnage per hour from the open hearth, a lower proportion of ingots per charge and heavier wear on the refractories.

The use of low-sulphur fuel would increase the output from the same furnaces by 5 to 10 per cent of better quality steel, which in itself would be a considerable advantage. In the case presented to justify the project, however, no attempt was made to weigh this advantage, since the other factors were sufficient to prove its merits. The change of fuel, which could be achieved by means of a 248-mile gas pipeline between the natural gas wells and the plant, implied sufficient savings to justify the investment.

At the projected expanded output rate, blast furnace gas could be use to generate electric power, and 16.25 million cubic feet of natural gas would also be required daily. Fuel-oil at present costs the enterprise 30 (dollar) cents per million BTU at the plant, whereas natural gas would

cost only half of this. Hence, at an annual production rate of 560 000 tons of steel, savings would amount to 800 000 dollars. Available technical data show that gas reserves should meet the steel plant's needs for 20 years at least.

The gas pipe-line would be the property of the steel plant and would cost 3 560 000 dollars, of which 2 307 500 would be for the purchase of imported pipes, valves, etc., while the remainder would be the equivalent of expenses in local currency. Without pumps, the line could supply the 16 million cubic feet required daily for the projected production, including the transformation of 560 000 tons of steel ingots into finished products.

It would be possible later to instal two pumping stations, which would increase the line's capacity to 32 million cubic feet daily, sufficient to produce 1 million tons of steel per year.

In order to determine the natural gas requirements and the extent of the savings, the technical study presented a series of thermal balance sheets for varying annual steel production. Table 57 gives examples for outputs of 560 000 and 1 million tons of steel per year.

2. *Change of ore*

The increase in steel production could be obtained using the present ore, but the technical and economic advantages of opening a new deposit led to the inclusion of the project within the expansion programme.

The ore at present used has a high iron content and little sulphur, and can be obtained at reasonable prices. If, however, it is used to provide the entire ferrous charge of the furnace, the resulting pig iron contains approximately 1.15 per cent phosphorus. This is a medium quality product, with a phosphorus content too high for the satisfactory operation of an open hearth (Siemens Martin) and to low to use in a basic converter (Thomas). The enterprise has to use a maximum of 80 per cent of this ore, completing the charge with a phosphorus-free ore from small mines which does not guarantee a continuous supply.

The uncertainty of achieving a parallel increase in the output of the large number of small mines producing low-phosphorus ore constitutes an obstacle to the expansion plan. The new mines proposed in the project solve the problem satisfactorily since they enable pig iron of 0.23 per cent phosphorus to be obtained as compared with the 0.70 per cent phosphorus to be obtained as compared with the 80 per cent high-phosphorus and 20 per cent low-phosphorus mixture. The cost of the ore would be approximately the same as for that used at present, and the iron content would be the same, but without the drawbacks arising from the phosphorus.

The new pig-iron quality would save one hour in each open-hearth charge, and with six furnaces working this means an annual saving of 4 160 hours of open-hearth operation.

A most cautious estimate would give an average of 10 tons of steel ingot per hour of open-hearth operation.

The direct savings resulting from the use of the new ore are estimated as follows:

	Dollars
(a) Saving of one hour of heat per charge of steel (4 160 hours annually) at 28 dollars per hour	116 500
(b) During these 4 160 hours, an output increase of 10 tons per hour may be estimated, which gives an annual production increase of 41 600 tons; with 70 per cent efficiency, an additional 29 200 tons of steel would be obtained. The profit on this production would be the difference between the direct production costs and the net selling value, since all overhead would be covered by present production. If the difference is taken at 48 dollars per ton, this would give an annual saving of	1 400 000
Total	1 516 000

Apart from these benefits, the increased assurance of supply and the better quality of the product were taken into account.

The operation of the mine would require a railway to be constructed, which must be charged to the project. The total investment for the purchase of properties, equipping the mine and constructing the railway would be 8 113 200 dollars, of which 3 214 000 represents expenses in local currency.

Table 57

CASE 21. SUMMARY OF HEAT BALANCE

(Millions of BTU per day)

	Annual production capacity in thousands of tons	
	560	1 000
Heat required		
I. For direct production.	12 772	22 840
II. To generate electric energy.	9 [illegible]	16 250
III. To produce steam for blowing the blast furnace.	2 948	4 600
IV. To produce steam for other operations .	2 500	5 300
V. Total heat required.	27 220	49 490
VI. Total available from blast furnace gases	12 000	19 700
VII. Thermal requirements obtained from natural gas.	15 220	29 790
VIII. Equivalent in cubic feet of category VII gas (1 cubic foot = 936 BTU). . . .	16 250 000	31 900 000

Size And Location In A Project For A Beet-Sugar Mill

This case (Case 25) was taken from the
Manual On Economic Development Projects,
United Nations Publication
E/CN.12/426/Add.1/Rev.1
TAA/LAT/12/Rev.1

Case 25

SIZE AND LOCATION IN A PROJECT FOR A BEET-SUGAR MILL

1. *Approach*

This is a case of an industry which must be located close to its basic raw material, the sugar beet, which is not economically transportable over long distances.

The problem was approached by selecting a beet-growing area for the installation of the first plant. Agricultural research on the crop in various parts of the country, indicating possible beet-growing areas, was taken into account. The first task was to determine which of these areas was most suitable for the initial plant. At the same time, the question of size was considered, since the extent of the sugar beet crop in the district would also decide the capacity to be installed.[1]

To determine the size, maximum and minimum limits were established, based on European experience, which is that a daily capacity of 500 tons is small, whilst 2 000 tons is large. The maximum size is fixed by supply conditions; the industry works only during the harvest period (some 100 days each year).

The investment was not proportionate to the size. Equipment for a plant of 800 tons daily cost 2.7 million dollars, and for 1 600 tons, 3.5 millions. These data confirmed the need for installing the largest possible plant compatible with the supply conditions. It was concluded that a plant for 800 tons daily, designed with a view to doubling its output later, was the most suitable in view of expected supply conditions. It was hoped to reach the 800 tons output during the third year of operation. An industry producing less than 800 tons daily would cost very little less in equipment, and almost the same in installation costs; general production costs would be almost equal, so that the net return would be very much less. The 800-ton plant in normal operation—at full capacity—would give 10-per-cent net return, increasing to 18 per cent when the size was doubled.

2. *Selection of beet-growing area*

The selection of the beet-growing area was based on the following considerations:

(*a*) Sufficient flat, irrigated land to supply a plant twice the size of that projected, if the whole area were used for rotated crops. The selected area covers 28 000 irrigated hectares; the total irrigated surface in the province, that is, the selected area and adjoining land, is some 70 000 hectares, to which irrigation works at present in progress will add another 20 000. The province would therefore have a flat, irrigated area of 90 000 hectares. For an annual production of 80 000 tons of sugar-beet, with an average yield of 30 tons per hectare—an estimate based on 5 years' experiments—2 600 hectares of beet would have to be sown, which, with a rotation of 1 in 5, would require a total available area of 13 000 irrigated hectares.

If the size of the plant were doubled, 5 200 hectares of beet would be required, and 26 000 hectares of land. Since there are 70 000 hectares in the province suitable for the crop (a figure which would later rise to 90 000), it was seen that even with longer rotation periods, and some sectors not growing beet, there would be a sufficient safety margin to supply a plant twice the size of that projected. In other words, the selected size was compatible with the available natural resources within the factory's zone of influence, and the real problem was to introduce the crop on an industrial scale. This aspect formed an agricultural project, parallel with the industrial one.

(*b*) Mechanization would be no problem in these flat lands; in this respect, they had an advantage over more hilly territory.

(*c*) It was not expected to obtain the whole supply from any one district during the first years. It would therefore be necessary to bring the beet from more distant areas, even though freight costs would thus be higher; for this reason, the factory was to be sited so as to utilize more distant crops. These possibilities would be lost by locating the plant elsewhere, since the distance would be much greater.

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1. Demand in this case did not constitute a problem, since it was an import substitution industry, and its maximum capacity would not exceed 10 per cent of the existing market.

(*d*) The agricultural yield was greater in the selected district during the experimental stage.

(*e*) Beet-growing must always be close to livestock farms, and it is precisely this combination which gives a better agricultural production. In the selected area, dairy farming is well-developed. Three plants already engaged in dairy production output would form an immediate market for the expected increase in milk output.

(*f*) Agricultural studies in the area showed that it would be possible to obtain labour. The mechanization of wheat-growing, and other types of crop-farming included in the parallel agricultural project, would free a large proportion of workers, who would be available for the intensive cultivation of beet. Furthermore, the beet-growing operations which require a heavy labour input—thinning and harvest—are carried out at times of the year when the manpower needs of other farm sectors are lowest.

(*g*) There is no market problem. In the proposed location, the plant will be close to large purchasing centres; this will also reduce freight costs.

Table 60

CASE 25. COMPARISON OF LOCATIONS FOR A BEET-SUGAR MILL

	Location A	*Location B*
Fresh water	—	X
Residual water	X	—
Labour	—	X
Housing	—	X
Roads	—	X
Land	X	—
Electrical connexion	—	X
Administrative facilities	—	X
Railway situation	X	—

(*h*) Other important raw materials are coal, limestone and coke. The largest coal mines in the country are close to the proposed location; coke and limestone will be purchased from an iron and steel plant in the same area, which gives further advantages over other locations.

(*i*) Comparing transport conditions with other possible areas, the selected district is again the most favourable, since it is more compact, and has an acceptable road network which will not be expensive to maintain.

3. *Siting*

Having selected the beet-growing area, the precise site was discussed. The problem was finally reduced to two alternatives, linked to the only railway in the area. These two possibilities were first compared for the following points: fresh water, disposal of residual water, labour, housing, roads, land, electrical and rail connexions, and administrative facilities. None of these factors presented substantial differences, so no attempt was made to quantify them.

Once the various factors had been analysed, Table 60 showing the more favourable location for each was prepared. Since there was no great difference, it was assumed that they all carried the same weight, so new factors were added, which gave location B six advantages.

The freight problem was examined next, including all products brought into or sent out of the plant. Incoming freights gave the following figures, expressed in monetary units per ton of beet:

	Location A	*Location B*
Sugar beet	41.80	31.50
Other materials	22.44	23.40
Total	63.24	54.90

The difference in favour of B represents a reduction of 0.5 per cent in total production costs. Outgoing freights produced no appreciable difference between the two locations, although B again had a very slight advantage. Finally, the expansion factor was considered, and the areas where increased beet production was planned to supply the plant once more favoured location B.

CASE 10.

Iran:

Dez Multipurpose Project

(This case illustrates problems in choosing sources of energy)

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Early in 1960 the World Bank lent Iran US$42 million equivalent to help finance a multipurpose project—for power, flood control, and agricultural development—in southwestern Iran. The project as originally proposed raised a number of difficult problems and was considerably modified before the Bank made its loan.

In September, 1957, the Iranian government first asked the Bank to help finance a proposed multipurpose project based on the Dez River, which was intended to be the initial step in a long-range program for the development of the Khuzistan area in southwestern Iran. Although the extensive oil fields of the area and the refinery at Abadan then produced about 80 percent in value of Iran's exports, the area was very poor, and the standard of living and the level of education of its 150,000 inhabitants were generally very low. As proposed, the project had three main aims: (a) to provide electric power to the towns of Ahwaz, Abadan, Khorramshar, Dezful, and Andimeshk from a hydroelectric power plant which was to have two 65-MW units initially and from six to eight ultimately; (b) to irrigate the potentially productive land along the Karun and Dez Rivers; and (c) to regulate the flow of the Dez River in order to diminish periodic but serious flood damage, particularly between Ahwaz and the Persian Gulf. It was not, however, until a year later that enough data had been assembled on the project as a whole to permit it to be reviewed in the field by an appraisal mission. This mission concluded that, although the project was technically feasible in its broad outlines, it had some doubtful aspects.

First, the economic justification of the irrigation scheme was not clear. As proposed, it was to provide irrigation for 110,000 hectares with an investment in irrigation facilities estimated at more than $100 million, over and above its share of the costs of the dam. To be successful, the scheme would require drastic changes in customary methods of farming, landlord-peasant relationships, agricultural credit, and the organization of agriculture generally. In view of the size of the investment,

the problems presented, and the time likely to be required in making these changes, the Bank suggested that alternative investments might be considered. Even assuming that the necessary changes could be achieved within a reasonable time, the mission calculated that the agricultural aspects of the project would earn an average return of only about 3 percent over the period 1962–85.

Second, there was a question about the economic aspects of the proposed hydro plant, because there was an obvious alternative to a hydro project in the form of a thermal plant using natural gas, large amounts of which were being flared off unused at the nearby oil fields. The Bank, therefore, retained consultants to study the alternatives for supplying power to the area.

In the fall of 1959 the Iranian authorities came forward with a revised project. The major change was in the irrigation scheme which, in its revised form, was to be carried out in two stages: a pilot scheme, involving some 20,000 hectares, which would test the feasibility of large-scale irrigation and determine the sort of organizational and educational programs needed to carry it out, to be followed, if the pilot project were successful, by the full development. In appraising the revised project, the second appraisal mission was faced with many questions, but these pages present only the question of whether this project was the most suitable means, under the circumstances in Iran at the time, for meeting the demand for power in the four or five most important urban centers of Khuzistan. The total investment for the revised project, excluding interest during construction, was roughly estimated as shown in Table 10.1.

In 1960 the largest producer and consumer of electric power in the area was the consortium of oil companies operating the exploration, production, and refining

Table 10.1 1959 Estimate of Costs of Dez Multipurpose Project

(million US$)

	Pilot stage (up to 1966)			*Completion of full scheme (1967-74)*		
	Foreign currency	*Local currency*	*Total*	*Foreign currency*	*Local currency*	*Total*
Dam and others works common to all purposes	14.4	19.6	34.0	–	–	–
Power facilities of authority	21.2	9.4	30.6	7.9	1.2	9.1
Irrigation facilities:						
Public works	4.4	9.8	14.2	25.1	38.1	63.2
"On farm"	–	3.7	3.7	–	9.3	9.3
Total	40.0	42.5	82.5	33.0	48.6	81.6
Sugar Cane Company[a]	–	11.3	11.3	–	0.3	0.3
Distribution systems[b]	4.0	–	4.0	–	–	–

[a] The Sugar Cane Company project had been started as a project distinct from the pilot scheme, but it would draw water and receive farmer-grown cane from the full scheme.

[b] Contribution of the Plan Organization toward rehabilitation and expansion of the electric power distribution systems of the five principal towns.

facilities in southern Iran. It owned and operated an oil and gas-fired thermal plant of 110 MW, to be enlarged in 1961 to 140 MW. Under the terms of its agreement with the government, the gas to fire this plant was free. The government was planning to buy power from the consortium to supply Ahwaz until Dez power became available, and the mission recommended that the consortium and a Khuzistan Water and Power Authority (an agency to be created to operate the project) establish a standby agreement for interchange of power, so as to be able to pool reserves and thus reduce the total investment in generating facilities.

ECONOMIC ASPECTS: SOURCES OF ENERGY

In approaching the problem of whether the hydro project was the most suitable means of meeting the needs for power in Khuzistan, the second appraisal mission asked itself three questions. In answering them, it relied heavily on the report of the consultants engaged by the Bank to review this problem. First, it asked whether the principal objectives of this project might not be met more economically during the first few years. Perhaps irrigation needs could be met by pumping water from the Dez and Karun rivers and power needs could be satisfied with a thermal plant. Then building the Dez dam and powerhouse could be deferred until the demands for irrigation and power had become larger and their future development had been established with more certainty. Second, the mission asked a more limited question: how the cost of power from the proposed hydro scheme (after an appropriate allocation of common costs) would compare with the cost of power from a thermal alternative. Third, it asked whether the needs of the area for electricity might not be met more economically by a thermal scheme, even if a dam were to be built in any event for purposes of irrigation and flood control.

Before these questions could be answered, the power project had to be allocated its appropriate share of the cost of the dam. It is always difficult to attribute appropriate shares of the cost of a multipurpose project to the several purposes. In the case of Dez there was an additional problem because it was planned to operate the reservoir in the early stages of the project to meet the requirements of flood control and electric power in that order; but in later stages both flood control and irrigation, if the latter proved successful, were to have priority over electric power. In the light of the demand forecasts, this system of priorities meant that thermal power facilities would have to be installed after the installation of six hydroelectric units, to provide firm power in dry years or seasons.

The government's consultants had allocated to each purpose roughly one-third of the costs of the dam and other works common to the three purposes, on the basis of an analysis of the cost of alternative single-purpose facilities. The mission observed that other methods of allocation might have produced somewhat different results, but accepted this allocation as reasonable. It also pointed out that because the cost of the dam was a relatively small part of the total investment in the scheme, a somewhat different allocation would not have significantly changed the mission's conclusions.

The general concept of the alternative. The Bank's consultants had determined the capacity and layout of the thermal alternative in such a manner that it would, during 1963–83, supply the same peak demand and consumption as forecast for the proposed Dez scheme. They concluded that technically and economically the most advantageous way to meet this objective would be to build a thermal plant at Ahwaz, supplied by natural gas from the nearest oil fields northeast of Ahwaz, or, possibly, from a gas field recently discovered just outside Ahwaz.

The technical characteristics of the alternative thermal scheme were made as nearly equivalent to the proposed hydro scheme as possible. It was designed to meet the same loads in the same locations, with the same criteria regarding reserves. The consultants believed that with a thermal scheme, the towns of Dezful and Andimeshk could probably be served more economically for the first few years by local diesel plants instead of by a transmission line from the principal thermal plant, because their initial load was expected to be very small. Both possibilities were considered in the comparison of costs.

The number, size, and timing of the installation of the units of the alternative thermal plant at Ahwaz were determined so as to obtain, on the one hand, a maximum of standardization and efficiency, and on the other, a minimum of excess capacity (see Table 10.2). In determining the reserve necessary at the plant, the same assumptions were made as for the hydro scheme regarding interconnection, the standby agreement with the consortium, and necessary reserve in the interconnected system.

For a number of technical reasons, 60 MW was chosen as the maximum size of the units. Initial steam pressure and temperatures were taken to be 600 pounds per square inch and 800° F, resulting in a relatively high heat rate. More efficient and, consequently, more expensive units were not considered justified in view of the low fuel costs. A 132-kv single-circuit transmission line on steel towers was assumed to supply the area of Shushtar, Dezful and Andimeshk.

The fuel. The consultants concluded that fuel supplies were ample. They expected that the fuel for the thermal plant at Ahwaz would be natural gas from the oil fields which were already in production about 130 km to the east and northeast. Gas was being produced in these fields in connection with oil production at the rate of 833 cubic feet per barrel of oil. Some 260 million cubic feet per day of this gas were then being wasted from the fields of Naft Safid, Haft Kel and Agha Jari alone, enough to fuel a thermal plant of 1,100 MW. When the adjoining field of Gach Saran began producing in 1962, even more gas, which would otherwise be wasted, would become available. The consultants noted that only a fraction of the oil reserves of these fields had then been used, and the fields were expected to produce at least at the present rates for another twenty to thirty years or so. In addition, each of these oil fields had a huge gas cap above the oil deposit which would become available for use after depletion of the oil reserve. Finally, a well producing only gas but not oil had just been brought in on the outskirts of Ahwaz. This discovery suggested that there were separate gas fields in the area.

The consultants estimated that the needs of the thermal alternative scheme

Table 10.2 **Dez: Peak Loads, Sales, Installed Capacity and Estimated Costs of Thermal Alternative, 1959-84**

(million Rls)

	Total all years	*1960*	*1961*	*1962*	*1963*	*1964*	*1965*	*1966*	*1967*	*1968*	*1969*	*1970*	*1971*
Peak load in MW					49	52	56	90	96	103	110	118	126
Sales in million kwh					215	228	246	394	422	451	483	516	553
Required generating capacity in MW					52	55	59	95	101	109	116	125	133
Installed generating capacity in MW													
Number and size of units					1x60			1x60			1x60		
Total in MW					60	60	60	120	120	120	180	180	180
Excess capability in MW					8	5	1	25	19	11	64	55	47
Costs at year of operation[a]													
Generating plant[b]	3,357				602			551			551		–
Transmission plant[c]	210				173			–			–		17
Gas supply system	1,117				188			36			168		–
Total	4,684				963			587			719		17
Expenditures by year	4,684	132	333	498	94	237	256	94	237	388	–	–	17
Operating costs					46	46	46	51	51	51	61	61	61

	1972	*1973*	*1974*	*1975*	*1976*	*1977*	*1978*	*1979*	*1980*	*1981*	*1982*	*1983*	*1984*
Peak load in MW	135	145	155	165	177	189	203	217	232	248	266	284	304
Sales in million kwh	591	633	677	725	775	830	888	950	1,016	1,087	1,164	1,245	1,332
Required generating capacity in MW	143	153	164	174	187	199	214	229	245	262	281	300	321
Installed generating capacity in MW													
Number and size of units				1 x 60					1 x 60			1 x 60	
Total in MW	180	180	180	240	240	240	240	240	300	300	300	360	360
Excess capability in MW	37	27	16	66	53	41	26	11	55	38	19	60	39
Costs at year of operation[a]													
Generating plant[b]				551					551			551	
Transmission plant[c]				–					–			20	
Gas supply system				158					288			279	
Total				709					839			850	
Expenditures by year	94	237	378	–	–	94	237	508	94	237	519	–	–
Operating costs	61	61	61	75	75	75	75	75	93	93	93	111	111

[a] Exclusive interest during construction.
[b] Includes substation at plant.
[c] Includes transmission facilities as far as 11-kv side of substation.

would be only about 50 million cubic feet per day at full station load in 1973; this requirement would be only a fraction of the gas being wasted, without taking into account other gas reserves of the area and future increases in production. The mission pointed out that a thermal scheme would thus make use of a raw material which was otherwise being wasted; yet the reserves were such that the use of this amount of gas for the thermal scheme would still leave enormous quantities of gas available for industrial uses.

The consultants assumed that the gas supply system of the plant at Ahwaz would initially consist of about 130 kilometers of 12" pipeline taking the gas from the fields of Naft Safid and Haft Kel at the pressure of the separators. Later, the capacity of the line would be increased by compressor stations. In case the gas well near Ahwaz could be used, the supply system would consist only of the equipment of the well and a very short pipeline. The calculation was based on the assumption that the longer pipeline would be needed, because not enough was known about the new gas field near Ahwaz.

Estimated costs of construction and operation. In estimating the costs of the generating equipment, electric power and gas transmission lines and substations of the alternative thermal system, the consultants used the upper range of current European prices, which were then about 80 percent of the corresponding U.S. prices. The mission believed this to be a conservative approach because a number of European manufacturers were offering comparable equipment at 60 to 70 percent of U.S. prices.

The consultants based the costs of erection of the equipment on European wages for the supervisory personnel and for certain skilled labor. Local labor cost was assumed to be about 60 percent of the U.S. labor cost for similar work, a figure arrived at by taking into account the lower wage rates and lower productivity of Iranian labor as compared with those in the United States. This assumption was supported by the experience of the consortium.

To the estimates thus arrived at there was added 10 percent for contingencies, which was comparable to the allowance made in the estimates for the hydro system.

The mission pointed out that these estimates resulted in a total cost per KW installed which was very close to that of a new thermal power station at Karachi, recently financed by the Bank, and of similar plants recently built elsewhere. These estimates were, therefore, accepted as reasonable.

The consultants based the costs of operation, maintenance and administration on normal requirements for staff, labor and materials in plants of this kind, and on wages and material prices then paid by the consortium.

Determining the price of the gas posed special problems. The mission concluded that under all the circumstances the appropriate price at the wellhead, for the purpose of making the thermal comparison, was zero. Its reasoning was as follows. Under the oil agreement, any gas which the consortium did not need for its own operations belonged to the National Iranian Oil Company (NIOC). Because all gas was then being wasted in the enormous quantities described above, because

there was no alternative use in sight for many years, because NIOC would not incur any cost in supplying the gas to a consumer at the wellhead, and because the calculation of costs was being used for a comparison made from the viewpoint of the national economy, it was considered proper not to assume any cost for gas at the wellhead. The mission noted that this conclusion was valid whether or not the electric power authority in fact had to pay a charge to NIOC for the gas at the wellhead, because, as far as the economy was concerned, this cost would be offset by an equal net income to NIOC. The costs of building and operating a system of pipelines, pumps, and auxiliary equipment for collecting, cleaning, and transporting the gas to the plant were, however, included in the capital costs of the thermal scheme.

Comparison of the costs of the hydro and the thermal schemes. The mission concluded that the most suitable method for comparing the costs to the economy of the alternative hydro and thermal schemes would be to establish for each the "present worth" of the capital costs plus operating costs over a suitable period of time (see Table 10.3). The principal elements entering into this present worth calculation were as follows:

a) The forecast of the capital costs (excluding interest during construction) was carried to the point where the Dez powerhouse would have installed six units of 65 MW each. According to the forecast of peak loads and sales, this stage would be reached in 1984. After that date, no provision was made for adding capacity to either scheme, because thermal capacity would then have to be added to the Dez scheme in order to provide firm capacity, and any further capital investment in either scheme would, therefore, be comparable. These forecasts of capital costs included a third of the common costs in the case of the hydro scheme, and the cost of the gas supply system in the case of the thermal alternative.

b) The forecasts of the cost of operation included only the cash expenditures for operation, maintenance, and administration (labor, lubricants, spares and materials, maintenance, and the like), because the cost of gas for the thermal plant, other than the capital costs mentioned above, was assumed to be zero. After 1984, the operating costs were held constant in each scheme, because any additional operating costs for plant to be added after that date would be the same under either alternative.

c) The period of comparison was limited to thirty years, the useful life of the initial installation of the thermal scheme, because the present worth factor beyond thirty years becomes so small in any case, with the rate of interest of 8 percent used for these calculations (see *d* below), that extending the calculations beyond thirty years would make less of a difference in the final results than the likely margin of error in the initial assumptions.

d) The rate of interest chosen for the present worth calculations was 8 percent. This figure was believed to be within the range of a composite of the rate at which the government might be able to borrow a part of the funds for the

Table 10.3 Dez: Comparison of Hydro and Thermal Systems

(million Rls)

	Total all years	*1959 and prior*	*1960*	*1961*	*1962*	*1963*	*1964*	*1965*	*1966*	*1967*	*1968*	*1969*	*1970*	*1971*	*1972*
PRESENT WORTH FACTOR (8% basis from 1959)		1.00	.93	.86	.79	.73	.68	.63	.58	.54	.50	.46	.43	.40	.37
INVESTMENTS[a]															
Hydro system[b, c]															
Expenditures year by year	4,689	693	707	1,050	530	140			110	166	166				61
Present worth	3,286	693	658	903	419	102			64	90	83				23
Thermal system[c]															
Expenditures year by year	4,684		132	333	498	94	237	256	94	237	388			17	94
Present worth	2,144		123	286	393	69	161	161	55	128	194			7	35
OPERATING COSTS															
Hydro system															
Expenditures year by year	984					23	23	23	23	23	23	26	26	26	26
Present worth	247					17	16	14	13	12	11	12	11	10	10
Thermal system[d]															
Expenditures year by year	2,421					46	46	46	51	51	51	61	61	61	61
Present worth	600					34	31	29	30	28	25	28	26	24	23

PRESENT VALUE OF OUTLAYS	HYDRO	THERMAL
Investment	3,286	2,144
Operation	247	600
Total	3,533	2,744

	1973	*1974*	*1975*	*1976*	*1977*	*1978*	*1979*	*1980*	*1981*	*1982*	*1983*	*1984*	*1985 . . . . . 1993*
PRESENT WORTH FACTOR (8% basis from 1959)	.34	.31	.29	.27	.25	.23	.21	.20	.18	.17	.16	.15	.14 07
INVESTMENTS[a]													
Hydro system[b, c]													
Expenditures year by year	91	91			176	264	264		45	67	68		
Present worth	31	28			44	63	55		8	11	11		
Thermal system[c]													
Expenditures year by year	237	378			94	237	508	94	237	519			
Present worth	81	117			23	54	107	19	43	88			
OPERATING COSTS													
Hydro system													
Expenditures year by year	26	26	30	30	30	30	30	35	35	35	35	40	. . . 40 per year . . .
Present worth	9	8	9	8	7	7	6	7	6	6	6	6	Total 1985/93 = 36
Thermal system[d]													
Expenditures year by year	61	61	75	75	75	75	75	93	93	93	111	111	. . . 111 per year . . .
Present worth	21	19	22	20	19	17	16	19	17	16	18	17	Total 1985/93 = 101

[a] Exclusive of interest during construction.
[b] Includes allocation of one-third cost of high dam.
[c] Includes transmission facilities as far as 11 kv side of substations.
[d] Assuming no cost at wellhead for gas transmitted to Ahwaz.

project and of the rate of interest which the government's own contribution could earn in an alternative investment.

From the projections made on the basis of these assumptions (see Tables 10.2 and 10.3) the mission drew the following principal conclusions about the thermal alternative and answered the three general questions it had raised about the economics of the hydro power aspects of the project:

a) During the first few years, the capital *plus* operating expenditures of the alternative thermal power scheme would be very much lower than those of the hydro scheme. Together with an alternative pumping irrigation scheme, it would thus serve the power and irrigation needs of the area during the initial six to ten years or so as well as the proposed high dam, but at a considerably lower total expense. The mission pointed out, however, that before deciding whether it would be more economical, as matters then stood, to proceed with this alternative thermal power and pumping irrigation scheme, account had to be taken of the investment of roughly $15 million already made in the dam and generating equipment.
b) The present worth of the capital expenditures *plus* operating expenditures of the alternative thermal scheme would, over the entire thirty-year period, be some 22 percent lower than those of the hydro scheme (with the latter including a third of the cost of the dam and other works common to all purposes). The thermal scheme would compare even more favorably with respect to the present worth of revenues over the same period of time. The mission pointed out, however, that the figures for the differences gave at best an order of magnitude; variations in the demand forecasts and cost estimates, within the margin of error inherent in them, and changes in the method of comparison and the rate of interest used for calculating present worth, could change the results of the comparison quite considerably in favor of either alternative. For example, if the cost estimates for the hydro scheme included a part of the diversion dam, and the estimate for the thermal alternative excluded the costs of the transmission line to Andimeshk and Dezful (assuming these towns to be initially supplied by local diesel plants) and the gas pipeline (assuming that the gas field near Ahwaz would be suitable), the difference in total cost between the hydro and thermal schemes would be substantially larger.
c) The third question, whether it would not be more economical to provide power by a thermal plant even if a dam were built for irrigation and flood control, was more difficult to answer. In addition to the calculations discussed above, the mission concluded that it would be necessary to estimate also the changes in the total cost of the civil works arising from a reduction in the height of the dam, the elimination of the diversion dam, the introduction of alternative tunnels and canals, and the like. Nevertheless it believed that, at least in order of magnitude, there would not be a large difference between the present worth of capital plus operating expenditures of the two solutions.

In spite of the doubts raised by these comparisons as to the economic justification of the project for power generation, the Bank decided in 1960 to make a loan of about $42 million out of a total cost estimated at $82.5 million for the first phase of the scheme. This phase was limited, as far as irrigation was concerned, to a pilot project only. A number of factors were responsible for the decision to lend for the project including the hydro power plant. These included a recognition that changes in the assumptions made in calculating the comparison of the hydro and thermal alternatives would have altered the results significantly and that, if a dam were to be built for irrigation and flood control in any case, there was not much to choose between the hydro and thermal alternatives (see *c* above). But probably most important was the fact that the Bank's freedom of choice had been considerably reduced by the investment already made by Iran of the equivalent of about $15 million in the dam and generating equipment.