

Application of Critical Path Method to a Highway Right-of-Way Operation

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•IN CONSTRUCTION of the Interstate System it is anticipated that more than 750,000 individual parcels of land will have been acquired by 1972. In addition, approximately 1,500,000 parcels will have been acquired for the ABC system of highways by the same date. The enormous workload has forced a number of State highway departments to take another look at their methods of operation, because experience has shown that some of them would not be able to meet their acquisition schedules without considerable improvement in their efficiency.

With this need for an acceleration in the acquisition process in mind, several of the States began experimenting with the Critical Path Method (CPM), a management information and control tool that has been successfully applied in many fields, as a possible solution of their right-of-way acquisition problem. The results of these experiments have been reported to the Washington Office of the U. S. Bureau of Public Roads by Division Right-of-Way Officers.

Following the establishment of the Office of Right-of-Way and Location, this Office reviewed these reports to determine if the Bureau could aid the States in the Application of the CPM to right-of-way activities. Observations indicated a need for the development of a CPM network for right-of-way acquisition procedures. In seeking to develop such a network, the Office of Right-of-Way and Location requested the Electronic Development Division of the Office of Research and Development to provide the needed technical assistance. That request resulted in the study described in this paper.

The study was not a research project in the true sense. It was an investigation of the feasibility of applying an accepted management method that has been successful in many fields, to a specific area of highway development (i. e., right-of-way acquisition).

As a background of the study, several basic thoughts were recognized at the outset:

1. The techniques and control used by many types of management systems are not readily adaptable to the right-of-way function.
2. Any proposed CPM network aimed at improving administration of the highway right-of-way program should be balanced against the requirements of the program.
3. Any CPM network initially developed for this purpose should be tested in a working situation to determine its general applicability to the right-of-way function.
4. Any CPM network found generally applicable to the right-of-way function should be retested in each situation being studied and modified to meet the requirements of that specific situation. The requirements we are concerned with here include such matters as the statutory requirements for eminent domain proceeding, as well as organizational policies, procedures, and personnel capabilities. Hence, the management principles, methods, and techniques that are used in the Critical Path Method must be tailored to fit these requirements as they exist in a specific organization. This tailoring process requires adjustments to both the management method and the organization to obtain a perfect fit; the objective being the satisfaction of the needs of the organization.

As further background, it was recognized that in the right-of-way field many State highway departments have four general needs which require satisfaction, as follows:

1. The need for a better understanding of the right-of-way operation by other divisions of the highway department.
2. The need for improved communications and coordination between the right-of-way division and other divisions of the organization.
3. The need for a clearer understanding of its own operation by the personnel of the right-of-way division.
4. The need for a systematic method of project control within each right-of-way division.

One of the first points which must be understood by all persons concerned with, or affected by, highway right-of-way acquisition is the nature of the acquisition process. To the novice, the acquisition of 100 parcels of real estate for a single highway project may appear as a single undertaking. However, the experienced hand recognizes it as much more than that. To him each parcel of land is a separate job, and 100 parcels mean 100 separate and distinct jobs which often have very little similarity to each other. The methods and procedures required for one of these jobs may be very different from the methods and procedures applicable to any of the others. Also, each individual job may require ten or more tasks. Hence, the supervision of some 1,000 or more individual, though essential, tasks is a very complex assignment. In fact, it is so complex that it cannot be effectively controlled by a simple "check off" procedure. Such control requires a management tool specifically designed for this purpose. The CPM is a management system that can be adapted to this task.

The CPM provides three things: first, a plan for the project in the form of a network; next, a schedule for the plan in the form of time estimates for each activity and calendar dates for completion of all activities; and finally, a control device to measure actual performance against schedule performance in the form of periodic reports. Management is permitted to concentrate its efforts on the problem areas that develop; that is, to operate under the "exception principle." According to this management concept, frequently recurring decisions should be reduced to routine, thereby leaving the manager free to concentrate on more important or exceptionally complex issues. The routine aspects of control under CPM are delegated to the plan, the schedule, and the computer. The electronic computer is also assigned the task of simulating various corrective actions. However, important decisions, such as the selection of the best corrective action for each problem situation, are left for management to decide.

As knowledge of CPM increased, it became obvious that a test application to a right-of-way acquisition project was clearly warranted. Such an application was made in the summer of 1963 when a model of a CPM right-of-way network was applied to the policies and procedures of a State highway right-of-way organization.

This application was broken into five major activities:

1. Development of a standard right-of-way CPM network by U. S. Bureau of Public Roads personnel.
2. Review of a State highway department's right-of-way operations in relation to the CPM network.
3. Discussion of the network and the State's right-of-way operations with the State highway department right-of-way personnel.
4. Initial revision of the network and its submission to the State highway department for review testing and comments.
5. Final revision of the network and the preparation of a report.

A standard CPM right-of-way network was developed through the use of the standard CPM techniques, namely, planning and scheduling of the activities involved.

In the planning phase, a preliminary list was made of all the activities necessary for the successful completion of a highway project. These ranged from the Right-of-Way Estimates for Alternate Location to the Certification of Right-of-Way for the Plans, Specifications and Estimates. To provide a complete picture of how engineering personnel and right-of-way personnel must work hand in hand, the major functions of engineering were also included in the preliminary list.

The preliminary list of activities was reviewed for errors or omissions and revisions were made where necessary. Next, a "follows what" column was developed from this list. In this step, each activity on the list was reviewed and its dependency on other listed activities was determined. This required a rearrangement in the chronological order of occurrence. Upon completion of the "follows what" column, an arrow diagram was drawn. It included all of the activities on the list in the chronological order of their occurrence. This diagram became the first draft of the preliminary CPM network.

During the review of the preliminary network, it was discovered that the activities of appraisal, review appraisal, recommendations of values and negotiations had been depicted incorrectly. The true relationship between these activities in the handling of numerous parcels is very difficult to show on a network. The diagram worked logically for a small number of parcels on a project but broke down for a larger number of parcels.

Many different methods of planning these activities were depicted in alternative arrow diagrams. Eventually, it became apparent that the activities of appraisal, review appraisal, recommended values and negotiations would have to be broken down by some identifiable type of parcels. The groupings adopted for this purpose were "Total Takes," "Partial Takes With Improvements," and "Partial Takes Without Improvements." With this problem resolved, an arrow diagram was designed for use as a prototype or "Standard" network.

On completion of the standard network, an input data form was developed. These data forms serve several purposes. For example, when a project is assigned to a supervisor, the standard form may be used as a checklist. In the development of a work schedule, the time estimates for the various activities may be inserted in the proper lines. If there are any activities that the supervisor feels are not needed for his project, a time estimate of zero is assigned to them. He then submits the data form with the time estimates to the computer section, where CPM calculations and calendar dates are made. The calendar-dated report produced by the computer provides the supervisor with the expected completion date of his right-of-way operations. If this date is not satisfactory, the supervisor must analyze the activities on the critical path and decide which may be completed in less time. Additional computer runs may be made until the desired completion date is obtained, or until it is decided to extend that date into the future.

The scheduling phase of this study was used, not to apply time estimates for a specific project, but to use time estimates to determine which activities would be on the critical path. The critical activities were reviewed and analyzed to determine whether there were any activities that could be removed from the critical path. By revising certain portions of the arrow diagrams and applying the time estimates, the number of critical activities were reduced to a minimum.

The completion of the initial phase of this investigation presented sufficient evidence of adaptability of CPM to justify the conclusion of the study. The available information on the experiences of the various States with CPM was reviewed, and the Minnesota Department of Highways was selected as the State with CPM experience that was typical of most State highway departments. Its network was reviewed and comments were noted in preparation for discussion with officials of that Department.

A two-day discussion was held with the personnel of the Minnesota Right-of-Way Division and the prototype network was presented to them. The various ways of depicting certain areas of concern were discussed and consideration was given to the Minnesota network diagram of right-of-way operation. At the end of the conference, agreement was reached on the revisions necessary to reflect the actual operating conditions in the State on the prototype network. It was agreed that an arrow diagram of the State's right-of-way operations and a revised prototype network would be submitted to the State for review and additional comments.

In the development of an arrow diagram for the State's operations and the prototype network, many areas of interest were found. When the network and the documentation were submitted, a list of suggestions on situations revealed by the CPM analysis was also presented for the consideration of the State's right-of-way personnel.

The comments of the State on the prototype network were received and are being incorporated in a finished prototype network of right-of-way operations (Appendix).

There is little question in the minds of the Minnesota right-of-way people that CPM is the best and most systematic method of project control thus far developed, and that its application to their operation will result in a substantial improvement in the communications and coordination between the various divisions.

The personnel of that Division have found that the time expended on the development of the CPM network has been highly beneficial in that it has brought about a critical analysis of the procedures involved in the preacquisition and acquisition phases of their work. They have found that this critical review has resulted in a substantial saving in time as well as streamlining the entire operation. As an illustration of this point, a 30-day time saving has been effected by a reduction in one operational step.

As this study is reviewed in perspective, it is noted that at least 18 States are using CPM in the three preconstruction operations of Design, Right-of-Way, and P. S. and E. preparation. For their benefit, and for the benefit of others who are seeking improvement of their right-of-way acquisition programs, the following observations are made:

1. CPM Techniques can be adapted to a highway right-of-way operation: Because of the numerous parcels contained in every right-of-way project, the planning and scheduling phases must be considered from different points of view. In the planning phase, the project must be considered with respect to the individual parcels; that is, the network indicates the path that each individual parcel will have to follow. In the scheduling phase the parcels must be considered as groups and the time estimates must be based on the starting time of the first parcel in the group and the finishing time of the last parcel in the group. It is, of course, necessary to estimate the number of parcels that will follow each path in addition to estimating the time required for each activity, but the reporting and "look ahead" features of CPM provide a better means of controlling these variables than with other available management tools.

2. The CPM network planning promotes increased understanding on the part of right-of-way personnel as to the nature of their responsibilities because it depicts the right-of-way operation in greater detail and with more accuracy than is possible with any other management method.

3. The CPM network strengthens the coordination of effort within the right-of-way division and, more particularly, between it and other coordinate divisions of a State highway department because it graphically illustrates the complexity of the right-of-way processes, and clearly identifies the restraints imposed upon that process by operation in other divisions of the State highway department. In this regard, the arrows on the network diagram that connect events occurring in separate sections of the State highway department identify and automatically establish appropriate channels of communication. When the activities on a network path transfer from one operational section to another, the attention of three separate supervisors is focused on one activity. First, the supervisor of the section in which the activity occurs monitors the performance for the completion date. Next, the supervisor of the section in which the terminating event occurs monitors for the starting date of his next activity. Third, and at another organizational level, a top management supervisor monitors the scheduled completion to insure that the transition occurs on time. Furthermore, the several layers of supervision that exercise control at all transition points must maintain communications with each other to provide for any adjustments in schedule which may become necessary.

4. A standard or prototype network can be developed so as to contain all of the activities normally required on about 90 percent of the right-of-way projects. In the other ten percent of the projects (i. e., those which contain special or unusual properties or activities) the standard network is useful as a guide or may be specifically modified for a particular project.

5. An interested State can use a network previously developed elsewhere as a framework or skeleton for the construction of its own right-of-way plan. Where such a plan is being developed, the separation of the parcels into like groups (i. e., Entire Takings, Partial Takings, Takings of Improved Property, etc.) can facilitate the concentration of supervision and control on the parcel group which will contain the greatest problem

areas. The problems encountered in right-of-way projects controlled by CPM will continually disclose needed revisions or modifications in the network plan or the division procedures until the operation is refined into its most efficient pattern.

6. The CPM can remove existing bottlenecks. Such bottlenecks are found to exist usually because the operation, as a unit, had never previously been subjected to a critical analysis. Since the development of the CPM network requires a very close study of each activity and its relationship to the other activities, the study generally produces two immediate results: first, an improvement in the operating procedures, and second, a better knowledge of the operation by the men who direct or perform the activities. The network spotlights illogical arrangements, as well as the relationship and interdependency of the various activities. The schedule can reveal time estimates that are out of proportion to the size and complexity of an activity. The periodic reports of the computer can reveal activities on the critical path that can be made noncritical by rearranging the network. Exposure of these weak points by a critical analysis of the project network works toward improving the operating procedures.

7. Some of the CPM networks developed by State highway department personnel indicated a need for additional training in CPM techniques. However, later revisions of these same networks have shown that some of this needed education is being accomplished through "trial and error" and self-education rather than through a more formal type of training program.

Although CPM is still in the embryonic stage in the right-of-way field, it is going to become increasingly effective as more and more applications are developed and instituted. At present, several groups are engaged in the development of Multi-Project Scheduling for highway programs with a view toward the scheduling of all right-of-way projects at the same time. Such a schedule would indicate when, where, and how the necessary resources of manpower and funds should be allocated to meet the scheduled starting and completion dates. When Multi-Project Scheduling becomes possible and a management system for reporting and control is perfected, the Right-of-Way Administrator will be relieved of many of his most pressing problems.

With the progress already made by a number of the State highway departments in the application of CPM to right-of-way activities, other State highway departments may wish to study its feasibility for their own operation. The standard network (Appendix) may provide a starting point for such a study. Other States that are already using CPM may wish to review this network for clues to possible revisions that will improve their own operations. The adaptation of CPM and the early states of its application require a constant critical analysis and revision of the network and of the operational procedures to perfect the acquisition process. The highest possible stage of perfection in the acquisition process is the goal that the State highway departments must strive for if they are to complete their Interstate Highway Program within available time limits.

The Electronic Development Division, Office of Research and Development, U. S. Bureau of Public Roads has prepared manual A-4, "Critical Path Method Reports," which presents computer programs that will perform all the necessary calculations and calendar dating. The manual is available on request. In addition, on request of any State highway department, the Bureau can provide some assistance in the adaptation of the standard network to the procedures of an individual State or in the development of a network based on the procedures of a State where the standard network is inapplicable.

Appendix

EXPLANATION OF THE STANDARD RIGHT-OF-WAY NETWORK

The "standard" right-of-way network was prepared to indicate a pattern for the development of a CPM network for a State right-of-way acquisition project. It was

therefore necessary to confine the activities to very broad areas and to include only those activities that will appear in the procedures of the majority of the States (see Figs. 1 and 2).

It is believed that the general pattern indicated by this network will be applicable to all of the States although revisions will be necessary to conform to the procedures of each individual State. The activities, as shown, are generally at the earliest point at which the information necessary for their performance is available. It is suggested that these early starting points be given serious consideration, and if possible, a trial, before changing the sequences even though it may mean a change in the existing State acquisition procedure.

The division of the real estate parcels into the separate categories of "Total Takings," "Improved Properties," and "Unimproved Properties" is recommended to provide for the earliest possible starting of the acquisition operation, a degree of balance in the workload of the operation, and the closest possible control of the operation in the problem areas. The separation of the appraisal process into "Before" and "After" Appraisals is suggested to provide for the earliest possible start on the appraisals; a balance in the appraisal workload; and to allow the appraisers to become familiar with the economic and comparable sales data, the unit land values that are applicable, and the value of all of the properties on the project before they consider the "After Value" (and Damages) of the individual parcels. It is believed that a more uniform set of "fair market values" for the acquisition of the required rights-of-way will be arrived at in this manner. This suggested separation should not be considered as requiring the use of different appraisers for the "Before" and the "After" appraisals. The "Before" and the "After" appraisals will be made by the same appraiser; however, it is suggested that he complete all of the "Before" appraisals that are assigned to him on a project before he starts on the "After" appraisals.

The activity "Assign After Appraisals" refers to the assignment or the distribution of information relating to the effect that the proposed construction will have on the individual parcels, rather than an assignment to make an appraisal of the "After Value" of the property. The assignment to appraise is considered to have been made when the individual parcels were distributed among the appraisal force for the "Before" appraisal.

It is not necessary, and probably not advisable, to restrict the individual appraisers to one parcel category, such as "Improved Properties," in the assignment of appraisals; however, the progress reports will have to be made by separate parcel categories. The assignment of information for the "After" appraisals by the project supervisor should include a priority rating by parcel categories so that each individual appraiser will perform his work in coordination with the other members of the appraisal staff.

If it is inadvisable to break the appraisal operation into "Before" and "After" appraisals, the activities labeled "Before" may be used for "Total Takings" and the complete partial taking appraisals will follow the paths labeled "After Appraisals," or all of the appraisal activities may follow the paths labeled "After Appraisals."

The Additional Titles, Appraisals, and Affected Improvements that are referred to in the network, beginning at Event 50, are those properties and improvements that are included within the final right-of-way lines that were not included within the right-of-way lines on the preliminary plans; that is the plans prepared by laying out a standard right-of-way width from the centerline of the selected route location (for example, right-of-way lines laid out 150 ft on either side of the centerline of the selected route of a highway that has a standard right-of-way width of 300 ft). These additionally affected properties will generally be few in number and their inclusion within the right-of-way lines will be caused by the need for additional right-of-way for slopes, drainage, interchanges, service roads, stream changes, sight easements, etc. In the majority of the cases, these additional right-of-way requirements will fall within properties that were included within the right-of-way lines on the preliminary plans.

The Negotiation activity was broken into "Initial Negotiations" and "Final Negotiations of Remaining Properties" for the purposes of conforming to CPM techniques as closely as possible, reducing the number of parcels that require the supervisor's attention and providing the supervisor with a tighter system of reports and control. The activity labeled "Initial Negotiations" will generally include the assignment of parcels

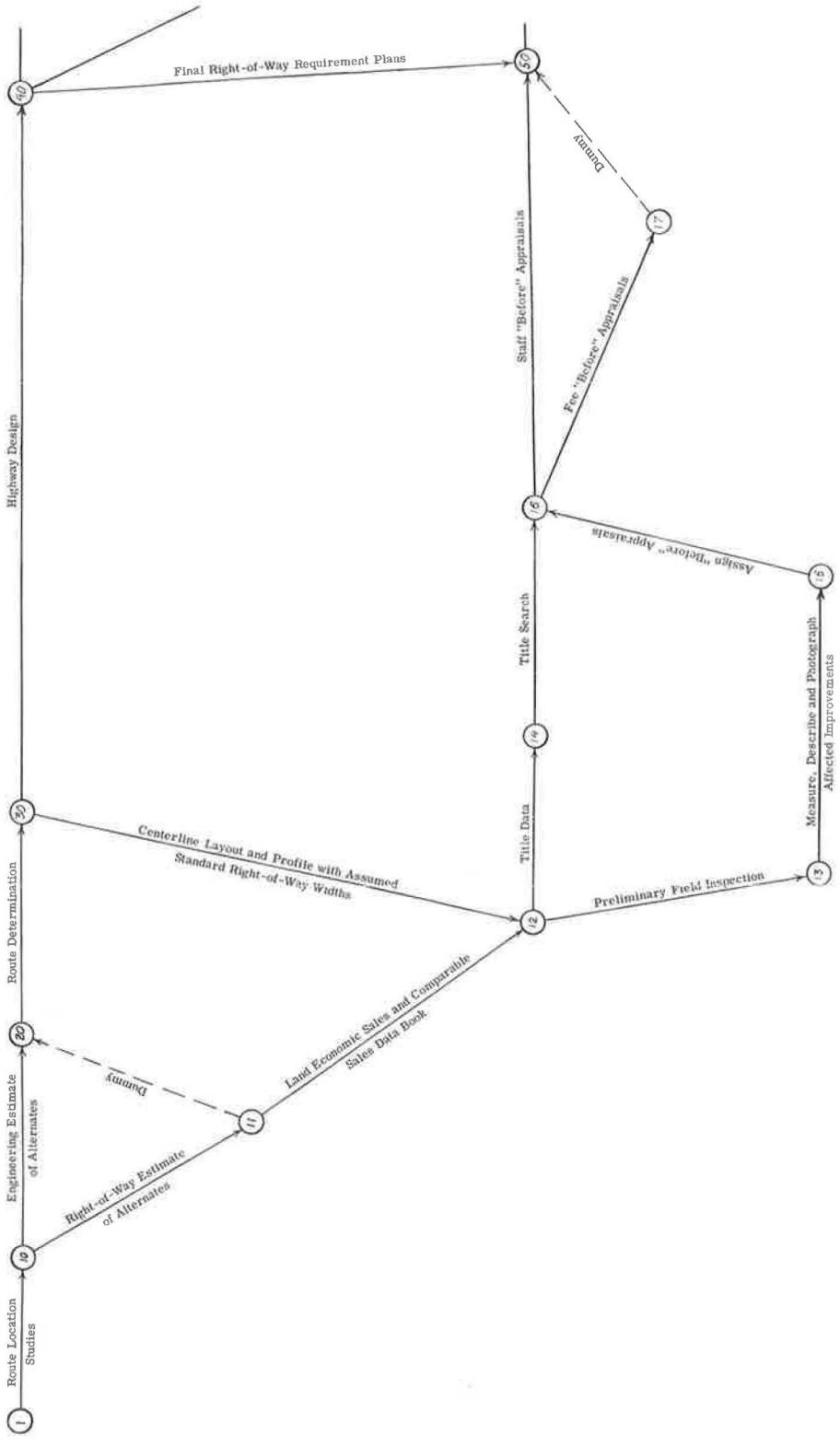


Figure 1.

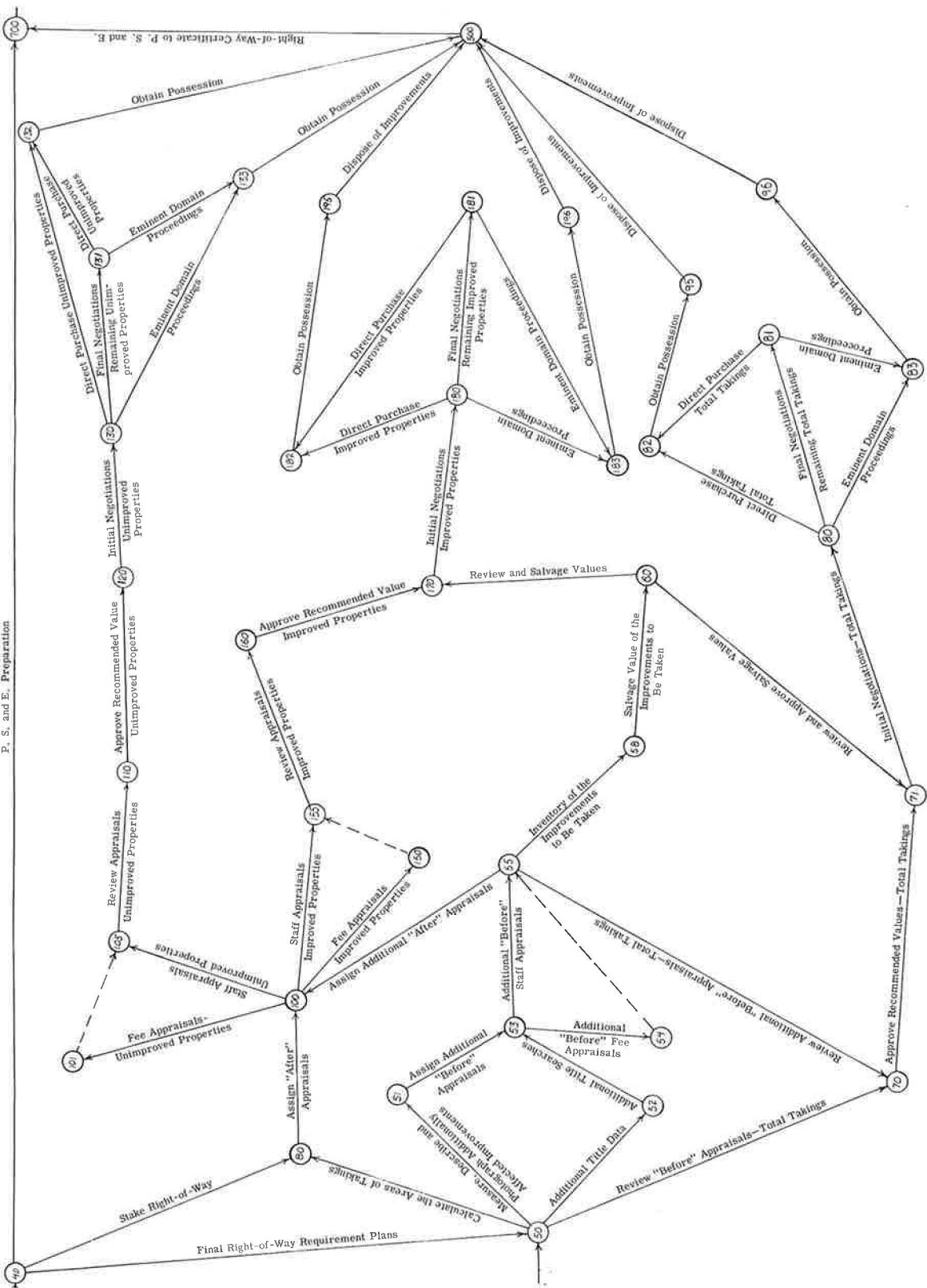


Figure 2.

to the negotiators, the opening of negotiations with the property owner or his representative, and several courtesy calls or contacts. These courtesy calls are made prior to instituting eminent domain proceedings when it is apparent that an amicable settlement will not be reached and the number of calls will be determined by the policy of the State highway department. The activity "Final Negotiations of Remaining Properties" should provide a sufficient period of time to allow additional contacts to be made in those cases where there is an indication that an amicable settlement may be made. This time may be limited by policy to a stated number of calls, after which eminent domain proceedings will automatically be started even though negotiations may be continued to the "courthouse steps" by a representative of either the right-of-way section or the legal section.

If it is the States' policy to dispose of all of the improvements at one time, all of the activities labeled "Obtain Possession" could end at Event 500 and the activity labeled "Dispose of Improvements" could take place between Events 500 and 501. The activity "Right-of-Way Certificate to P. S. and E." would then take place between Events 501 and 700.

Because of the many variations in the engineering and acquisition procedures in the States, the activities in this network have included a very broad area (i. e., Highway Design, Eminent Domain Proceedings). It will be necessary, therefore, for the individual States to break these broad activities into smaller activities and to add such other activities as are necessary to illustrate correctly the acquisition operation within the State. The activities used in this network will be very helpful in developing a "follows what" list to insure that nothing is overlooked. The necessary submissions to and approvals from the U. S. Bureau of Public Roads have been purposely omitted from this network because the necessary additions to and revisions of activities would require their relocation on each of the individual networks of the States.

After a right-of-way network has been developed for a State acquisition operation from this standard or pattern network, time estimates should be taken from the historical records of the right-of-way division and applied to all of the activities to determine which activities fall on the critical path. The activities that appear on the critical path should be examined very closely to determine if they can be performed at the same time as another critical activity or if the time span of the activity can be reduced economically by changing the job methods or by increasing the labor force. Additional computer runs should be made whenever changes are made in the network, or the time estimates, until the network is refined to the point where additional changes are no longer economical.

This network and explanation are presented to aid in the development of individual networks for right-of-way operations by the State highway departments. This network is not expected to be usable in this form by any of the State highway departments at any level of management. For operational use it will need more detail, and for management information and supervision it will need less detail.

The individual State networks should be developed by the men who will actually perform and supervise the acquisition operation. To do this they should know or be instructed in the theory and techniques of CPM networking. With this background and a pattern to follow, the development of a network for right-of-way operations should be considerably reduced in complexity.