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This is the first of two volumes of the TRANSIM V Manual.

Contents contain a discussion of the main features and the reasons for the use of the TRANSIM V computer simulation program package.

Volume II is "The TRANSIM V User's Manual."

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August 1978

The TRANSIM V Manual
Volume I
Introduction to TRANSIM V

Alfred M. Feiler

UCLA • SCHOOL OF ENGINEERING AND APPLIED SCIENCE

ENG-7848

THE TRANSIM V MANUAL.

Volume I

Introduction to TRANSIM V.

Prepared for

The Department of the Navy

Under Contract N00014-76-C-0112

Project TRANSIM
School of Engineering and Applied Science
University of California, Los Angeles
August 1978

THE TRANSIM V MANUAL

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EXECUTIVE SUMMARY

This TRANSIM V Manual consists of two volumes: Volume I, Introduction to TRANSIM V, is a primer on the TRANSIM V technique and its use in Project Risk Management. Volume II, The User's Manual, describes the latest version of the TRANSIM general-purpose computer simulator, originally developed in 1966 by Project TRANSIM, School of Engineering and Applied Science, University of California, Los Angeles. TRANSIM V has evolved through a series of improvements in analytical power and efficiency and extensions toward new types of problem-solving applications.

The current TRANSIM V version (also referred to as PROMAP) is a project management tool which accounts for uncertainties in project planning, technology development, schedule, resource requirements and cost, and facilitates project control within acceptable risk levels. TRANSIM V is designed for ease of use by nontechnically-oriented personnel.

Project Uncertainty and Risk.

TRANSIM V accounts for project uncertainties and performance variability, in contrast with conventional project management techniques which are "deterministic" in that they utilize single value inputs for the purpose of analysis. The lack of accounting for uncertainties and variabilities on large, complex projects can often result in optimistic schedule and cost targets, and schedule slippage and cost growth may be inevitable from the project's start.

Where there is uncertainty--there's risk. TRANSIM V allows for project risk analysis by determining the level of risk related to the attainment of project targets such as:

- o Technological developments
- o Schedules
- o Resource utilization and expenditures
- o Costs

Project Model.

In order to use TRANSIM V, it is first necessary to develop a project "model" (critical path network), which identifies the individual project activities from project start to its completion. Project activities may be described at any level of detail at the option of the user. The model network defines the sequential order and interrelationships between the individual activities and may reflect uncertainties in the work plan associated with design changes, test and evaluation, etc.

Data Requirements.

Project risk analysis with TRANSIM V requires data describing activity sequencing and interdependency, duration, resource requirements, and costs. To account for uncertainty and variability, three estimates are provided: Optimistic, pessimistic, and most likely.

Output Analysis.

The project model is analyzed via a computer simulating a large number of project "realizations," each sampling from the ranges of values described by the input data. The results then indicate the range of possible results--between the earliest and latest or between minimum and maximum--together with the probability of attainment of target values and those in between.

Update, Monitor and Control.

The initial project model is repeatedly updated to reflect changing project circumstances and progress of project work. TRANSIM V utilizes several unique measures of performance and sensitivity to indicate trends and early identification of potential project problem areas, thereby reducing management "firefighting" or "management by crisis."

Organization of This Manual.

The TRANSIM V Manual has two purposes: (1) To introduce the subject of Project Risk Management with TRANSIM V, and (2) To serve as a reference guide for the TRANSIM V program operation requirements so that it may be used as a project management tool. This manual, presented in two volumes, is organized so that a particular reader can turn to a relevant section for the information he seeks without having to read through all of the preceding material.

Volume I, Introduction to TRANSIM V, introduces the TRANSIM V concept and the subject of Project Risk Management.

Volume II, The TRANSIM V User's Manual, is organized so that the user can go directly to this section for directions on how to use the TRANSIM Program. Data input requirements and directions for appropriate coding onto predesigned forms are discussed. Each type of report generated from the computer simulation program is described and a sample analysis is utilized to demonstrate its use in a simplified "how to do it" format.

THE TRANSIM V MANUAL

VOLUME I

INTRODUCTION TO TRANSIM V

VOLUME I

Introduction to TRANSIM V

What TRANSIM V Is.

TRANSIM V is a "second generation" project management system designed for use by Navy project managers for the purposes of project:

- Planning
- Scheduling
- Costing
- Resource analysis
- Management and control

TRANSIM V can help project management to:

- develop a realistic project plan which satisfactorily meets management's time and cost objectives
- make better use of men, money, materials and machines
- establish realistic schedules and budgets
- measure the impact of alternative decisions on overall project performance before firm policies are laid down
- highlight critical project activities and potential problems requiring special attention--early enough to allow preventive measures
- assess and control the level of project risks

What Is Unique About TRANSIM V?

TRANSIM V differs from most conventional, deterministic network analysis techniques (such as PERT and CPM) in that TRANSIM V can account for the impacts of uncertainty and performance variability upon project time and cost performance. Hence, TRANSIM V can be used for project

Presumably this is the major difference

risk analysis. Conventional project network analysis techniques cannot be used for risk analysis because the project plan must have 100 percent certainty and single value inputs are used to calculate the project schedule and cost. Otherwise, TRANSIM V network analysis employs network diagrams and input and output formats resembling the conventional techniques.

What Factors Contribute to Project Uncertainty and Variability?

Typical examples of the many factors which can contribute to project performance uncertainty and variability are:

- uncertainty regarding pertinent governmental actions
- uncertainty in rate of technological development
- uncertainty regarding the exact nature of the detailed work to be done
- errors and omissions in working drawings
- delays in obtaining management approvals
- changes in drawings, specifications, and instructions
- effects of weather on work processes
- normally variable performance rates on certain types of tasks
- uncertain delivery dates for government or owner-furnished equipment and information
- uncertain results of system test and checkout
- uncertain rate of cost escalation or interest
- mechanical breakdown or malfunction
- rejects, rework, and unavoidable delays associated with the quality of materials, products, and processes
- learning effects, personnel morale, and efficiency

Why Uncertainty and Variability Are Important.

Project uncertainty and variability of performance of individual project tasks can have a profound effect on schedule and budget. It has been conclusively demonstrated[1] that unless uncertainty and variability are accounted for, project schedules and budgets tend to be optimistic--the degree of optimism for individual projects varying from 10 to 50 percent or more. Using the deterministic methods of conventional network analysis techniques therefore may inadvertently incorporate project overruns into schedules and budgets from the very beginning of the project!

What Is Project Risk Management?

Where there's uncertainty--there's risk. Management has long known of the existence of risk on many projects but has not had the means of determining how much of a risk exists and how to control it. Under such circumstances, the element of risk can be the most critical factor in the making of a decision; each time the decision to proceed is made, project management is playing a "game of chance."

On major acquisition projects, the "stakes" are too high to rely on "playing a game of chance" without knowing what the odds are. This is what Project Risk Management attempts to do--to ascertain, for example, what the odds are for project completion time and cost-to-complete a large scale acquisition project.

The availability of TRANSIM V makes feasible the concept of Project Risk Management. The basic elements of Project Risk Management

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[1] See Klingel and Van Slyke articles.

are that management can:

- o determine the level of risk associated with its adopted project plans, schedules, and budgets
- o develop a project plan, schedule, and budget conforming to a level of risk acceptable to management
- o control the project from beginning to end in a manner to assure that the acceptable levels of schedule and budget risk are not exceeded.

The Key Features of TRANSIM V.

The Project Plan.

The foundation of the TRANSIM V approach is the project plan (activity network) which provides a diagrammed display of all project activities from beginning to end of the project or subproject. Activities are arranged in proper sequence of performance as an activity network depicting all the steps necessary to attain project objectives. The network shows the interrelationships and interdependencies between the activities. Figure 1 is an example project plan. The boxes represent activities; the arrows, the sequencing logic of the activities.

A key feature of TRANSIM V is its ability to account for uncertainty and performance variability in the planning of a project. For example, governmental approval may not be granted until the second or third submittal of an application; a set of design drawings may be returned for corrections or changes; a system may fail to pass testing and checkout procedures. Such factors can have a significant effect upon project time and cost performance.

If the project plan is to be realistic, such uncertainties must be accounted for. TRANSIM V has the unique capability of allowing representation of uncertainties in the project plan.

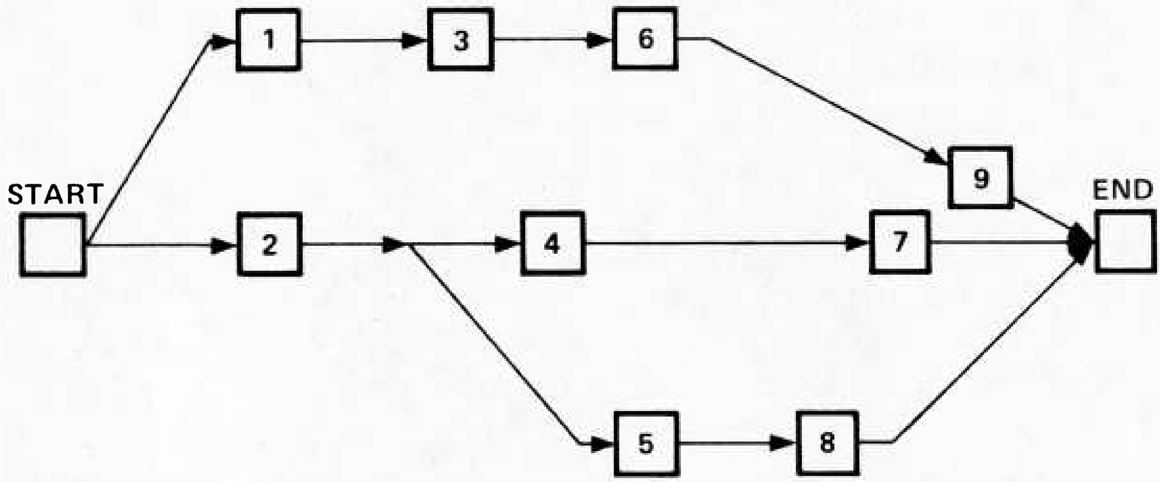

FIGURE 1. PROJECT PLAN (ACTIVITY NETWORK).

Figure 2 illustrates a project situation with plan uncertainty. Suppose Activity 6 is a test and checkout procedure for a complex system. Data based on past experience indicates a 90 percent probability that the system will pass its test (Activity 9) and a 10 percent probability that the test will fail and have to undergo further checkout, repair and test (Activity 10). This situation is depicted by showing the Activity 9 network branch as having a 90 percent probability and the Activity 10 branch with a 10 percent probability. In such a case, TRANSIM V will account for this uncertainty in its computer analysis of the network and the results will include the impact of the uncertainty on resource requirements and project schedule and cost performance.

Because of their inability to account for uncertainty, project planners using conventional, deterministic network analysis techniques tend to design networks in which the longest time (critical) path is "over-critical," that is, significantly longer than any other path. This is done to assure that one or more of the other paths which are "near-critical" do not become "critical." With normal variability of activity performance, "near-critical" paths may become "critical." When they do, schedule slippages will result.

In contrast, by utilizing TRANSIM V, overall project time can be materially reduced by "tightening" the network to equalize "criticality" among all activities--the opposite of a highly linearized plan in which the critical path is "over-critical." Reduced project time usually means less project cost. With TRANSIM V's constant monitoring of activity "criticality" (See the section on Activity "Criticality," pg. I-12), the project

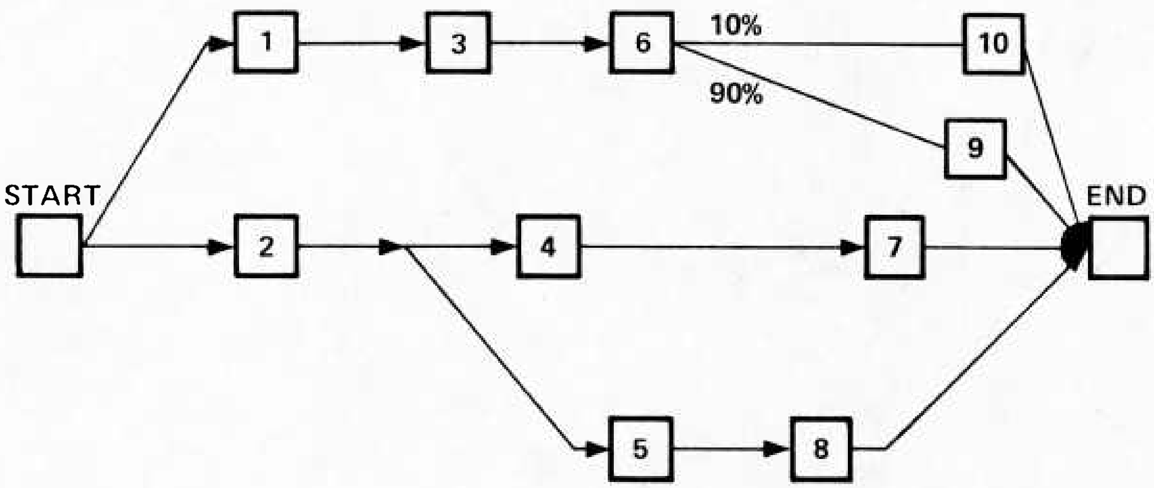

FIGURE 2. PROBABILISTIC BRANCH.

manager can maintain effective project control under the "tightest" network circumstances.

Input Time and Cost Estimates.

TRANSIM V uses the estimator's full range of experience for its input data. Whereas conventional, deterministic techniques are based on a single input time or cost value whether or not the activity has any uncertainty or variability, TRANSIM V can utilize a range of values from the smallest to the largest probable value (See Appendix B). This bracketing of activity durations and costs provides a far better objective and indepth estimate.

For activity durations and costs which are uncertain or have known variability, three or more estimates may be given to cover the range of possible durations between the extremes of "optimistic" and "pessimistic" values. If only three are given, the middle value should be the "most likely" value. TRANSIM V can accept single value inputs for those durations and costs which are fixed and known.

Figure 3 shows examples of estimated time durations in workdays --given in three values--for each activity of the example project model.

TRANSIM V Network Analysis.

With TRANSIM V, the project plan undergoes analysis by being "run" (simulated) in the computer as many as several hundred times. Each run represents a complete project realization from start to end. During each project realization, activity durations are sampled randomly from individual distributions of activity duration times based on input data. The result is a range of times covering the span between the shortest and longest simulated project completion times with accompanying activity schedules.

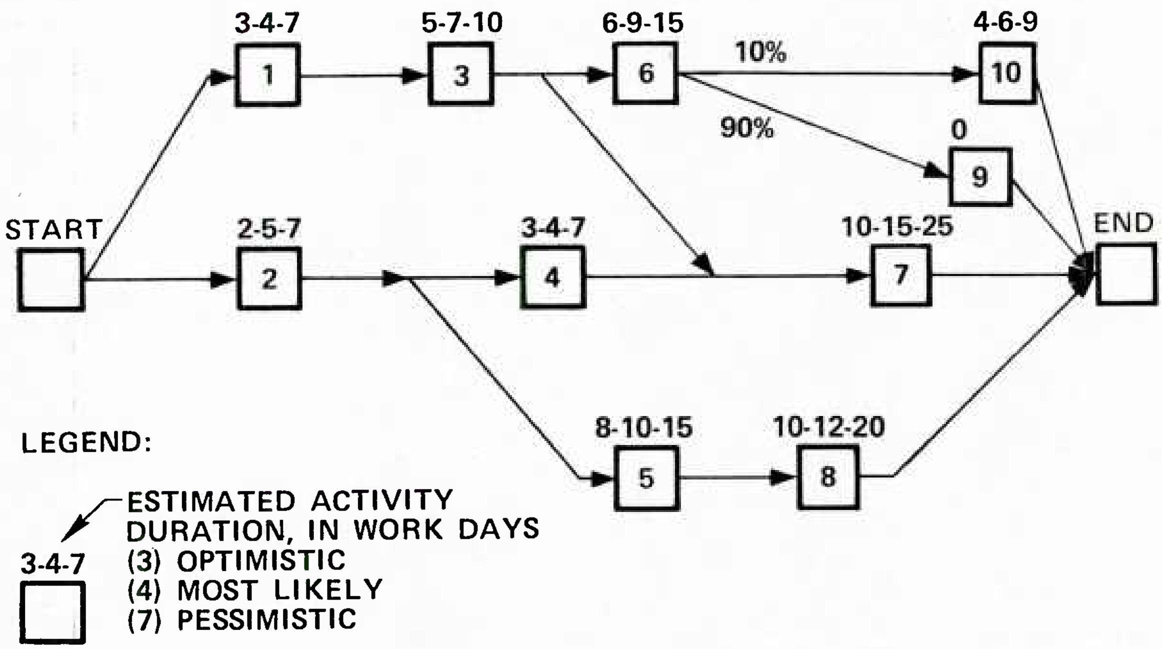

FIGURE 3. ACTIVITY TIME ESTIMATE.

The TRANSIM V Time Summary Graph shown in Figure 4 illustrates the range of project completion times[2] for the example project model of Figure 3. The results show that the project might be completed in from 24.42 to 42.00 workdays with an expected (average) completion in 31.45 workdays. By means of cumulative plot, the TRANSIM V Time Summary Graph also presents the probabilities of project duration between the two extremes. For example, there is a 90% probability that the project will be completed in 36 workdays or less, a 60% probability in 32 workdays, or less, and a 47% probability in 31 workdays, or less, and so forth.

Thus the project manager has available a data presentation which will allow his selection of a completion date which would be compatible with the level of risk acceptable to management. Capacity for risk-taking differs among individuals and under different project circumstances. Hence, each project manager has his own unique acceptable level of risk, dependent perhaps on considerations such as size of investment, interaction with other projects, urgency of delivery, availability of budget funds, etc. The ability of the project manager to select a project schedule to fit the degree of acceptable risk is one of the unique features of the TRANSIM V technique.

Project managers are not universally aware that the project completion time produced by deterministic methods has perhaps as much as a 45 to 50% probability of being exceeded. This can have important

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[2] In Figure 4, the "X" symbols denote the percentage probabilities of project completion during the time intervals shown at the left hand side of the sheet. The "C" symbols present the cumulative probabilities of project completion up to and including the respective time intervals.

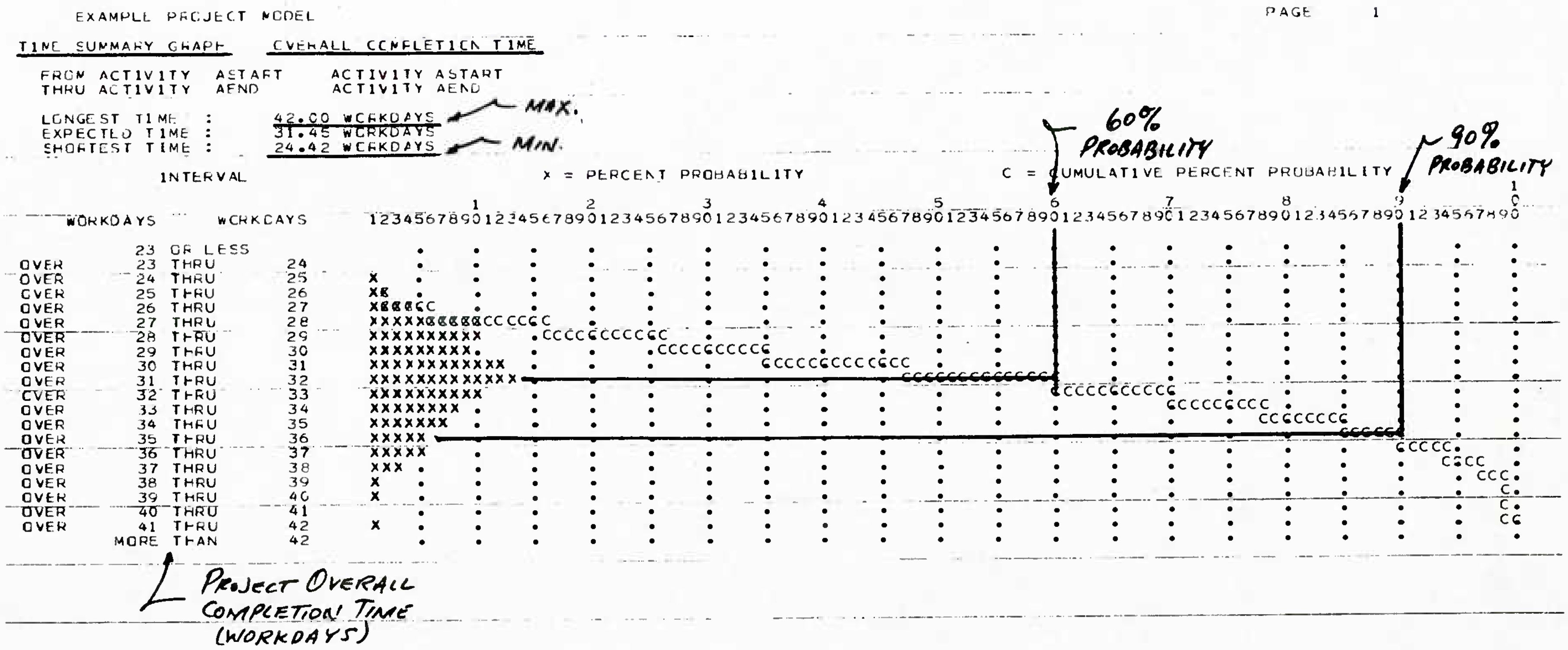

FIGURE 4. TIME SUMMARY GRAPH.

implications where the project plan contains milestone dates that are keyed to important events such as a design review conference, completion of development of a new weapon system, or perhaps, delivering a new ship to the fleet. In the example case (See Figure 4), the "expected" completion time of 31.45 workdays has a 47% probability[3] of being exceeded!

Activity "Criticality."

Conventional network analysis techniques identify a "critical path" representing the longest time path through a network. This "critical path" then becomes the focal point for management monitoring of the project.

However, when the uncertainty and activity performance variability (which are characteristic of most projects) are accounted for, there can actually be a number of different network paths which have some probability of becoming critical. In fact, the "longest time" path of the conventional technique usually has a far less than 100% probability of becoming critical and remaining critical during the entire course of the project. Potentially, any single activity can lie on any number of paths which have some probability of becoming critical during the course of the project.

Hence, TRANSIM V departs from the conventional technique's reference to a specific critical path and (for the sake of more precise project

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[3] This probability may be computed by interpolation between the 47% probability shown on the Time Summary Graph for a 31 workdays completion and a 60% probability of a 32 workdays completion. A 53% probability of completion within 31.45 workdays corresponds to a 47% probability of exceeding that duration.

monitoring and control) refers to "activity criticality" which is defined as the probability of an individual activity lying on any critical path. This concept of activity "criticality" is fundamental in the TRANSIM V approach and provides a major parameter for management evaluation of project performance and control.

Figure 5 illustrates the levels of criticality of the individual activities of the example network. For example, Activity 5 has a 53.8% criticality, while Activity 4 has a 5% criticality, and so forth.

<u>Resource Analysis</u>.

Schedules and budgets may not be realistic without considering the availability of resources to accomplish the individual project activities. Required resources may include manpower, materials, equipment, facilities, funds, and even space, or suitable weather conditions, among others.

Most projects suffer from some scarcity of resources--the net effect can significantly delay project completion and add to project cost. TRANSIM V provides the project manager with resource requirements data which facilitates the tradeoff analysis between schedule and resource availability which is so important to effective project management.

Several of the conventional deterministic network techniques can account for resource requirement and the net effects on schedule caused by limitations in resource availability. Typically, the planner first develops the schedule. Next, he sums up the net requirements for each of the resources. Usually, the level of required resources will

ACTIVITY CRITICALITY REPORT WITH PREDECESSORS (LISTED ACCORDING TO DECREASING CRITICALITY)

ACTIVITY CODE	ACTIVITY DESCRIPTION	CRITICALITY (PERCENT)	PREDECESSOR ACTIVITIES CODE	PREDECESSOR ACTIVITIES DESCRIPTION	CRITICALITY (PERCENT)	EXPECTED SLACK (WORKDAYS)
AEND	ACTIVITY AEND	100.00	09	ACTIVITY 9	1.00	8.46
			10	ACTIVITY 10	2.20	0.33
			07	ACTIVITY 7	43.00	2.54
			08	ACTIVITY 8	53.80	1.71
ASTART	ACTIVITY ASTART	100.00		NONE		
02	ACTIVITY 2	58.80	ASTART	ACTIVITY ASTART	100.00	
05	ACTIVITY 5	53.80	02	ACTIVITY 2	58.80	
08	ACTIVITY 8	53.80	05	ACTIVITY 5	53.80	
07	ACTIVITY 7	43.00	03	ACTIVITY 3	41.20	0.13
			04	ACTIVITY 4	5.00	2.88
01	ACTIVITY 1	41.20	ASTART	ACTIVITY ASTART	100.00	
03	ACTIVITY 3	41.20	01	ACTIVITY 1	41.20	
04	ACTIVITY 4	5.00	02	ACTIVITY 2	58.80	
06	ACTIVITY 6	3.20	03	ACTIVITY 3	41.20	
10	ACTIVITY 10	2.20	06	ACTIVITY 6	3.20	
09	ACTIVITY 9	1.00	06	ACTIVITY 6	3.20	

PREDECESSORS OF ACTIVITY 07

FIGURE 5. CRITICALITY REPORT.

show peaks and valleys, when viewed over the length of the project. The planner will generally "level" the resources; that is, establish a resource level compatible with project objectives, cost, and resource availability. Establishing resource requirements with the deterministic network analysis technique is straightforward, but because of the inability to account for activity uncertainty and variability, it can have serious shortcomings.

On the other hand, with TRANSIM V, the determination of resource requirements takes into account the variable start and finish dates of the activities, and as well, any uncertainty in activity resource requirements. These results deal with "probabilities" of different levels of resources being required on different project dates. As in the case of probabilistic scheduling, the resource decision should be dependent on an acceptable level of risk. Where certain resources are required by activities with high criticality, a low risk[4] level such as 10% might be appropriate--for others, a higher risk level such as 50% might be tolerated.

What Can TRANSIM V Do?

There are several immediate benefits derived from TRANSIM V:

1) Improved planning action

2) Clearly established responsibilities for each task

3) Risk analysis

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[4] Resource risk is the probability that the resource is <u>not</u> available when required, resulting in delays to the activities.

Improved Planning Action.

The process of building the project plan necessitates identifying all key activities and events as well as sequencing and relating them. TRANSIM V thus provides assurance that detailed planning does take place and that it is orderly, thorough and logical. Also, the use of the graphical model (network) facilitates communication and common understanding by all concerned.

In contrast to other planning approaches, TRANSIM V makes the plan more realistic by allowing for consideration of uncertainty in the planning process (See Figure 2).

Establishment of Responsibilities.

TRANSIM V assists in one of management's more difficult tasks--that of establishing clearcut responsibilities for individual activities. Each activity is assigned to a "Responsibility"--who may be a manager, supervisor, contractor or other individual, or a group of individuals (i.e., a department, team of specialists, etc.).

As a further assist, responsibilities may be identified in a network drawing through the use of symbolic codes on the project plan as shown in Figure 6 (Other means of differentiation such as coloring, stratification of the network activity fields, etc. may also be used). This identification procedure will assure effective communication at all project levels. For further clarification, sets of computer output reports may be produced for each responsibility, covering only those activities under that responsibility's control.

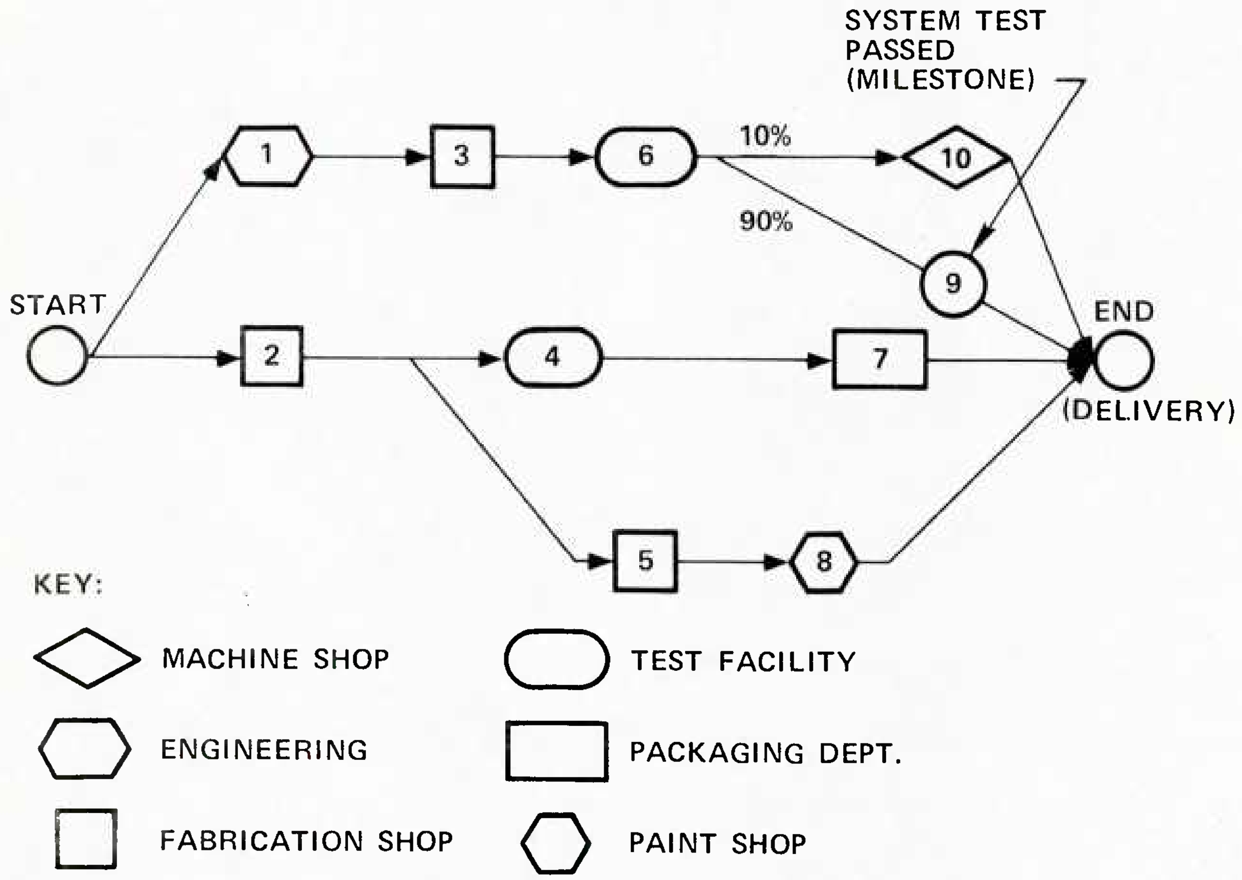

FIGURE 6. RESPONSIBILITY SYMBOLS.

Risk Analysis.

The initial computer analysis of the project plan will clearly indicate the degree to which the project plan meets management objectives. Suppose, for instance, that the management's target is to complete the project within 30 workdays (See Figure 3).

As depicted in Figure 4, the probability of completing within 30 days is 35%. Accordingly, there is a 65% probability that the 30 days target date will be exceeded. Management may find the 65% risk level to be unacceptable and would direct a replanning or resource reallocation effort designed to produce a 30 days completion probability of, say 90%. On the other hand, management may decide to change the target date to 36 workdays with an acceptable risk level of 10% (See Figure 4).

Where TRANSIM V Has Been and Should Be Used

TRANSIM V is designed to be used at all levels of project management, and is particularly suited to the needs of top management--those who must bear the full burdens of decision-making and risk-taking in the face of uncertainty.

TRANSIM V is particularly designed for use on projects which are affected to a significant degree by uncertainty and variability in project plan or in time, technological, or cost performance. Typical examples of such projects are:

Research and Development.

R & D projects represent one of the major areas of TRANSIM V usage because of the greater significance of time, technological, and cost uncertainty in such projects.

System and Combat System Acquisition.

Because of planning uncertainty and project model complexity, TRANSIM V is ideally suited to ship and combat system acquisition project management.

Other Industry/Projects.

Other industrial-related areas using the TRANSIM V simulation technique include:

- Defense
  - Weapon systems
  - Ships, aircraft and bases
- Land development
  - Regional shopping centers
  - Hotels and resorts
  - Urban redevelopment
  - Recreational and residential
- Health care
  - New hospitals and clinics
  - Rehabilitation of old facilities
- Energy resources
  - Oil/gas exploration and development
  - Hydro, fossil and nuclear power plants
  - Coal mining
- Mineral resources
  - Exploration and development
- Public works
  - Water treatment
  - Sewerage treatment
  - Dams and reservoirs
- Product development
- Construction

- o Marine Construction

  --Offshore drilling platforms
  --Ships
  --Terminals

What are Data Sources?

The key to the effective use of TRANSIM V is obtaining realistic duration, cost and resource estimates. Where adequate background information about similar projects is available, suitable data bank sources may exist. TRANSIM V can accept as input histograms of activity durations, costs, and resource requirements reflecting past experiences.

In most instances, however, suitable data bank sources (especially for a new type of project) are not available. In such cases, the required input data may be based on the subjective judgment of experienced individuals. A considerable amount of research[5] has been conducted on how to obtain objective, accurate estimates from experienced workers. TRANSIM V makes use of such techniques and can use data from any reliable source.

How to Make TRANSIM V Effective.

1. Define the organizational responsibilities of technical and administrative managers.

2. Conduct training and indoctrination programs at all levels of project management on a continuing basis, not only to assure proper use of the system, but so that new personnel can become acquainted with it also.

3. Establish an implementation task team whose leader reports directly to the project manager or to an equivalent management level. Assign personnel responsible for network planning and status control to report directly to the project manager.

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[5] See Bonger's article which is devoted to this subject.

4. Provide for periodic discussions and critiques of the implementation of TRANSIM V to identify and correct problem areas.

5. Develop a precise definition of the project in terms of a project work breakdown structure and require that project's management and operating departments agree on the definitions and breakdown of the work packages.

6. Assign responsibility for performance and reporting of performance for each work package.

7. Assign the primary responsibility for time estimating or at least approval of estimates by others to personnel who are accountable for performance of work packages.

8. If the activity network has more than 600 individual work packages, prepare a management level of summary network of below 200 consolidated work packages to facilitate management evaluation and control. Where there are more than 1200 activities, divide the large network into subnetworks at an intermediate level which would consist of less than 600 activities. As far as practicable, breakdown large networks into subnetworks for individual responsibilities.

9. Assure that work packages and associated network plans clearly define work to be performed before time estimating begins.

10. Require ranges of time and cost estimates for any work packages involving significant degrees of uncertainty.

11. Integrate, consolidate and/or eliminate all redundant systems for data collection.

12. Establish updating procedures and for each updating cycle set due dates for input and distribution of output reports. Establish a follow-up system to assure timely performance.

13. Employ TRANSIM V management reports selectively and avoid overwhelming key managers with excessive detail.

How TRANSIM V Assists Management in Decision-Making.

The TRANSIM V technique can assist on a wide range of problems on projects where uncertainty and risk are significant factors. Problems which typically face project management are:

Planning Under Uncertainty.

In addition to the many activities in a project plan which have 100% likelihood of occurring, the TRANSIM V project plan can include activities which are not certain to occur; that is, where there is some likelihood that the activity will or will not occur. Such uncertainties can have a profound impact on the probabilities of meeting specific target dates.

Technological Uncertainty.

Whether or not a technological development is successful may have significant impact on the probability of attaining overall project objectives. TRANSIM V can account for technological uncertainty by allowing the project plan to include assessments of the probability of successful technological development. Because of this attribute, TRANSIM V can be used for a "decision tree" type of analysis of project alternatives under its routine use for project management purposes.

Schedule Uncertainty.

TRANSIM V schedules reflect the uncertainties of project plan, technological development, and activity performance. Rather than fixed dates for project milestones, TRANSIM V develops the probability of attainment of any specific target date. Scheduled starts for individual activities reflect the variability of their predecessor activities.

Thus, the project manager can select a schedule for activity, milestone, or project which reflects an acceptable level of risk.

Cost Uncertainty.

TRANSIM V Cost Reports reflect several uncertainties which can affect activity costs. Included are:

- variable labor utilization and rates
- uncertain material requirements and material costs
- uncertain escalation rates
- uncertain overhead and money costs

TRANSIM V presents costs in terms of the probability of realizing different target budgets, and hence, project management can select a budget level compatible with an acceptable level of risk.

Resource Requirement Uncertainty.

TRANSIM V's ability to establish activity resource demand resulting from variable activity performance and resource requirement provides management with the range of requirements from minimum to maximum. Even though management may decide to "level" demands at an average likelihood level, not providing for a peak requirement for a critical activity will cause project time slippage and perhaps increased costs. TRANSIM V allows a resource leveling to account for uncertainty, thereby reducing project slippage due to variable resource demand.

"What If" Gaming.

TRANSIM V's ease of setting up an analysis and its user-oriented approach facilitate the use of the technique for evaluation of alternative plans and schedules and the conducting of schedule-resource-cost tradeoff analyses.

Project Control.

The probabilistic analytic features of TRANSIM V provide for improved project control through early identification and direction of management's attention to potential problem areas. The activity criticality feature allows close monitoring of those activities which are the most important. An activity criticality level which changes from update to update provides a very sensitive indicator of activity importance to overall project performance and allows for early detection of problems.

Risk Management Philosophy.

For projects with a relatively high level of uncertainty, the project manager can experience an apparent dilemma by not having a firm enough basis to initiate the planning and scheduling processes. Yet, TRANSIM V can be highly useful in such a situation. Being able to account for uncertainty, TRANSIM V can provide early indications of schedule and budget risks upon which to base initial schedule and budget estimates for feasibility purposes.

With conventional deterministic approaches where schedules and budgets are based on single ("Best") value estimates, there is an "average" likelihood of attaining project schedule and budget objectives. Project controls are then set up to detect problems as they occur, allowing suitable corrective actions to be undertaken. In many instances, however, management is not even aware of the problem or its significance in terms of impact on overall project performance until later in time when only a limited number of corrective action options remain. The usual corrective action is to "crash" the work at high cost.

However, the project risk management capability provided by TRANSIM V allows for a completely different management approach. Knowing in advance specific uncertainties and their possible impact on overall project performance, management can set up alternative plans for implementation, based on the actual development of the project. Because such alternatives can be evaluated early in the planning process, they may represent options which can avoid the costly last minute "crash."

With TRANSIM V, the concept of maintaining desired levels of schedule resource and cost "risk" throughout the project provides management with an additional powerful measure for project control. Maintenance of the desired risk level becomes an integral part of maintenance of schedule and budget. In terms of management philosophy, maintenance of "low risk" levels for schedule and cost targets usually requires early application of sufficient resources to provide the required margins of safety. As the project unfolds, management reallocates resources as necessary to maintain desired risk levels.

The manager continually evaluates actual project performance in light of the possible range between optimistic and pessimistic extremes. If the project's actual progress is favorable, the management should find it desirable to lighten its application of resources in order to maintain a constant level of risk.

How About Computer Facilities?

TRANSIM V is designed to operate on most modern large, high speed digital computers. These include: IBM 360 and 370, CDC 6600 and 7600, UNIVAC 1100, Honeywell 6000, and the AMDAHL series.

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APPENDICES

APPENDIX A

HISTORY OF TRANSIM

TRANSIM is the acronym applied to the general-purpose simulator developed at UCLA under sponsorship of several government agencies, including the U.S. Departments of Commerce, Defense, and Transportation. Documentation for the first prototype version, TRANSIM I (1966) is available from the National Technical Information Service, Springfield, Virginia 22151. Later designations, including TRANSIM II, III, and IV, refer to successive major milestone developments resulting from the continuing research and development program at UCLA in the field of advanced computer simulation. TRANSIM II, for example, marked the incorporation of all TRANSIM I input-output features into a single computer program, eliminating the need for pre-editing or post-processing. TRANSIM III marked the conversion of the basic TRANSIM Program from an IBM 7094-only version to one which could be used on many different machines. Further development as featured in TRANSIM IV marked the elimination of most fixed-format requirements of the input data, together with the addition of several new output report options.

The earlier TRANSIM IV User's Manual, Report UCLA-ENG-7168, December 1971, provided a general description of the TRANSIM IV simulation technique, together with procedures and instructions for its use. A supplement to the TRANSIM IV User's Manual was issued in August 1974 (UCLA-ENG-7443). This supplement updated the previous publication and provided a more formalized set of procedures for project model applications.

Volume II of the TRANSIM V Manual, The TRANSIM V User's Manual, presents the new features and formats developed since the publication of the TRANSIM IV Supplement.

APPENDIX B

KEY ELEMENTS OF PROJECT RISK MANAGEMENT WITH TRANSIM V: PROJECT PLANNING AND ESTIMATING.

I. PROJECT PLAN

A. Project Objectives and Scope.

To be effective, the implementation of project risk management must be tailored to the organization that will use it and it must be capable of meeting the organization's objectives, the nature of its operations, and its managerial and supervisory requirements and limitations. The integrated approach provided by network-based planning and control systems provides a significant assist in meeting project objectives.

The first step in developing a planning structure is to define the project objectives and scope:

- What are the beginning and end points?
- What constitutes successful completion?
- Are there time, budget, or other major constraints?
- Who are the decision-makers?
- Which task responsibility areas are to be included in the project plan?

B. Work Breakdown Structure (WBS).

The next step is to identify the individual elements of work to be included in the project plan. Within NAVSEA, the Work Breakdown Structure (WBS) has been accepted as the basic foundation upon which all management systems rest. A WBS serves many purposes and facilitates planning by providing a formal structure for identifying the individual elements of work. It simplifies the problems of summarizing project-oriented data and establishes the reporting structure for command-required management information.

The WBS defines and organizes the work to be done; the organizational structure reflects the way the project manager has organized the people who will accomplish the work. If work responsibility is to be assigned to appropriate organization elements, the WBS and organizational structure must be interfaced; that is, functional responsibility must be established for identified units of work.

Once the WBS has been established, the project planning effort can proceed with:

- Establishing the scope and number of network plans to be prepared.
- Assigning organizational responsibilities to elements of the WBS.
- Specifying and coordinating contract administration, fiscal planning, and control structures.
- Specifying the management reporting structure and the individual reports.

C. Project Network Plans.

The WBS serves as the basis for the project network plans which provide the logical framework for depicting the interfacing interrelationships among and between the individual work packages. At the lowest level of WBS detail, individual networks will represent all related activities required to accomplish the goals for that level--the "lowest" level at which management feels it still has sufficient visibility for proper planning and control. At this detail level, "work packages" will be identified. Work packages represent the basic units of work to be used as scheduling elements to estimate cost and resources and against which actual costs will be collected and compared with estimates for cost control. These detailed, low-level networks may be organized as subnetworks which, when required for analysis purposes, can be assembled into higher level networks.

The number of different levels of detail represented by network plans depends upon the requirements of the different levels of management. Top management will need only a top-level, master schedule network, depicting only the major activities and milestones encompassing the entire project.

The requirement for the next level of the "project management" network plan is universal. Depicted will be all activities assigned to the major project task responsibilities. Single activities may represent entire networks or subnetworks at a lower detail level; milestones will include all major end-product deliveries, decision points and management reviews.

At the lower levels, network activities should represent work categorized into one of three different types of effort:

- o Discrete tasks which have a specific end product or end result.
- o Work which does not result in a final product; for example, continuing engineering, liaison, logistics or other support type activities.
- o "Factored" efforts which can be directly related to other identified discrete tasks; for example, portions of quality control or inspection.

The discrete tasks are referred to as "work packages," support type as "level of effort (LOE)," and factored work as "apportioned effort." Each work task on the project can be placed in one of these categories.

D. Work Packages.

The work packages constitute the basic building blocks used by the project manager in planning, controlling, and measuring project performance. From the standpoint of evaluating accomplishment, it is desirable to have short-term work packages; however, it is also desirable to minimize the amount of data being processed. Hence, unless dictated by the natural subdivisions of the work packages, their scope should be a compromise between too short and too long.

E. Constructing the Network Plan.

Although all contractual efforts should be planned and controlled through work packages, level of effort (LOE), or apportioned effort, it may not be practical or possible to do such detailed planning for an entire project at the outset. A "rolling window" concept, for which work is planned in a finite but gross level detail, may be used at the outset of the project. As the project work becomes defined and planned in more detail, tasks suitable for a job and responsibility assignment evolve naturally and can be segregated into work packages.

There are several ways to begin the construction of the initial network for a project using the work packages together with LOE and apportioned effort tasks as the basic building blocks of the network plan. In some cases, where there has been some previous planning, a list of milestones or possible a summary-level network may be available. In other cases, the network may be constructed based entirely on the knowledge of a group of people who are familiar with the objectives or requirements of the project, and who have had experience in the functional areas involved.

If the latter situation exists and where there is little or no prior comprehensive project planning, one may start at the beginning event (project start) or at the ending event (project completed). Of course, the beginning and ending points must first be well defined, so that all of the network participants have a common understanding concerning the current status and the objectives to be reached.

In such cases, the people must together present (among them) a total picture (at a summary or overall planning level) of the entire project. This group approach is likely to be more economical of time and effort than would an approach involving separate networking sessions with many individuals. Later, individual areas (one or more activities) may be selected for more detailed treatment and specialists in the area will be consulted.

The "top level down" approach seems to be the most desirable, as it quickly produces an integrated picture of the entire project and provides a logical basis for deciding how much of the program must be detailed down to what level. Starting at a detailed level and summarizing for higher management may result in unneeded work, too large a network for the entire project, and unnecessary delay in presenting an integrated plan to management.

If one starts at the beginning, the logical question "what can come next" is asked as each activity is designated. As an activity is added, the question "what else must be done in order to reach this activity" is asked. This procedure may continue along the path of one given functional area, reach the final objective, and then start again in another more or less independent functional area, or all areas may be developed concurrently. The latter is more difficult, because the advantage of following one train of logical development is lost. However, the former requires notation at each event of possible interactions with other functional areas, so that connecting activities or restraints may later be added.

If one starts at the final event, the question is "What activity or what other activities must be completed before this event is completed?" This avoids the question of what must have occurred. The "must have occurred" question will more often result in an initial network free of any planning biases, presenting a more objective picture which may then be modified as needed. However, experience has shown that this method of working from the rear forward may tend to result in more detail than desired, and perhaps in unnecessary constraints, as a "must have occurred" activity may be a predecessor in time only, not a direct requirement.

Another approach which has been found to be successful entails the use of a simplified Gantt Bar chart. Each major area of activity (such as each subsystem, or testing, or spare parts logistics) is represented as an approximate time-phased bar on a time scale chart, with the bars far enough apart so that boxes (activities) may be added along each one. Once the major areas are identified and represented, major events are identified and added along each of the activity bars. Interactions between them may be easily added at the same time the events are identified. Some portions of the bar will enlarge into several activities or even a small subnetwork on the first time around, but in general, it is easier to put the entire chart into network form at a gross summary level before attempting very much detailing.

Still another approach may be taken to the development of a project network if a milestone list or "bubble chart" has been previously prepared. In this case, a "dependency network" showing the relationships between the events, may be constructed by laying out the milestones with connecting lines showing only what milestones must be reached before others can be reached. All of these lines (none of which are identified as activities at this step) will not necessarily turn out to be major* activities--some will be restraints and some will be minor activities needed to accomplish an event for which the major activity was not shown on the dependency network.

The various methods of laying out the network--starting at the first event or the ending event, using a simple Gantt chart, laying out a dependency network from a milestone list--all have one common tie. That is the desirability of starting with a summary level, non-detailed picture from which further detailed networks can be developed as necessary.

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* The determination of an activity as being minor or major depends on whether or not the time and effort spent on them is large or small.

II. ESTIMATING

Once the planner has decided how the job is to be done and the top level plans have been laid out and authenticated, the fully developed network plans will provide the basis for determining how long it will take to complete the planned project and when resources such as time, manpower, dollars and facilities will be needed to best achieve the project objective.

A. Activity Duration.

Although there have been recent major advances in data management technology, there is little chance that a project manager faced with an uncertainty-laden project will find an existing formal "data bank" adequate for his needs. He must resort to other data sources such as engineering estimates, estimating relationships, and subjective judgment.

The most prolific and readily available (and perhaps the most reliable) data source is the subjective judgment of experienced and knowledgeable workers in a specialty field. Successful application of TRANSIM V therefore often depends upon the analysts' ability to locate and interrogate suitable subjects. The interrogation process should be conducted under circumstances which assure objectivity on the part of the estimator.[1]

Because network analysis is conducted within the project time framework, the first step is to establish the project schedule.

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1. See Bongers' article cited in references.

Duration estimates for each activity are obtained from the manager, engineers, or other project personnel who are most directly concerned with the performance of each activity. If the network analysis includes resource and cost analyses, then estimates are provided for resource requirements for each activity and for the appropriate cost elements (i.e., labor rates, material costs, overhead costs, etc.).

Obtaining duration estimates becomes complicated for a project where uncertainty plays a significant role. In an attempt to overcome this problem, the estimator uses his professional judgment in an objective way to estimate a range of times for the completion of an activity. This range realistically reflects his typical understanding of the uncertainties involved in performing the tasks.

1. The Three-Time Estimate Technique.

Under this concept three duration estimates are obtained--an "optimistic," a "most likely" and a "pessimistic"--which form the basis for assessing the uncertainties involved in the variability of performance of a given task.

Optimistic Time. This is the estimate of the shortest possible time in which an activity can be completed. The optimistic estimate assumes that the activity is accomplished under the most favorable conditions, free of even the normal degree of problems or setbacks.

Pessimistic Time. This is the estimate of the longest time it might take to complete an activity. It is assumed that in the performing of the work, everything which can go wrong--does go wrong--and that all of the possible problems or setbacks short of strikes, acts of God, etc., occur.

Most Likely Time. This estimate falls between the optimistic and the pessimistic and assumes normal conditions and routine problems will be encountered in performing the activity.

In providing the above estimates, the estimators should keep certain considerations in mind. These are as follows:

- Estimates should be based on a specified level of manpower and other required resources. The time estimates should be initially given for the "desirable" levels of resources expected to be available for each activity. If, for some reason, the desirable levels are not attainable, the time durations should be adjusted accordingly.

- Estimates should not allow for failure on the part of interfacing activities, such as delivery of parts or materials, or release of facilities, funds, or work authorization. Such impacts should be accounted for by specific interfacing activities incorporated in the network plan.

- The possibility of "acts of God" such as fire, flood, strike, or other disaster should not be considered in estimating.

- It is important in the initial analyses, not to expand or contract time estimates to fit time or cost constraints. The initial analyses are usually designed to determine project duration and cost, free of constraints.

Once the duration estimates are obtained, the project risk management technique, TRANSIM V, departs from the conventional PERT approach in the use of the three time estimates. In the original PERT, the three time estimates were used to derive a single value to represent the "expected" activity duration time through the use of a mathematical formula. With TRANSIM V, the three estimates are used to describe a statistical distribution covering the range of values.

B. Resource Requirements and Cost.

Adding resource and cost data to the basic time-oriented network allows management to study the interrelationships between time, resources and costs and to determine the impacts on time, manpower, or costs of any variations in one of them.

As in the case of the project time analysis discussed earlier, estimates are required for activity resource requirements such as labor, material, and cost associated with the activity performance.

TRANSIM V can be used to analyze requirements for any type of resource; non-consumable and consumable. Included are:

- Manpower (by number and skill)
- Space
- Material
- Special tools and facilities

TRANSIM V defines cost as a resource so that, as in the above, any kind of cost may be accounted for (i.e., labor, material and equipment, taxes, overhead, etc.).

In order to account for the uncertainty in the resource requirements and cost factors involved, the same three-estimate approach (Optimistic, Pessimistic, and Most Likely) is used for estimating activity time durations, resource requirements and costs. For example, for a given activity, the requirements for a particular worker (by skill) may range from 100 (Optimistic) to 180 (Pessimistic) manhours, with a "Most Likely" requirement of 125 manhours. For costs, material costs for a given activity may range from $1,000 (Optimistic) to $1,500 (Pessimistic), with a "Most Likely" value of $1,200.