

THESIS

APPLICATION OF THE PERT SCHEDULING TECHNIQUE  
TO A NURSERY OPERATION

Submitted by

Beverly A. Ludwick

Horticulture Department

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED  
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ENTITLED APPLICATION OF THE PERT SCHEDULING TECH-  
NIQUE TO A NURSERY OPERATION BE ACCEPTED AS FULFILL-  
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Committee on Graduate Work

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Adviser

\_\_\_\_\_  
Head of Department

## ABSTRACT OF THESIS

### APPLICATION OF THE PERT SCHEDULING TECHNIQUE TO A NURSERY OPERATION

Improved management techniques are needed by the nursery industry as methods of control and scheduling have failed to keep pace with rapid growth. PERT (Program Evaluation and Review Technique) is a management system which could have useful application to the nursery industry.

The PERT system was developed by the United States Navy to coordinate the Polaris submarine program, and is based on a critical path network which allows the user to see important interrelationships. Analysis of these interrelationships allows for the improved coordination, control, and scheduling of a project. The purpose of this study is to investigate the feasibility of applying PERT to nursery production and using the PERT concept in a nursery management classroom.

A broad, general network of production activities was developed based on information provided by 13 nurseries. Bailey Nurseries, Inc. of St. Paul, Minnesota, supplied the estimated time durations for each activity in the network. This study deals with three species: Lonicera sp., Cotoneaster sp., and Fraxinus pennsylvanica. Time durations

were assigned to each activity necessary in the production of that particular species; each activity was assigned either a date that activity would begin or a date it would be completed. This information was prepared for the computer and reports were generated.

The reports which are derived from using the PERT system allow the user to see an overview of the entire operation. Therefore, the effect management's decisions have on interrelated activities can be closely observed and monitored.

Though the scope of this study is general, it would appear that the logic and organization necessary in the development of PERT as a nursery management system could greatly benefit the nursery industry and be useful in teaching nursery principles of business and technology.

Beverly A. Ludwick  
Department of Horticulture  
Colorado State University  
Fort Collins, Colorado 80523  
Spring, 1979

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## INTRODUCTION

### Situation

The nursery business is a rapidly growing business which deals with the production and/or distribution of plant materials. In 1968 Horticulture Research Institute (HRI) made a survey of those nurseries which belonged to a state, regional, or national nursery organization; 5,500 firms were surveyed and of this number 2,000 were wholesale growers (13). In 1977 a similar survey, with the same criteria, was conducted and the number of wholesale growers had increased to more than 5,000 firms (14). As a business grows the decisions made by management become more complex. Too often the methods used in the decision-making process are based upon memory or incomplete records. With increased growth, competition, and market pressures, the effective nursery manager can no longer rely on memory or casual record keeping. In order to deal with the economic pressures caused by such growth, management techniques need to be developed and updated.

To modernize and meet the challenge of a competitive market, it is not uncommon today to find that large nurseries have turned to the use of the computer in such areas as payroll and inventory control. However, the use of the computer has, as yet, not been extended into

the area of production scheduling. It is to this end this study is directed.

### Statement of the Problem

A production manager must make decisions relative to scheduling jobs, ordering supplies, managing inventories, etc.

The Program Evaluation and Review Technique (PERT) is a method available which has been used by some managers to coordinate, control, and schedule the activities necessary for their projects.

Can PERT be utilized or adapted in such a way as to make it an acceptable management tool for nursery production?

### Objectives

This study is the first of several which will be necessary in the process of developing the PERT scheduling method so that it will be acceptable and useful to the nursery industry, therefore, there are both short and long term objectives. The purpose of this study is to:

1. Identify the major production operations which take place in a nursery.
2. Design a basic network which will show the logic sequence of the production operations and assign a duration for each activity.
3. Describe a method in which a network approach can be used as a teaching tool in a nursery management class.

The ultimate objectives of a schedule network will be to provide the nursery manager with a tool which will:

1. Show at a glance the overall plan and progress achieved.
2. Make evident those activities which could be in difficulty and require close observation.
3. Enable managers to visualize operations in more detail and with more accuracy.

### PERT

The Program Evaluation and Review Technique (PERT) is a method used by managers to plan, schedule, and control projects.

The method is one based on the graphic portrayal of the logical arrangement of activities and events. The PERT Guide for Management Use (23) defines an activity as "a job or task to be done, characterized by persons using resources for some period of time." An event is "a specific definable achievement, either the beginning of or the completion of one or more activities." An activity is represented on a network by an arrow which links two successive events. An event may be represented by a circle, square, or rectangle. A logic network is based on the premise that an activity cannot begin until the event preceding it has been completed. Furthermore, an event is not accomplished until all activities leading to it have been completed.

The effectiveness of a network is derived from analysing the interrelationships of activities and events. Of primary importance is

identification of the critical path. The critical path is that path through the network which requires the longest time for completion. The significance lies in the realization that if the time duration is changed for an activity on the critical path, the overall time for the project is altered unless other changes are made. By viewing the network as a whole, it becomes clear what changes can be made and to what degree that change effects other activities. This logical approach to management should greatly facilitate decision-making for the nursery industry.

## REVIEW OF THE LITERATURE

The critical path method of scheduling is identified by various names: PERT (Program Evaluation and Review Technique), PEP (Program Evaluation Procedure), CPM (Critical Path Method), CPPS (Critical Path Planning and Scheduling), and arrow diagramming. This review of the literature is directed towards exploring the use of critical path methods, particularly CPM and PERT, as management tools.

CPM and PERT were developed concurrently and are essentially alike except for one point. The distinction between these two methods is that PERT is probabilistic and CPM is deterministic (20). PERT treats the uncertainty of performance times for an activity by assigning three time estimates for each activity: optimistic, most likely and pessimistic. By using these three times the probability of meeting a schedule date is determined. The statistical approach for PERT is well detailed by Moder and Phillips (20). CPM omits this statistical consideration and deals with a single time estimate. This method is used when there is sufficient historical information and a specific time for an activity can be determined.

The first practical applications of PERT and CPM occurred in 1957 and 1958. PERT was developed by the United States Navy and

was used in the Polaris submarine program while CPM was developed and used by the DuPont Company.

The goal of the Polaris program was to produce a nuclear powered submarine capable of launching an intercontinental missile from below the ocean's surface. The Polaris Program was confronted with the problems of coordinating 60,000 operations involving 3,800 major contractors. It was further complicated by the fact that a project like this had never been attempted (20). For this project, researchers from Lockheed Aircraft Corporation, the Navy Special Projects Office, and the consulting firm of Booz, Allen, and Hamilton developed the Program Evaluation and Review Technique (PERT). PERT is credited for saving 18 months on the project (2).

DuPont Company was looking for a method to minimize the turn-around time and cost of renovating a refinery. DuPont and the Univac Division of the Remington Rand Company developed a project planning and scheduling technique based on a network analysis. This was referred to as Critical Path Planning and Scheduling (CPPS), later known as Critical Path Method (CPM). They found that approximately one half as much planning effort was required as compared to past projects (10).

Other applications of PERT and CPM have resulted in considerable time savings. The Catalytic Construction Company reported that as a result of using PERT in over 50 projects, they had an average time

reduction of 22%. Sun-Maid Growers in California (23) estimated a 25% time reduction when building a processing plant. Not only was time saved, but due to the effectiveness of scheduling and control, Sun-Maid was able to time completion of the plant to coordinate with the growing season and estimated their benefits at about \$1,000,000. The United States government, in particular, has made extensive use of the PERT scheduling technique. Space research, military weapons systems and development of large-scale technical equipment have used the PERT scheduling method. The U.S. government has also used PERT in civil defense programs, training programs, and administrative planning.

The use of network planning has not been limited to governmental ventures but has also been used in small businesses:

- staging a theatrical play from casting through opening night
- establishment of new business locations and outlets
- introduction of new products
- construction, modification, and repair of homes
- advertising campaigns
- management operations
- receipt, classification and handling of materials
- publishing of books.

In general, network planning has provided the users with a better management tool with which to make decisions that result in a savings of time and money.

The use of network scheduling has not been confined to the United States as England and France also use critical path scheduling. However, the United States is credited with the major role in the development of network scheduling (32).

CPM, as developed by DuPont, caught on immediately with the construction industry. One of the first users was a Canadian affiliate of Perini Corporation. Perhaps the largest user was Olin Mathieson which, in 1962, scheduled \$70,000,000 of construction with CPM (3). DuPont and Union Carbide are using CPM to schedule maintenance on large plants. Since the development of CPM and PERT in 1957-58, the U. S. government and the construction industry have been the major users of network scheduling. Thornley (32) provides a summary of project types which have used network planning,

In general, the sophisticated scheduling techniques of networks have been applied to those tasks which involve development of a project from a beginning point to a definite conclusion. A network system has, as yet, not been used in a recurring operation. Battersby (2) points out the difference between management of a project and a recurring activity, however, the distinction is not always sharp as ongoing management may be a series of small projects. In this study we are interested in

the feasibility of applying a network system to the activities in a production oriented nursery and will consider the operations as a series of projects.

Since a nursery business has many uncertainties associated with it, control and management of production can be very difficult and the use of traditional scheduling methods are not completely satisfactory (21, 22, 29, 30, 33). Traditionally in nurseries, either no formal scheduling is attempted, or various types of work calendars, "diaries," or bar charts have been used to control production (15).

Hill Nursery, Dundee, Illinois (28), uses a large flow chart in their landscape department for job scheduling. The chart indicates the jobs to be done, crew assignment, and status of the job. The information is not specific and is limited to: in progress, not completed, and completed.

Inter-State Nurseries of Hamburg, Iowa, use a combination of the work flow idea and a calendar. Sjulín (39) reports that there are satisfactory aspects of their scheduling procedure but there are also limitations. The major problem concerns the uncertainty of the weather; the second limitation is the ability to predict demand.

These same limitations were described by George Oki, Oki Nursery in California (22) as: "weather activities" and the "fickle

purchasing public." Oki uses target marketing data to schedule critical dates for various cultural operations.

Weather is such an important variable that the production manager of Mt. Arbor Nurseries of Shenandoah, Iowa, states "Most of our operations are so dependent on the weather and time of year, it would not be feasible to establish a certain time for each procedure" (21).

William Flemer III (11) of Princeton Nurseries, Princeton, New Jersey, also feels that the uncertainty of weather overrides the possibility of scheduling nursery operations beyond the level of a weekly operations diary.

Similar to Princeton Nurseries, Monrovia Nursery, Azusa, California, also keeps a record book. Their books contain the amount of stock to be grown and the preferred times to accomplish this. They are quite successful in meeting their quotas but have difficulty in "getting things done on time" (33).

Shugert (30), production manager of American Garden Cole, Inc., Circleville, Ohio, recognizes the need for scheduling and uses production lists for 28 production functions. These lists cover such operations as harvest, planting, hardwood cuttings, softwood cuttings, grafting, budding, etc. The lists include a date due to the general manager and approximate completion date for the operation. Bar graphs and monthly labor hours for these 28 production functions are also used as

management tools. The program at A. G. Cole works well but Shugert reports a tremendous amount of paper work and dedicated people are required.

Pinney (24) of Evergreen Nursery Co., Inc., Sturgeon Bay, Wisconsin, also recognizes the importance of good management procedures and called in a management consultant who worked with the nursery for approximately seven and one half months. The resulting management system is one which fits that particular nursery's needs, but as Shugert stated, a tremendous amount of time by all levels of personnel is needed in order for the system to work.

In most cases, it would seem that nursery businesses recognize the importance of scheduling production but have not yet devised a completely satisfactory method. The uncertainty of weather is often cited as a cause for unsuccessful programs. A. G. Cole, Inc., seems not to have this problem but states paper work and labor dollars are a definite factor to contend with. Whether the limitation is paper work, weather, or the unpredictable public, a method needs to be devised to overcome these limitations and enable the nursery industry to control and manage more effectively.

Carlson (5), a horticultural economist, feels that the uncertainties that arise in the production process can be reduced by means of a more thorough description of the process. The keeping and making of

records is essential if the production process is to be detailed. Unfortunately, nurserymen are not historically known for keeping detailed records. John Armstrong (8), past president of American Association of Nurserymen, put it aptly when he said, "Although the nursery business is one of the most interesting, useful, and honorable of vocations, authentic and accurate information pertaining to it is exceedingly scarce."

Shugert (19) recognizes that much effort is necessary to collect useful information. He devised a system in which responsible individuals in the field maintain a record for each planting block. These records contain labor, materials, and harvesting data and are collected and used by Shugert in making production decisions.

Once data is collected, an efficient method is needed for analysis. Since time is of concern, the use of a computer would be desirable. Already many nurseries recognize the value of the computer and use them in such areas as payroll, order acknowledgements, confirmations, billing, commission and inventory records (22, 27).

However, the use of a computer in a nursery operation has met with some opposition. Lamb, Kelly, and Bowbrick (16) state that computer-aided planning will not be suitable for a nursery for a long time. They give the following reasons:

1. Computer programs deal with one year crops rather than crops which may take three or four years to produce.

2. The level of detail in computer programs is not sufficient to allow for complexities of the nursery business.

These authors feel that the strongest argument against using computers is that nurserymen learn by doing their own planning and can discover for themselves where the difficulties and bottlenecks are.

Contrary to the opinion of Lamb, et al. (16), Oki (1) credits the computer with his success in business. A computer is used in order preparation and processing and in dispatching. "Shrinking the time between receiving and delivering a customer's order has given us a competitive edge."

Perhaps the adaptation of PERT to the nursery business could overcome the doubts expressed by some nurserymen concerning scheduling procedures and computers. The very nature of PERT demands that management be involved in planning. This factor alone would eliminate the argument of Lamb, Kelly, and Bowbrick. Moder and Phillips (20) list some additional advantages of using PERT which would apply to the nursery business as well as other types of business:

1. PERT imposes a discipline for considering elements and their interrelationships required to achieve objectives.
2. PERT provides a structured plan which leads to a determination of the total estimated required time. This can be compared to a desired completion date.

3. PERT provides quick and effective methods of communicating plans.
4. PERT provides visible proof that a job has been done.
5. PERT provides a means for evaluating progress and for forecasting problems in meeting a schedule.

PERT allows the manager to:

1. Measure accomplishments against objectives and due dates
2. Fix responsibility and assure continuity (even if there is a turnover)
3. Avoid omission of tasks and obtain visibility of total program
4. Spot potential problem areas in time to make corrections
5. Allocate funds, labor resources, and time between critical and non-critical areas.

However, even with a list of obvious advantages for using PERT, the literature also reveals problems (4, 12, 32). Pocock (25) lists potential problem areas which management should be aware of:

1. PERT is no automatic system, human judgement is at the source of all that PERT can provide and all that PERT can do is provide output to aid further human judgement.
2. PERT often clashes with traditional organization patterns.

Pocock goes on to state, "There have been successes and failures with PERT, but there emerges one clear fact: some managements using some variation of PERT state specifically that it has improved

their performance and saved them money." Seelig and Rubin (20) compared the results of 48 research and development projects and concluded that use of PERT lead to improvement of schedule performance and that this was, primarily, as a result of improvement in communications.

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## METHODS

As described by Collins (6), a network consists of three elements: planning, scheduling, and control. The planning element results in a graphic model which shows logic and is a foundation for the other two. Scheduling involves estimating time durations for each activity and in order that the network be an effective management tool, the third element, control, must be closely monitored.

Planning requires the assimilation of accurate information. To obtain this information, network manuals stress the importance of working with those individuals most directly involved with the activities being scheduled. Input was, therefore, solicited from the nursery industry. Thirteen nurseries were chosen, giving consideration to size and location. Large nurseries (business volume \$500,000 or above) were selected as they could provide the diversity of information needed. Location of the nursery was also important in the selection as climate will affect the type of activity carried out.

A questionnaire and cover letter (Appendices A and B) were designed to survey representative major nurseries as to the type of scheduling procedures in use or, if indeed, scheduling was attempted on any organized level. The questionnaire was sent to the following nurseries:

American Garden Cole Inc.  
Circleville, Ohio

Bailey Nurseries Inc.  
St. Paul, Minnesota

Evergreen Nursery Co. Inc.  
Sturgeon Bay, Wisconsin

Forrest Keeling Nursery  
Elsberry, Missouri

Hill Nursery Co.  
Dundee, Illinois

Inter-State Nurseries Inc.  
Hamburg, Iowa

Monrovia Nursery Co.  
Azusa, California

Mount Arbor Nurseries  
Shenandoah, Iowa

Oki Nursery Inc.  
Sacramento, California

Polk Nursery Co. Inc.  
Winter Haven, Florida

Princeton Nurseries  
Princeton, New Jersey

Wilmore Nurseries Inc.  
Wheat Ridge, Colorado

Zelenka Evergreen Nursery Inc.  
Green Haven, Michigan

Following the questionnaire, a checksheet (Appendix C) listing major production operations was sent to the eleven responding nurseries. The managers were asked to check the operation if it occurred in the month listed and to list any additional activities which

should be included in their operation. The replies from the eleven nurseries were consolidated into a master list showing major production activities which could occur in a given month depending on geographical location. Upon completion of the list of activities, the graphic network model was constructed (Fig. 1). The procedures for graphic representation are well documented (7, 20, 26).

The level of detail to be included in a network must also be considered. The Special Projects Office of the Navy has used PERT extensively and warns that too large a network is unwieldy and that changes are difficult and time-consuming (31). However, if detail is inadequate, control is lost. Walton's (32) discussion on levels of detail was used as a guide for designing a summary network for nursery production. To insure integration, the total program must be considered first and then moved downward to a more detailed level. The procedure is to progress through various levels with Level I consisting of the areas of operation, Level II containing the activities necessary to complete the operations in Level I, and Level III being subdivisions of certain single activities into subnetworks. Levels I and II have been accomplished, but the third level will be developed in subsequent studies as subdivision of single activities was considered too detailed for the initial study.

Figure 1. Nursery network for field production.

Abbreviations:

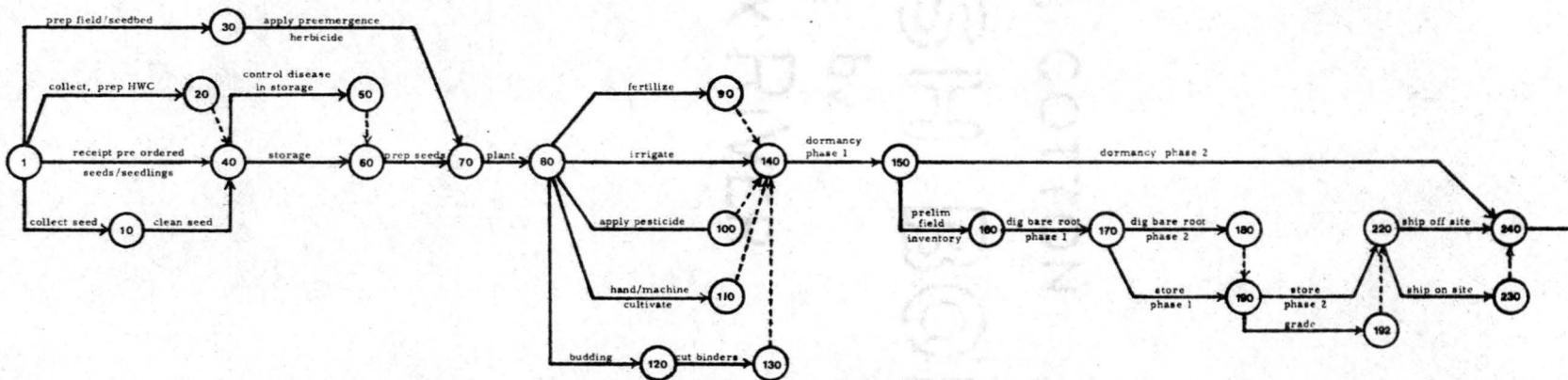
HWC ..... hardwood  
pre ..... previously  
prep ..... prepare  
prelim ..... preliminary

Symbols:

activity  The arrow represents a logical relationship and its length has no relation to duration.

dummy  A zero time activity used to show logic and a dependent relationship.

event  A specific accomplishment which consumes neither time nor resources.



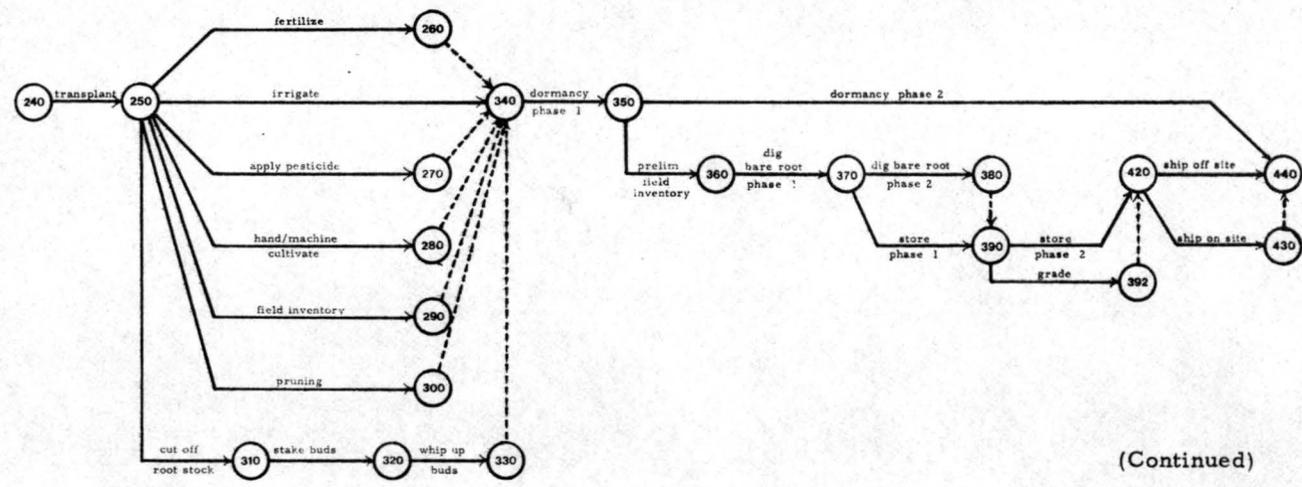
(Continued)

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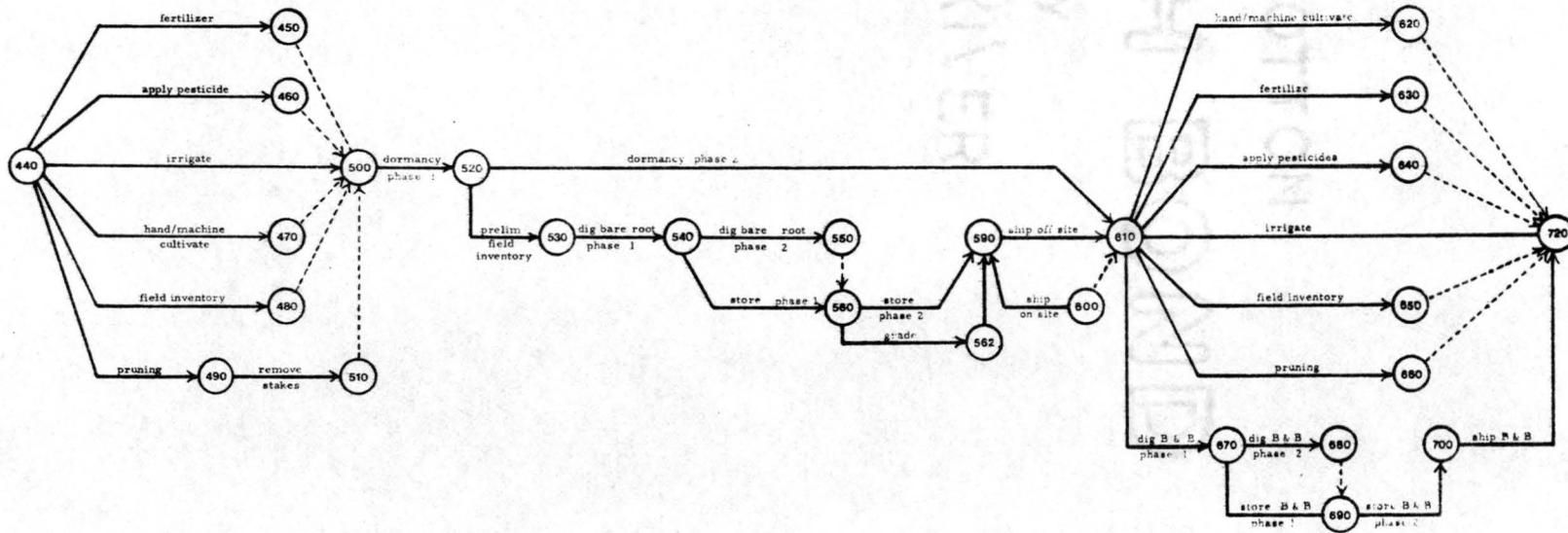
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Once the graphic portrayal of events and activities was complete, the second phase, scheduling, began. Time durations were estimated and assigned to each activity. In the nursery industry, the factors which must be considered in making time estimations are climate, species grown, and the number of men and machines to be used. The times assigned for each activity are unique to individual nurseries, therefore, for the scheduling phase the input for this study was limited to one source. Bailey Nurseries, Inc., of St. Paul, Minnesota agreed to provide the necessary data (Appendices D, E and F).

Three sets of data were provided by Bailey's and were based on the production of green ash (Fraxinus pennsylvanica), honeysuckle (Lonicera sp.), and cotoneaster (Cotoneaster sp.). The time estimates were expressed in units that varied from fractions of hours to months. For clarity and ease of calculations, the units were standardized into day units.

Following the procedure outlined in the PERT/Time Reference Manual (7), input was prepared for computer calculations. The computerized activity reports for a nursery production schedule are sorted by predecessor event number, successor event number, least slack, expected date ( $T_E$ ) and latest allowed date ( $T_L$ ). Examples are presented in Appendices G, H, I, J, and K. A glossary of terms which are used in conjunction with PERT can be found in Appendix L.

## RESULTS AND DISCUSSION

The activity reports generated by the computer contain identical information, but the order in which it is listed varies. Though a manager may find each of the report forms relevant, the sorts by "Expected Date" and "Latest Allowed Date" seem most useful. For example, a manager may not choose to begin all activities at the earliest expected date. If he wishes to determine what activities could be started by a particular date, however, he can use the report ordered by "Expected Date" and merely draw a line under that date; all activities above that line could have been started prior to that date. For reference, see the activity report in Appendix J. Appendix K contains a report ordered by "Latest Allowed Date" and is useful when a manager wants to review progress. A line can be drawn under the current date and if there are any activities above that line, which have not been started, they are behind schedule. To comprehend the analysis process, the components of the activity report must first be understood.

The column headed "Activ. Time"(Tables 1 and 2) reports the most likely amount of time an activity is expected to take for completion. The activity time ( $t_e$ ) is derived from calculation of an optimistic ( $t_o$ ), most likely ( $t_m$ ), and pessimistic ( $t_p$ ) time estimation

Table 1  
 PERT/TIME  
 ACTIVITY REPORT  
 REPORTING ORGN. CONTRACT NO.

PERT NETWORK 2 COTONEASTER  
 1ST SORT KEY PREDECESSOR EVENT NO.  
 2ND SORT KEY LEAST SLACK  
 EVENT

TERM-  
 REPORT DATE- 8/31/79  
 RELEASE DATE- 8/31/79

PRED.	SUCC.	ACTIVITY DESCRIPTION	PROB.	ACTIV. TIME	DATE EXPECTED	DATE ALLOWED	DATE COMP/SCHED	SLACK	REMAINING TIME	ORG.	ACCOUNT NO.
A1	A30	PREP FIELD/SEEDBED		0.1		9/ 5/79	A 8/31/79	0.6	0.0		
A1	A1	COLLECT SEED		0.2		9/ 4/79	A 8/31/79	0.4	0.0		
IA10	A40	CLEAN SEED		0.1	9/ 2/79	9/ 4/79	B 9/ 2/79	0.2	0.3		
A140	A150	DORMANCY PHASE 1		4.3	10/ 5/79	10/10/79	R11/15/79	0.7	4.9		
A150	A240	DORMANCY PHASE 2		26.4	4/10/80	4/15/80	R 4/15/80	0.7	31.3		
A240	A250	TRANSPLANT		0.1	4/11/80	4/30/80	R 4/30/80	2.8	31.4		
A250	A260	FERTILIZE		0.1	4/11/80	9/15/80	R 9/15/80	22.2	31.5		
A250	A280	HAND/MACHINE CULTIVATE		0.1	4/11/80	9/15/80	R 9/15/80	22.2	31.5		
A250	A340	IRRIGATE		0.2	4/12/80	9/15/80	R 9/15/80	22.1	31.6		
A250	A290	FIELD INVENTORY		0.1	4/11/80	9/15/80	R 9/15/80	22.2	31.5		
A260	A340	DUMMY ACTIVITY		0.0	4/11/80	9/15/80	R 9/15/80	22.2	31.5		
A260	A340	DUMMY ACTIVITY		0.0	4/11/80	9/15/80	R 9/15/80	22.2	31.5		
IA30	A70	APPLY PREEMERGENCE HERBICIDE		0.0	8/31/79	9/ 5/79	R 9/ 5/79	0.6	0.0		
A340	A350	DORMANCY PHASE 1		4.3	10/25/80	10/25/80	B10/25/80	0.0	59.5		
A350	A360	PRELIM. FIELD INVENTORY		0.0	10/25/80	10/25/80	R11/16/80	0.0	59.5		
A350	A440	DORMANCY PHASE 2		17.0	2/24/81	4/30/81	R 4/30/81	9.2	76.5		
A360	A370	DIG BARE ROOT PHASE 1		0.1	10/26/80	10/26/80	R11/17/80	0.0	59.6		
A370	A380	DIG BARE ROOT PHASE 2		0.1	10/27/80	11/18/80	R11/18/80	3.2	59.7		
A370	A390	STORE PHASE 1		3.0	12/22/80	12/22/80	R 1/15/81	0.0	67.6		
A360	A390	DUMMY ACTIVITY		0.0	10/27/80	11/18/80	R11/18/80	3.2	59.7		
A390	A420	STORE PHASE 2		14.0	4/ 1/81	4/ 1/81	R 4/ 1/81	0.0	81.6		
A390	A392	GRADE		0.3	12/24/80	4/ 1/81	B12/ 3/80	13.7	67.9		
A392	A420	DUMMY ACTIVITY		0.0	12/24/80	4/ 1/81	R 4/ 1/81	13.7	67.9		
A40	A60	STORAGE		0.1	9/ 4/79	9/ 5/79	R 9/ 5/79	0.2	0.4		
A420	A440	SHIP OFF SITE		0.1	4/ 2/81	4/30/81	B 4/ 2/81	4.0	81.7		
A60	A70	PREP SEEDS		0.0	9/ 4/79	9/ 5/79	R 9/ 5/79	0.2	0.4		
A70	A80	PLANT		0.1	9/ 4/79	9/ 9/79	R 9/15/79	0.7	0.5		
A80	A140	IRRIGATE		0.1	9/ 5/79	9/10/79	R 9/16/79	0.7	0.6		

ENGINEER SM BROWN

Table 2

PERT/TIME  
ACTIVITY REPORT

REPORTING ORGN. CONTRACT NO.

PERT NETWORK 3 HONEYSUCKLE HWC  
1ST SORT KEY PREDECESSOR EVENT NO.  
2ND SORT KEY LEAST SLACK  
EVENTTERM-  
REPORT DATE- 2/ 1/79  
RELEASE DATE- 2/ 1/79

PRED.	SUCC.	ACTIVITY DESCRIPTION	PROB.	ACTIV. TIME	DATE EXPECTED	DATE ALLOWED	DATE COMP/SCHED	SLACK	REMAINING TIME	ORG.	ACCOUNT NO.
A1	A20	COLLECT.PREP HW CUTTINGS		0.2		2/ 1/79	A 2/ 1/79	0.0	0.0		
A1	A30	PREP FIELD/SEEDBED		0.1		4/16/79	A 4/18/79	-0.3	0.0		
A100	A140	DUMMY ACTIVITY		0.0	4/21/79	10/ 3/79	R10/30/79	23.4	11.3		
A110	A140	DUMMY ACTIVITY		0.0	4/22/79	10/ 3/79	R10/30/79	23.2	11.5		
A140	A150	DORMANCY PHASE 1		4.3	10/31/79	11/ 2/79	B10/31/79	0.2	38.8		
A150	A160	PRELIM FIELD INVENTORY		0.0	10/31/79	11/ 9/79	R11/15/79	1.3	38.8		
A150	A240	DORMANCY PHASE 2		26.4	5/ 8/80	5/ 8/80	B 5/ 8/80	0.0	65.4		
A160	A170	DIG BARE ROOT PHASE 1		0.1	11/ 1/79	11/10/79	R11/16/79	1.3	38.9		
A170	A180	DIG BARE ROOT PHASE 2		0.1	11/ 2/79	11/18/79	R11/18/79	2.3	39.0		
A170	A190	STORE PHASE 1		8.0	12/29/79	1/ 8/80	B12/29/79	1.3	46.9		
A180	A190	DUMMY ACTIVITY		0.0	11/ 2/79	1/ 8/80	R 1/18/80	9.2	39.0		
A190	A192	GRADE		0.3	4/ 3/80	4/15/80	B 4/ 3/80	1.7	60.5		
A190	A220	STORE PHASE 2		14.0	4/ 6/80	4/15/80	R 4/15/80	1.3	60.9		
A192	A220	DUMMY ACTIVITY		0.0	4/ 3/80	4/15/80	R 4/15/80	1.7	60.5		
IA20	A40	DUMMY ACTIVITY		0.0	2/ 1/79	2/ 1/79	R 2/ 1/79	0.0	0.0		
A220	A240	SHIP OFF SITE		0.1	4/16/80	5/ 8/80	B 4/16/80	3.1	62.3		
IA30	A70	APPLY PREEMERGENCE HERBICIDE		0.1	4/19/79	4/17/79	R 4/17/79	-0.3	11.0		
A40	A60	STORAGE		0.8	2/ 6/79	4/17/79	R 4/18/79	9.9	0.8		
A40	A50	CONTROL DISEASE IN STORAGE		0.1	2/ 1/79	4/17/79	R 4/18/79	10.6	0.1		
A50	A60	DUMMY ACTIVITY		0.0	2/ 1/79	4/17/79	R 4/18/79	10.6	0.1		
A60	A70	PREP SEEDS		0.0	2/ 6/79	4/17/79	R 4/17/79	9.9	0.8		
A70	A80	PLANT		0.2	4/20/79	4/18/79	R 4/18/79	-0.3	11.2		
A80	A90	FERTILIZE		0.1	4/21/79	10/ 3/79	R10/30/79	23.4	11.3		
A80	A100	APPLY PESTICIDE		0.1	4/21/79	10/ 3/79	R10/30/79	23.4	11.3		
A80	A140	IRRIGATE		0.1	4/21/79	10/ 3/79	R10/30/79	23.4	11.3		
A80	A110	HAND/MACHINE CULTIVATE		0.3	4/22/79	10/ 3/79	R10/30/79	23.2	11.5		
A90	A140	DUMMY ACTIVITY		0.0	4/21/79	10/ 3/79	R10/30/79	23.4	11.3		

for each activity. The optimistic time is the minimum time in which an activity can be accomplished if everything goes well. The pessimistic time is based on the length of time an activity would take under adverse conditions. The most likely time is the most realistic estimate. To then calculate the expected time ( $t_e$ ) for each activity, a formula approximating the beta distribution is used (7):

$$t_e = \frac{t_o + 4(t_m) + t_p}{6}$$

The activity time is expressed in units of weeks and tenths of weeks.

Sand (17) reports that the major weakness of a PERT system is the subjectivity involved in determining the three time estimates for each activity. Sand goes on to state, however, that if the project is completely novel, the "educated guess of the specialist may be the best available time estimate." The reports are only as accurate as the information upon which they are based and the time estimations which are used are critical to the network. Carruthers (32) defines an ideal estimate as one which is consistent, accurate, and unbiased, therefore, estimations must be made by those people most closely involved with the individual activities and great care must be taken so that the resulting estimates are as accurate as possible.

The PERT method of using three time durations per activity can be utilized to advantage in the weather dependent nursery industry

where much uncertainty exists. Each activity can be analysed for its weather sensitivity and the three times estimated accordingly. The time estimates for activity A1 - A10 (Collect Seed) in Table 1 were  $t_o$  of 1 day,  $t_m$  of 2 days, and  $t_p$  of 3 days. Using the equation noted above:

$$t_e = \frac{1 + 4(2) + 3}{6} = 2 \text{ days} = 0.2 \text{ week} .$$

The weighted average derived from the calculation of  $t_e$  gives the manager a realistic time for the duration of an activity. The calculation for  $t_e$  may be performed manually, but a computer greatly speeds up the process.

The earliest time an event can be expected to take place ( $T_E$ ) is located under the column headed "Expected." The dates found here were acquired by a forward pass through the network events in which the expected duration for each activity was considered. The "Allowed" column provides the dates by which an activity must be accomplished in order to avoid a delay in the overall project. This calculation is derived by making a backward pass through the network from a required or scheduled completion date and with consideration given to the expected duration for each activity. A description of the calculations used in the forward and backward pass can be found in PERT literature (4, 7, 9, 20).

The dates in the column headed "Comp/Sched" are dates provided by the user. The letter "A" preceding the date indicates the

actual completion date for that activity. "R" represents the required completion date for an activity and can have an affect on the backward pass analysis. If an expected begin date is used, the letter "B" precedes the date and the date which appears in the report is the begin date plus the expected time ( $t_e$ ). The "Slack" column reflects the difference between the latest allowed date and the expected completion date for an activity.

The "Remaining Time" column indicates how much time exists from the report date until the expected completion date ( $T_E$ ) of the activity. The column headed "Prob." is for probability and was not used, however, the option exists if a manager desires, and it will indicate the probability of meeting the scheduled or allowed date, whichever is provided. The remaining columns are "Org." (Organization) and "Account No.", and are used for identification of various sectors within the organization.

The information found under these headings is used by the manager to make decisions. He must analyse the reports to make decisions pertaining to resource and time allocations. He must decide what, if any, changes need to be made to maximize the efficiency of his operation and meet his objectives. Due to the general scope of this initial study, the reports that have been generated do not effectively demonstrate the degree to which analysis can serve as a useful

management tool, but do reveal the potential for effective control and management at a more detailed level.

In Table 1 it can be seen that activity A420-A440 (Ship Off Site) requires 0.1 week for completion. The expected begin date reflects that date (4/1/81) plus the  $t_e$  of 0.1 week resulting in the report date of 4/2/81. The date supplied as input for the required completion date for event 440 (termination of network) was 4/30/81, therefore, the "Allowed Date" for activity A420-A440 is indicated as 4/30/81. The difference in the times of  $T_E$  and  $T_L$  for A420-A440 result in a slack of four weeks. Theoretically, this would mean that the activity of shipping has the flexibility to occur within this four week period without causing a delay in the required completion date 4/30/81 as specified by the user.

Slack analysis enables the manager to quickly identify potential or immediate problems. If there is a considerable amount of positive slack, consideration should be given to reducing levels of effort in that area and perhaps using those resources in other areas where they could be more beneficial. If slack is negative, that is  $T_E$  is greater than  $T_L$ , a manager may choose to reallocate resources, change the performance requirements, or if these changes cannot be made and the activity lies on the critical path, the ultimate completion date may have to be extended. Because of treating the species independently,

and at a general level, a critical path determination was not made in this study.

The activity reports which have been generated from the broad skeleton network show that the length of activity time is small relative to the total network length. A normal delay, therefore, would not create a serious problem as sufficient flexibility is reflected due to the relationship. Table 2 illustrates this point. It can be seen that if activity A1-A30 (Prep Field/Seedbed) was not completed until 4/18/79, that it exceeds its allowed time by 0.3 week. This negative slack is reflected in the succeeding activities A30-A70 (Apply Pre-emergence Herbicide) and A70-A80 (Plant); at which time there is sufficient slack in the succeeding activities and the negative slack is absorbed.

This report, in itself, would not be detailed enough to allow a manager to make a decision as to what action, if any, should be taken. For example, if the situation were such that the field was not prepared as originally scheduled, the manager could determine only the long term effect caused by the delay. He could not make a decision as to where the resources, which had been allocated to this activity, could be efficiently used as this study has limited itself to production of only

three species and these on a broad level. If the network were more detailed, however, a manager could review his reports and make a sound decision as to where the freed resources could be used to most benefit the total nursery operation.

Once a network system has been adopted for use, a decision must be made concerning the frequency of reports. To allow PERT to be a dynamic tool, biweekly intervals are suggested (23). However, in the nursery business, a manager may want to consider a schedule which would vary over the course of the year with the most frequent reporting during the growing season.

Information obtained by this study indicates that PERT can aid nursery management but to be accepted it must be tailored to individual operations. A second consideration necessary for acceptance is the total support by those individuals within the operation without whose aid the manager could not obtain the necessary data to make PERT a success. A business interested in working with PERT must plan for its introduction, and training is of the utmost importance. Training is usually of two types: it involves those people who must be familiar with the computations, and it pertains to those who need only to understand the principles. A suggested outline for a training program can be found in Appendix M.

A user of PERT or any new or different management system should expect some problems. Initially, there is the resistance to

change. This must be overcome. Communication and involvement of personnel at all levels is of the greatest importance. If properly presented, the principles involved in PERT can be understood and appreciated by most people. Other problems which may be encountered involve improper preparation of the network, unrealistic time estimates and lack of adequate monitoring. All of these problems can be overcome but their existence must be recognized.

It would appear that there is a future for PERT in the nursery industry, but methods need to be developed which will present the network concept to the industry. Articles in trade journals and introduction of the network scheduling concept in nursery management classes at the college level could facilitate the use of PERT or a similar system. The following chapter will present information as to how a network scheduling technique could be utilized in the classroom.

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## USE OF A NETWORK SCHEDULING TECHNIQUE IN A CLASSROOM

A nursery management class is complex in that it involves knowledge of horticulture, business, and the integration of the two. Attempting to interrelate these areas can be most difficult as transition from one to the other may lack coherence. Perhaps the use of a network scheduling technique could more clearly illustrate the relationship for the student.

Formats used in any class presentation are as numerous and varied as the instructors who teach them. There is no intent in this chapter to dictate how a class should be taught but to present some ideas which could be adapted to an individual's program.

One possible approach when using a schedule network in a nursery management class would be to spend 1.5 quarters on nursery technology and nursery business. The remaining one half quarter could be used to teach the principles of networking and its integration into the nursery operation. Gaming situations could be included where certain conditions and changes occur in a nursery operation requiring analysis and subsequent managerial decisions. An additional higher level course might also be made available to students requesting more detailed knowledge and application of the concept.

An outline for the network portion of a class might include the following:

I. Introduction

- A. Concept and purpose of schedule networks
- B. History of networks

II. Fundamental Concepts

- A. Graphic symbols
- B. Simple examples of networks
- C. Rules of network planning
- D. Preparation of the logic plan
- E. Time assignments and computations

III. Scheduling Techniques

- A. Determining management objectives
- B. Allocation of resources
- C. Preparing the schedule
- D. Adjusting the schedule
- E. Updating

IV. Computer Use

- A. Basic principles of computers
- B. Application of computers in network analysis

The preceding outline was adapted from an outline used in a 16 hour course by Radcliffe, et al. (26).

The calculations necessary in networking may be accomplished manually or by computer. The calculations are simple and may be accomplished with relative ease up to 150 activities. Beyond this point, calculations can become cumbersome and the use of a computer is advisable. Whether or not to use the computer in the class will most likely be determined by budgetary considerations. The use of a computer would have the benefit of exposing the student to a management tool which has become prevalent in today's business, however, it is important to point out that the benefits of network planning can be derived without the use of a computer. The principles of networking are basic to good management in that they demand the important concepts of logic and the importance of interrelationships. Malcolm, et al. (18) reports that more effective management can be realized with just the procedures used in preparing a graphic logic diagram. Not all students will be working for large nurseries where a large network management system is required or where computer use is readily available. The concepts, however, could be applied in practically any endeavor the student might undertake.

When a computer approach is used, care must be taken that learning to use a computer package does not predominate over the more critical technological nursery procedures and their application to the principles of networking. Information pertaining to both manual and computer networking is available (18, 20).

Presenting technical and managerial information to a class in a form which is interesting, useful, and challenging, is the goal of a concerned instructor but one that is often difficult to achieve. Perhaps the addition of network planning to a nursery management class can facilitate the achievement of this goal.

## SUMMARY AND CONCLUSION

The nursery industry has grown rapidly in the last 10 years and in many cases has outgrown management capabilities. This study has provided a necessary skeleton network needed as a prototype for the industry and instructors to perceive the concept and technique of networking and its application to the nursery industry. It is recommended, however, that future studies address those areas which have surfaced as potential problems.

The general approach chosen for this study was necessary, but now a more specific focus must be sought. In order to encourage the nursery industry to adopt PERT or a similar network system, future studies should be carried out in conjunction with a specific nursery. Further breakdown into more detailed activities will most likely be nursery specific and may not have general application. A total program which is applicable and profitable to one real, existing nursery will do more for the general acceptance of PERT by the industry than any general or hypothetical situation no matter how well conceived.

A second area which must be analysed further is that of time durations assigned to each activity. This study used activity time based on the time required by a specific number of men and

machines to complete a task. Input data was then adjusted to accommodate the time required for growth and dormancy; this was done by specifying certain begin and end dates. Using this approach resulted in an undefined critical path. There are several points that might be considered in future study which would clarify the situation:

1. The network could reflect a growth activity.
2. The time durations could be based on the total amount of time over which an activity takes place rather than man hours. For example, should irrigation require .6 weeks of man hours or 12.0 weeks of time?
3. A combination of times based on man hours and total duration could be considered.

Once the study of PERT is carried further and the problem with time assignment has been clarified, consideration should be given to developing a time scale and investigating resource leveling. An example of a time scale and a resource leveling chart may be found in Appendices N and O.

Although problems do exist in the application of PERT, they can be overcome. A certain amount of dedication and commitment will be necessary by those desiring to use PERT but they will be appropriately rewarded with a tool which can be used not only in scheduling and control, but also as a simulation model, and thus, enable the manager to better direct and predict his future.

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APPENDICES

## Appendix A

June 13, 1978

Dear

Coordination and scheduling of activities necessary to take a plant from propagation to sale can be difficult as the activities are many and varied. Could we have a few minutes of your time and benefit of your experience and knowledge in investigating this complex area of the nursery business.

Dr. Bert Swanson and myself are working on a technique for scheduling the many activities that comprise a nursery operation. The objective of this scheduling technique is to be able to clearly see how one activity interrelates with another and to better predict problem areas and remedy the situation prior to the problem occurring.

We have selected 11 nurseries because of their size, location and success in business. With such a small sampling your response is valuable to us and hopefully you can find the time to complete the attached questionnaire and return it to us in the enclosed stamped envelope.

Sincerely yours,

B. T. Swanson

Beverly Ludwick

Enc.

## Appendix B

A scheduling procedure is any method, calendar, bar chart, flow chart, etc., which indicates what nursery operation is going on at a particular time, when it will be started and completed, and perhaps additional information.

Please Answer All Applicable Questions

1. Are you using some type of a scheduling procedure in your nursery business? Yes \_\_\_\_\_, No \_\_\_\_\_.
2. If your answer to the above is no, please comment as to why you don't feel it necessary.
3. If the answer to number one is yes, briefly explain what method is being used.
4. Is the method used one with which you are completely satisfied? Yes \_\_\_\_\_, No \_\_\_\_\_.
5. What aspects of the method are most satisfactory? Please list.
6. What aspects of this method are least satisfactory? Please list.

COMMENTS Please use the remaining space on this page, as well as the back to make any comments you may have.

## Appendix C

The following list of activities is an attempt at composing a comprehensive list of major nursery operations on a monthly basis. It is assumed that sales take place each month and thus are not included.

In explanation of occurrence:

- 0 - activity not performed
- 1 - activity performed during first half of the month
- 2 - activity performed during second half of the month
- 1 & 2 - activity performed during first and second half of the month

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MARCH

Activities	Occurrence			
	0	1	2	1 & 2
1. plant hardwood cuttings, deciduous and evergreen grafts				
2. prune trees and shrubs				
3. receive and stock plant material				
4. ship orders				
5. mix soil				
6. plant container stock				
7. irrigate fields				
8. irrigate containers				
9. fertilize fields				
10. fertilize containers				
11. prepare fields for planting				
12. plant lining out stock				
13. prepare seed bed				
14. seed				
15. apply preemergence herbicide				
16. control diseases in storage				
17. dig bare root stock				
18. grade spring dug stock				
19. dig B & B stock				
<u>Additional:</u>				

APRIL

Activities	Occurrence			
	0	1	2	1 & 2
1. plant hardwood cuttings				
2. prune trees and shrubs				
3. receive and stock plant material				
4. ship orders				
5. mix soil				
6. plant container stock				
7. irrigate fields				
8. irrigate containers				
9. fertilize fields				
10. fertilize containers				
11. plant fields				
12. plant seed beds				
13. apply preemergence herbicide				
14. dig bare root stock				
15. grade spring dug stock				
16. cultivate field for weed control				
17. hand weed				
18. dig B & B				
<u>Additional:</u>				

MAY

Activities	Occurrence			
	0	1	2	1 & 2
1. plant hardwood cuttings				
2. receive and stock plant material				
3. ship orders				
4. mix soil				
5. plant container stock				
6. irrigate fields				
7. irrigate containers				
8. fertilize fields				
9. fertilize containers				
10. plant fields				
11. plant seed beds				
12. apply preemergence herbicide				
13. dig bare root				
14. grade spring dug stock				
15. cultivate fields for weed control				
16. hand weed				
17. dig B & B				
18. apply pesticides				
19. remove polyethylene film cover from container stock				
20. apply shade cloth				
<u>Additional:</u>				

JUNE

## Activities

## Occurrence

	0	1	2	1 & 2
1. root prune trees and shrubs				
2. receive and stock plant material				
3. ship orders				
4. mix soil				
5. potting operations				
6. irrigate fields				
7. irrigate containers				
8. collect, clean and store seeds				
9. apply preemergence herbicide				
10. cultivate fields for weed control				
11. hand weed				
12. apply pesticides				
13. disease control				
14. apply shade cloth				
15. apply shade cloth and compound				
16. take softwood cuttings				
17. stick softwood cuttings				
18. stake and tie plants requiring support				
19. apply pest emergent herbicide				
20. complete field fertilization				
21. container fertilization				
<u>Additional:</u>				

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## Appendix D

50,000 Honeysuckle (Lonicera sp.)  
Hardwood Cuttings

I	J	Description	Time*		
			t <sub>0</sub>	t <sub>m</sub>	t <sub>p</sub>
1	20	collect, prep hw cuttings	15	20	25
1	30	prep field/seedbed	6	8	10
30	20	apply preemergence herbicide	2	3	4
40	60	storage	1 mo	2 mo	3 mo
40	50	control disease in storage	1	2	3
60	70	prepseeds	0	0	0
70	80	plant	12	16	18
80	90	fertilize	1	2	3
80	100	apply pesticide	6	9	12
80	140	irrigate	4	6	8
80	110	hand/machine cultivate	18	24	30
140	150	dormancy phase 1	1 mo	1 mo	1 mo
150	160	prelim field inventory	0	0	0
150	240	dormancy phase 2	5 mo	6 mo	7 mo
160	170	dig bare root, phase 1	8	8	8
170	180	dig bare root, phase 2	6	8	10
170	190	store, phase 1	2 mo	2 mo	2 mo
190	192	grade	22	26	35
190	220	store, phase 2	3.5 mo	3.5 mo	3.5 mo
220	240	ship off site	7	8	9

\* time units are hours unless otherwise specified.

## Appendix E

50,000 Green Ash (Fraxinus pennsylvanica) Buds

I	J	Description	Time*		
			t <sub>o</sub>	t <sub>m</sub>	t <sub>o</sub>
1	40	receipt preordered seedlings	6	7	8
1	30	prep field/seedbed	7	8	10
30	70	apply preemergence herbicide	0	0	0
40	60	storage	1 mo	1 mo	1 mo
60	70	prep seeds	0	0	0
70	80	plant	14	16	20
80	120	budding	40	50	60
80	100	apply pesticide	0	0	0
80	110	hand/machine cultivate	25	40	50
80	90	fertilize	0	0	0
80	140	irrigate	18	30	42
120	130	cut binders	100	200	300
140	150	dormancy phase 1	1 mo	1 mo	1 mo
150	240	dormancy phase 2	5 mo	6 mo	7 mo
240	250	transplant	0	0	0
250	310	cut off root stock	30	40	50
250	300	pruning	24	28	32
250	270	apply pesticide	0	0	0
250	290	field inventory	3	5	6
250	280	hand/machine cultivate	18	24	30

\* time units are hours unless otherwise specified.

I	J	Description	Time*		
			t <sub>o</sub>	t <sub>m</sub>	t <sub>p</sub>
250	260	fertilize	1	2	3
250	340	irrigate	30	40	50
310	320	stake buds	40	50	60
320	330	whip up bud	8	10	12
340	350	dormancy phase 1	1 mo	1 mo	1 mo
350	360	prelim field inventory	0	0	0
350	440	dormancy phase 2	5 mo	6 mo	7 mo
360	370	dig bare root phase 1	8	8	8
370	380	dig bare root phase 2	7	12	22
370	390	store phase 1	2 mo	2 mo	2 mo
390	392	grade	30	35	45
390	420	store phase 2	3.5 mo	3.5 mo	3.5 mo
420	440	ship off site	10	12	14

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## Appendix F

50,000 Cotoneaster (Cotoneaster sp.)  
Seedlings

I	J	Description	Time*		
			t <sub>0</sub>	t <sub>m</sub>	t <sub>p</sub>
1	30	prep field/seedbed	3	4	6
1	10	collect seed	4	18	24
10	40	clean seed	5	6	8
30	70	apply preemergence herbicide	0	0	0
40	60	storage	0	0	0
60	70	prep seeds	0	0	0
70	80	plant	3	4	5
80	90	fertilize	2	2	4
80	140	irrigate	8	8	16
140	150	dormancy phase 1	1 mo	1 mo	1 mo
150	240	dormancy phase 2	5 mo	6 mo	7 mo
240	250	transplant	10	12	14
250	260	fertilize	2	3	4
250	340	irrigate	8	16	24
250	280	hand/machine cultivate	1	2	3
250	290	field inventory	3	5	6
340	350	dormancy phase 1	1 mo	1 mo	1 mo
350	440	dormancy phase 2	5 mo	6 mo	7 mo
350	360	prelim field inventory	3	5	6
360	370	dig bare root, phase 1	8	8	8

\* time units are hours unless otherwise specified.

I	J	Description	Time*		
			t <sub>o</sub>	t <sub>m</sub>	t <sub>p</sub>
370	380	dig bare root, phase 2	6	8	10
370	390	store phase 1	2 mo	2 mo	2 mo
390	392	grade	22	26	35
390	420	store phase 2	3.5 mo	3.5 mo	3.5 mo
420	440	ship off site	7	8	9

Appendix G

PERT/TIME  
ACTIVITY REPORT

REPORTING ORGN. CONTRACT NO.

PERT NETWORK 1 ASH BUDS  
1ST SORT KEY PREDECESSOR EVENT NO.  
2ND SORT KEY LEAST SLACK  
EVENT

TERM-  
REPORT DATE- 3/14/79  
RELEASE DATE- 3/14/79

PRED.	SUCC.	ACTIVITY DESCRIPTION	PROB.	ACTIV. TIME	DATE EXPECTED	DATE ALLOWED	DATE COMP/SCHED	SLACK	TIME REMAINING	ORG.	ACCOUNT NO.
A1	A43	RECEIPT PRE ORDERED S/SPLNGS		0.1		3/16/79	A 3/15/79	0.2	0.0		
A1	A31	PREP FIELD/SEEDBED		0.1		4/16/79	A 3/15/79	4.6	0.0		
A100	A140	DUMMY ACTIVITY		0.0	4/17/79	9/ 9/79	R10/30/79	20.6	4.8		
A110	A140	DUMMY ACTIVITY		0.0	4/21/79	9/ 9/79	R10/30/79	20.0	5.4		
A120	A130	CUT BINDERS		3.6	8/26/79	9/ 9/79	B 8/26/79	1.8	23.6		
A130	A140	DUMMY ACTIVITY		0.0	8/26/79	9/ 9/79	R10/30/79	1.8	23.6		
A140	A150	DORMANCY PHASE 1		4.4	9/27/79	10/10/79	R11/15/79	1.8	28.0		
A150	A240	DORMANCY PHASE 2		26.5	4/ 3/80	4/15/80	R 4/15/80	1.8	54.5		
A240	A250	TRANSPLANT		0.0	4/ 3/80	4/30/80	R 4/30/80	3.9	54.5		
A250	A310	CUT OFF ROOT STOCK		0.7	4/ 7/80	5/15/80	R 5/15/80	5.4	55.2		
A250	A300	PRUNING		0.5	4/ 6/80	8/31/80	R 8/31/80	21.0	55.0		
A250	A270	APPLY PESTICIDE		0.0	4/ 3/80	8/31/80	R 8/31/80	21.5	54.5		
A250	A290	FIELD INVENTORY		0.1	4/ 3/80	8/31/80	R 8/31/80	21.4	54.6		
A250	A280	HAND/MACHINE CULTIVATE		0.4	4/ 5/80	8/31/80	R 8/31/80	21.1	54.9		
A250	A260	FERTILIZE		0.0	4/ 3/80	8/31/80	R 8/31/80	21.5	54.5		
A250	A340	IRRIGATE		0.7	4/ 7/80	10/ 9/80	R10/15/80	26.2	55.2		
A260	A340	DUMMY ACTIVITY		0.0	4/ 3/80	10/ 9/80	R10/15/80	26.9	54.5		
A270	A340	DUMMY ACTIVITY		0.0	4/ 3/80	10/ 9/80	R10/15/80	26.9	54.5		
A280	A340	DUMMY ACTIVITY		0.0	4/ 5/80	10/ 9/80	R10/15/80	26.5	54.9		
A290	A340	DUMMY ACTIVITY		0.0	4/ 3/80	10/ 9/80	R10/15/80	26.8	54.6		
IA30	A70	APPLY PREEMERGENCE HERBICIDE		0.0	3/15/79	4/16/79	R 4/16/79	4.6	0.1		
A300	A340	DUMMY ACTIVITY		0.0	4/ 6/80	10/ 9/80	R10/15/80	26.4	55.0		
A310	A320	STAKE BUDS		0.9	6/ 8/80	10/ 8/80	B 6/ 8/80	17.3	64.0		
A320	A330	WHIP UP BUD		0.1	8/ 3/80	10/ 9/80	B 8/ 3/80	9.4	72.0		
A330	A340	DUMMY ACTIVITY		0.0	8/ 3/80	10/ 9/80	R10/15/80	9.4	72.0		
A340	A350	DORMANCY PHASE 1		4.4	9/ 3/80	11/ 9/80	R11/15/80	9.4	76.4		
A350	A360	PRELIM FLD INVENTORY		0.0	9/ 3/80	11/ 9/80	R11/15/80	9.4	76.4		
A350	A440	DORMANCY PHASE 2		17.1	1/ 5/81	4/30/81	R 4/30/81	16.5	93.5		
A360	A370	DIG BARE FOOT PHASE 1		0.1	9/ 4/80	11/ 9/80	R11/16/80	9.4	76.5		
A370	A380	DIG BARE FOOT PHASE 2		0.2	9/ 6/80	11/18/80	R11/18/80	10.4	76.7		
A370	A390	STORE PHASE 1		8.0	12/29/80	1/ 7/81	B12/29/80	1.2	92.7		
A380	A390	DUMMY ACTIVITY		0.0	9/ 6/80	1/ 7/81	R 1/16/81	17.2	76.7		
A390	A392	GRADE		0.7	4/ 6/81	4/15/81	B 4/ 6/81	1.3	106.6		
A390	A420	STORE PHASE 2		14.0	4/ 7/81	4/15/81	R 4/15/81	1.2	106.7		
A392	A420	DUMMY ACTIVITY		0.0	4/ 6/81	4/15/81	R 4/15/81	1.3	106.6		
IA40	A60	STORAGE		4.4	4/15/79	4/16/79	R 4/16/79	0.2	4.5		
A420	A440	SHIP OFF SITE		0.2	4/ 8/81	4/30/81	R 4/30/81	3.1	106.9		
A60	A70	PREP SEEDS		0.0	4/15/79	4/16/79	R 4/16/79	0.2	4.5		
A70	A80	PLANT		0.3	4/17/79	4/18/79	R 4/18/79	0.2	4.8		
A80	A120	BUDDING		0.9	7/ 8/79	8/14/79	B 7/ 8/79	5.3	16.5		
A80	A100	APPLY PESTICIDE		0.0	4/17/79	9/ 9/79	R10/30/79	20.6	4.8		
A80	A110	HAND/MACHINE CULTIVATE		0.6	4/21/79	9/ 9/79	R10/30/79	20.0	5.4		
A80	A90	FERTILIZE		0.0	4/17/79	9/ 9/79	R10/30/79	20.6	4.8		
A80	A140	IRRIGATE		0.5	4/20/79	9/ 9/79	R10/30/79	20.1	5.3		
A90	A140	DUMMY ACTIVITY		0.0	4/17/79	9/ 9/79	R10/30/79	20.6	4.8		

Appendix H

PERCENT/TIME  
ACTIVITY REPORT

REPORTING ORGN.

CONTRACT NO.

PERT NETWORK : ASH BUDS  
1ST SORT KEY SUCCESSOR EVENT NO.  
2ND SORT KEY LEAST SLACK

TERM-  
REPORT DATE- 3/14/79  
RELEASE DATE- 3/14/79

EVENT	PREL.	SUCC.	ACTIVITY DESCRIPTION	PROB.	ACTIV. TIME	EXPECTED DATE	ALLOWED DATE	COMP/SCHED DATE	SLACK	REMAINING TIME	ORG.	ACCOUNT NO.
A80	A100		APPLY PESTICIDE		0.0	4/17/79	9/ 9/79	R10/30/79	20.6	4.8		
A80	A110		HAND/MACHINE CULTIVATE		0.6	4/21/79	9/ 9/79	R10/30/79	20.0	5.4		
A80	A120		BIDDING		0.9	7/ 8/79	8/14/79	B 7/ 8/79	5.3	16.5		
A120	A130		CUT BINDERS		3.6	8/26/79	9/ 9/79	B 8/26/79	1.8	23.6		
A130	A140		DUMMY ACTIVITY		0.0	8/26/79	9/ 9/79	R10/30/79	1.8	23.6		
A100	A140		DUMMY ACTIVITY		0.0	4/17/79	9/ 9/79	R10/30/79	20.6	4.8		
A110	A140		DUMMY ACTIVITY		0.0	4/21/79	9/ 9/79	R10/30/79	20.0	5.4		
A80	A140		IRRIGATE		0.5	4/20/79	9/ 9/79	R10/30/79	20.1	5.3		
A90	A140		DUMMY ACTIVITY		0.0	4/17/79	9/ 9/79	R10/30/79	20.6	4.8		
A140	A150		DORMANCY PHASE 1		4.4	9/27/79	10/10/79	R11/15/79	1.8	28.0		
A150	A240		DORMANCY PHASE 2		26.5	4/ 3/80	4/15/80	R 4/15/80	1.8	54.5		
A240	A250		TRANSPLANT		0.0	4/ 3/80	4/30/80	R 4/30/80	3.9	54.5		
A250	A260		FERTILIZE		0.0	4/ 3/80	8/31/80	R 8/31/80	21.5	54.5		
A250	A270		APPLY PESTICIDE		0.0	4/ 3/80	8/31/80	R 8/31/80	21.5	54.5		
A250	A280		HAND/MACHINE CULTIVATE		0.4	4/ 5/80	8/31/80	R 8/31/80	21.1	54.9		
A250	A290		FIELD INVENTORY		0.1	4/ 3/80	8/31/80	R 8/31/80	21.4	54.6		
A1	A300		PREP FIELD/SEEDBED		0.1		4/16/79	A 3/15/79	4.6	0.0		
A250	A300		PRUNING		0.5	4/ 6/80	8/31/80	R 8/31/80	21.0	55.0		
A250	A310		CUT OFF ROOT STOCK		0.7	4/ 7/80	5/15/80	R 5/15/80	5.4	55.2		
A310	A320		STAKE BUND		0.9	6/ 8/80	10/ 8/80	B 6/ 8/80	17.3	64.0		
A320	A330		WHIP UP BUD		0.1	8/ 3/80	10/ 9/80	B 8/ 3/80	9.4	72.0		
A300	A340		DUMMY ACTIVITY		0.0	4/ 6/80	10/ 9/80	R10/15/80	26.4	55.0		
A240	A340		DUMMY ACTIVITY		0.0	4/ 5/80	10/ 9/80	R10/15/80	26.5	54.9		
A250	A340		DUMMY ACTIVITY		0.0	4/ 3/80	10/ 9/80	R10/15/80	26.8	54.6		
A260	A340		DUMMY ACTIVITY		0.0	4/ 3/80	10/ 9/80	R10/15/80	26.9	54.5		
A270	A340		DUMMY ACTIVITY		0.0	4/ 3/80	10/ 9/80	R10/15/80	26.9	54.5		
A330	A340		DUMMY ACTIVITY		0.0	8/ 3/80	10/ 9/80	R10/15/80	9.4	72.0		
A250	A340		IRRIGATE		0.7	4/ 7/80	10/ 9/80	R10/15/80	26.2	55.2		
A340	A350		DORMANCY PHASE 1		4.4	9/ 3/80	11/ 9/80	R11/15/80	9.4	76.4		
A350	A360		PRELIM FLD INVENTORY		0.0	9/ 3/80	11/ 9/80	R11/15/80	9.4	76.4		
A360	A370		DIG BARE ROOT PHASE 1		0.1	9/ 4/80	11/ 9/80	R11/15/80	9.4	76.5		
A370	A380		DIG BARE ROOT PHASE 2		0.2	9/ 6/80	11/18/80	R11/18/80	10.4	76.7		
A370	A390		SLOPE PHASE 1		8.0	12/29/80	1/ 7/81	B12/29/80	1.2	92.7		
A300	A390		DUMMY ACTIVITY		0.0	9/ 6/80	1/ 7/81	R 1/16/81	17.2	76.7		
A390	A392		GRADE		0.7	4/ 6/81	4/15/81	B 4/ 6/81	1.3	106.6		
A1	A400		RECEIPT PRE ORDERED S/SALINGS		0.1		3/16/79	A 3/15/79	0.2	0.0		
A390	A420		STORE PHASE 2		14.0	4/ 7/81	4/15/81	R 4/15/81	1.2	106.7		
A390	A420		DUMMY ACTIVITY		0.0	4/ 6/81	4/15/81	R 4/15/81	1.3	106.6		
A420	A440		SHIP OFF SITE		0.2	4/ 8/81	4/30/81	R 4/30/81	3.1	106.9		
A350	A440		DORMANCY PHASE 2		17.1	1/ 5/81	4/30/81	R 4/30/81	16.5	93.5		
I040	A60		STORAGE		4.4	4/15/79	4/16/79	R 4/16/79	0.2	4.5		
A60	A70		PREP SEEDS		0.0	4/15/79	4/16/79	R 4/16/79	0.2	4.5		
I030	A70		APPLY PREEMERGENCE HERBICIDE		0.0	3/15/79	4/16/79	R 4/16/79	4.6	0.1		
A70	A80		PLANT		0.3	4/17/79	4/18/79	R 4/18/79	0.2	4.8		
A80	A90		FERTILIZE		0.0	4/17/79	9/ 9/79	R10/30/79	20.6	4.8		

Appendix I

PERT/TIME  
ACTIVITY REPORT

REPORTING ORGN.

CONTRACT NO.

PERT NETWORK 1 ASH BUDS  
1ST SORT KEY LEAST SLACK  
2ND SORT KEY LEAST SLACK  
EVENT

TERM-  
REPORT DATE- 3/14/79  
RELEASE DATE- 3/14/79

PRED.	SUCC.	ACTIVITY DESCRIPTION	PROB.	ACTIV. TIME	EXPECTED DATE	ALLOWED DATE	COMP/SCHED	SLACK	REMAINING TIME	ORG.	ACCOUNT NO.
A70	A80	PLANT		0.3	4/17/79	4/18/79	R 4/18/79	0.2	4.8		
IA40	A60	STORAGE		4.4	4/15/79	4/16/79	R 4/16/79	0.2	4.5		
A60	A70	PREP SEEDS		0.0	4/15/79	4/16/79	R 4/16/79	0.2	4.5		
A1	A4	RECEIPT PRE ORDERED S/SOLNGS		0.1		3/16/79	A 3/15/79	0.2	0.0		
A370	A390	STORE PHASE 1		8.0	12/29/80	1/ 7/81	B12/29/80	1.2	92.7		
A390	A420	STORE PHASE 2		14.0	4/ 7/81	4/15/81	R 4/15/81	1.2	106.7		
A392	A420	DUMMY ACTIVITY		0.0	4/ 6/81	4/15/81	R 4/15/81	1.3	106.6		
A390	A392	GRADE		0.7	4/ 5/81	4/15/81	B 4/ 6/81	1.3	106.6		
A150	A240	DORMANCY PHASE 2		26.5	4/ 3/80	4/15/80	R 4/15/80	1.8	54.5		
A140	A150	DORMANCY PHASE 1		4.4	9/27/79	10/10/79	R11/15/79	1.8	28.0		
A130	A140	DUMMY ACTIVITY		0.0	8/26/79	9/ 9/79	R10/30/79	1.8	23.6		
A120	A130	CUT BINDERS		3.6	8/26/79	9/ 9/79	B 8/26/79	1.8	23.6		
A420	A440	SHIP OFF SITE		0.2	4/ 8/81	4/30/81	R 4/30/81	3.1	106.9		
A240	A250	TRANSP ANT		0.0	4/ 3/80	4/30/80	R 4/30/80	3.9	54.5		
A1	A3	PREP FIELD/SEEDBED		0.1		4/16/79	A 3/15/79	4.6	0.0		
IA30	A70	APPLY PREEMERGENCE HERBICIDE		0.0	3/15/79	4/16/79	R 4/16/79	4.6	0.1		
A80	A120	BUDDING		0.9	7/ 8/79	8/14/79	B 7/ 8/79	5.3	16.5		
A250	A310	CUT OFF ROOT STOCK		0.7	4/ 7/80	5/15/80	R 5/15/80	5.4	55.2		
A320	A330	WHIP UP BUD		0.1	8/ 3/80	10/ 9/80	B 8/ 3/80	9.4	72.0		
A360	A370	DIG BARE ROOT PHASE 1		0.1	9/ 4/80	11/ 9/80	R11/16/80	9.4	76.5		
A340	A350	DORMANCY PHASE 1		4.4	9/ 3/80	11/ 9/80	R11/15/80	9.4	76.4		
A350	A360	PRELIM FLD INVENTORY		0.0	9/ 3/80	11/ 9/80	R11/15/80	9.4	76.4		
A330	A340	DUMMY ACTIVITY		0.0	8/ 3/80	10/ 9/80	R10/15/80	9.4	72.0		
A370	A380	DIG BARE ROOT PHASE 2		0.2	9/ 6/80	11/18/80	R11/18/80	10.4	76.7		
A350	A440	DORMANCY PHASE 2		17.1	1/ 5/81	4/30/81	R 4/30/81	16.5	93.5		
A380	A390	DUMMY ACTIVITY		0.0	9/ 6/80	1/ 7/81	R 1/16/81	17.2	76.7		
A310	A320	STAKE BUDS		0.9	6/ 8/80	10/ 8/80	B 6/ 8/80	17.3	64.0		
A80	A110	HAND/MACHINE CULTIVATE		0.6	4/21/79	9/ 9/79	R10/30/79	20.0	5.4		
A110	A140	DUMMY ACTIVITY		0.0	4/21/79	9/ 9/79	R10/30/79	20.0	5.4		
A80	A140	IRRIGATE		0.5	4/20/79	9/ 9/79	R10/30/79	20.1	5.3		
A100	A140	DUMMY ACTIVITY		0.0	4/17/79	9/ 9/79	R10/30/79	20.6	4.8		
A80	A100	APPLY PESTICIDE		0.0	4/17/79	9/ 9/79	R10/30/79	20.6	4.8		
A90	A140	DUMMY ACTIVITY		0.0	4/17/79	9/ 9/79	R10/30/79	20.6	4.8		
A80	A90	FERTILIZE		0.0	4/17/79	9/ 9/79	R10/30/79	20.6	4.8		
A250	A330	PRUNING		0.5	4/ 0/80	8/31/80	R 8/31/80	21.0	55.0		
A250	A280	HAND/MACHINE CULTIVATE		0.4	4/ 5/80	8/31/80	R 8/31/80	21.1	54.9		
A250	A290	FIELD INVENTORY		0.1	4/ 3/80	8/31/80	R 8/31/80	21.4	54.6		
A250	A260	FERTILIZE		0.0	4/ 3/80	8/31/80	R 8/31/80	21.5	54.5		
A250	A270	APPLY PESTICIDE		0.0	4/ 3/80	8/31/80	R 8/31/80	21.5	54.5		
A250	A340	IRRIGATE		0.7	4/ 7/80	10/ 9/80	R10/15/80	26.2	55.2		
A300	A340	DUMMY ACTIVITY		0.0	4/ 0/80	10/ 9/80	R10/15/80	26.4	55.0		
A280	A340	DUMMY ACTIVITY		0.0	4/ 5/80	10/ 9/80	R10/15/80	26.5	54.9		
A290	A340	DUMMY ACTIVITY		0.0	4/ 3/80	10/ 9/80	R10/15/80	26.8	54.6		
A260	A340	DUMMY ACTIVITY		0.0	4/ 3/80	10/ 9/80	R10/15/80	26.9	54.5		
A270	A340	DUMMY ACTIVITY		0.0	4/ 3/80	10/ 9/80	R10/15/80	26.9	54.5		

Appendix J

PERT/TIME  
ACTIVITY REPORT

REPORTING ORGN.

CONTRACT NO.

PERT NETWORK 1 ASH BUDS  
1ST SORT KEY EXPECTED DATE (TE)  
2ND SORT KEY LEAST SLACK  
EVENT

TERM-  
REPORT DATE- 3/14/79  
RELEASE DATE- 3/14/79

PRED.	SUCC.	ACTIVITY DESCRIPTION	PROB.	ACTIV. TIME	DATE EXPECTED	DATE ALLOWED	DATE COMP/SCHED	SLACK	REMAINING TIME	ORG.	ACCOUNT NO.
A1	A30	PREP FIELD/SEEDBED		0.1		4/16/79	A 3/15/79	4.6	0.0		
IA30	A70	APPLY PREEMERGENCE HERBICIDE		0.0	3/15/79	4/16/79	R 4/16/79	4.6	0.1		
A1	A40	RECEIPT PRE ORDERED S/SDLNGS		0.1		3/16/79	A 3/15/79	0.2	0.0		
A60	A70	PREP SEEDS		0.0	4/15/79	4/16/79	R 4/16/79	0.2	4.5		
IA40	A60	STORAGE		4.4	4/15/79	4/16/79	R 4/16/79	0.2	4.5		
A70	A80	PLANT		0.3	4/17/79	4/18/79	R 4/18/79	0.2	4.8		
A100	A140	DUMMY ACTIVITY		0.0	4/17/79	9/ 9/79	R10/30/79	20.6	4.8		
A80	A100	APPLY PESTICIDE		0.0	4/17/79	9/ 9/79	R10/30/79	20.6	4.8		
A90	A140	DUMMY ACTIVITY		0.0	4/17/79	9/ 9/79	R10/30/79	20.6	4.8		
A80	A90	FERTILIZE		0.0	4/17/79	9/ 9/79	R10/30/79	20.6	4.8		
A90	A140	IRRIGATE		0.5	4/20/79	9/ 9/79	R10/30/79	20.1	5.3		
A110	A140	DUMMY ACTIVITY		0.0	4/21/79	9/ 9/79	R10/30/79	20.0	5.4		
A80	A110	HAND/MACHINE CULTIVATE		0.6	4/21/79	9/ 9/79	R10/30/79	20.0	5.4		
A60	A120	BUDDING		0.9	7/ 8/79	8/14/79	B 7/ 8/79	5.3	16.5		
A130	A140	DUMMY ACTIVITY		0.0	8/26/79	9/ 9/79	R10/30/79	1.8	23.6		
A120	A130	CUT BINDERS		3.6	8/26/79	9/ 9/79	B 8/26/79	1.8	23.6		
A140	A150	DORMANCY PHASE 1		4.4	9/27/79	10/10/79	R11/15/79	1.8	28.0		
A150	A240	DORMANCY PHASE 2		26.5	4/ 3/80	4/15/80	R 4/15/80	1.8	54.5		
A240	A250	TRANSPLANT		0.0	4/ 3/80	4/30/80	R 4/30/80	3.9	54.5		
A250	A270	APPLY PESTICIDE		0.0	4/ 3/80	8/31/80	R 8/31/80	21.5	54.5		
A250	A260	FERTILIZE		0.0	4/ 3/80	8/31/80	R 8/31/80	21.5	54.5		
A270	A340	DUMMY ACTIVITY		0.0	4/ 3/80	10/ 9/80	R10/15/80	26.9	54.5		
A260	A340	DUMMY ACTIVITY		0.0	4/ 3/80	10/ 9/80	R10/15/80	26.9	54.5		
A290	A340	DUMMY ACTIVITY		0.0	4/ 3/80	10/ 9/80	R10/15/80	26.9	54.6		
A250	A290	FIELD INVENTORY		0.1	4/ 3/80	6/31/80	R 8/31/80	21.4	54.6		
A250	A280	HAND/MACHINE CULTIVATE		0.4	4/ 5/80	8/31/80	R 8/31/80	21.1	54.9		
A280	A340	DUMMY ACTIVITY		0.0	4/ 5/80	10/ 9/80	R10/15/80	26.5	54.9		
A300	A340	DUMMY ACTIVITY		0.0	4/ 6/80	10/ 9/80	R10/15/80	26.4	55.0		
A250	A300	PRUNING		0.5	4/ 6/80	8/31/80	R 8/31/80	21.0	55.0		
A250	A340	IRRIGATE		0.7	4/ 7/80	10/ 9/80	R10/15/80	26.2	55.2		
A250	A310	CUT OFF ROOT STOCK		0.7	4/ 7/80	5/15/80	R 5/15/80	5.4	55.2		
A310	A320	STAKE BUDS		0.9	6/ 8/80	10/ 8/80	B 6/ 8/80	17.3	64.0		
A320	A330	WHIP UP BUD		0.1	8/ 3/80	10/ 9/80	B 8/ 3/80	9.4	72.0		
A330	A340	DUMMY ACTIVITY		0.0	8/ 3/80	10/ 9/80	R10/15/80	9.4	72.0		
A340	A350	DORMANCY PHASE 1		4.4	9/ 3/80	11/ 9/80	R11/15/80	9.4	76.4		
A350	A360	PRELIM FLD INVENTORY		0.0	9/ 3/80	11/ 9/80	R11/15/80	9.4	76.4		
A360	A370	DIG BARE ROOT PHASE 1		0.1	9/ 4/80	11/ 9/80	R11/16/80	9.4	76.5		
A370	A380	DIG BARE ROOT PHASE 2		0.2	9/ 6/80	11/18/80	R11/18/80	10.4	76.7		
A380	A390	DUMMY ACTIVITY		0.0	9/ 6/80	1/ 7/81	R 1/16/81	17.2	76.7		
A370	A390	STORE PHASE 1		8.0	12/29/80	1/ 7/81	B12/29/80	1.2	92.7		
A390	A440	DORMANCY PHASE 2		17.1	1/ 5/81	4/30/81	R 4/30/81	16.5	93.5		
A392	A420	DUMMY ACTIVITY		0.0	4/ 6/81	4/15/81	R 4/15/81	1.3	106.6		
A390	A392	GRADE		0.7	4/ 6/81	4/15/81	B 4/ 6/81	1.3	106.6		
A390	A420	STORE PHASE 2		14.0	4/ 7/81	4/15/81	R 4/15/81	1.2	106.7		
A420	A440	SHIP OFF SITE		0.2	4/ 8/81	4/30/81	R 4/30/81	3.1	106.9		

Appendix K

PERT/TIME  
ACTIVITY REPORT

REPORTING ORGN.

CONTRACT NO.

PERT NETWORK : ASH BUDS  
1ST SORT KEY : LATEST ALLOWED DATE  
2ND SORT KEY : LEAST SLACK

TERM-  
REPORT DATE- 3/14/79  
RELEASE DATE- 3/14/79

EVENT		ACTIV.	DATE	DATE	DATE	REMAINING	SLACK	TIME	ORGN.	ACCOUNT NO.
PRED.	SUCC.	PROB.	EXPECTED	ALLOWED	COMP/SCHED	SLACK	TIME	ORGN.	ACCOUNT NO.	
A1	A41	0.1		3/16/79	A 3/15/79	0.2	0.0			
A60	A70	0.0	4/15/79	4/16/79	R 4/16/79	0.2	4.5			
A1	A34	0.1		4/16/79	A 3/15/79	4.6	0.0			
IA30	A70	0.0	3/15/79	4/16/79	R 4/16/79	4.6	0.1			
IA40	A60	4.4	4/15/79	4/16/79	R 4/16/79	0.2	4.5			
A70	A80	0.3	4/17/79	4/18/79	R 4/18/79	0.2	4.8			
A80	A120	0.9	7/ 8/79	8/14/79	B 7/ 8/79	5.3	16.5			
A80	A110	0.6	4/21/79	9/ 9/79	R10/30/79	20.0	5.4			
A130	A140	0.0	8/26/79	9/ 9/79	R10/30/79	1.8	23.6			
A120	A130	3.6	8/26/79	9/ 9/79	B 8/26/79	1.8	23.6			
A80	A140	0.5	4/20/79	9/ 9/79	R10/30/79	20.1	5.3			
A110	A140	0.0	4/21/79	9/ 9/79	R10/30/79	20.0	5.4			
A90	A140	0.0	4/17/79	9/ 9/79	R10/30/79	20.6	4.8			
A80	A90	0.0	4/17/79	9/ 9/79	R10/30/79	20.6	4.8			
A100	A140	0.0	4/17/79	9/ 9/79	R10/30/79	20.6	4.8			
A80	A100	0.0	4/17/79	9/ 9/79	R10/30/79	20.6	4.8			
A140	A150	4.4	9/27/79	10/10/79	R11/15/79	1.8	28.0			
A150	A240	26.5	4/ 3/80	4/15/80	R 4/15/80	1.8	54.5			
A240	A250	0.0	4/ 3/80	4/30/80	R 4/30/80	3.9	54.5			
A250	A310	0.7	4/ 7/80	5/15/80	R 5/15/80	5.4	55.2			
A250	A300	0.5	4/ 6/80	8/31/80	R 8/31/80	21.0	55.0			
A250	A290	0.1	4/ 3/80	8/31/80	R 8/31/80	21.4	54.6			
A250	A280	0.4	4/ 5/80	8/31/80	R 8/31/80	21.1	54.9			
A250	A270	0.0	4/ 3/80	8/31/80	R 8/31/80	21.5	54.5			
A250	A260	0.0	4/ 3/80	8/31/80	R 8/31/80	21.5	54.5			
A310	A320	0.9	6/ 8/80	10/ 8/80	B 6/ 8/80	17.3	64.0			
A250	A340	0.7	4/ 7/80	10/ 9/80	R10/15/80	26.2	55.2			
A280	A340	0.0	4/ 5/80	10/ 9/80	R10/15/80	26.5	54.9			
A300	A340	0.0	4/ 6/80	10/ 9/80	R10/15/80	26.4	55.0			
A270	A340	0.0	4/ 3/80	10/ 9/80	R10/15/80	26.9	54.5			
A200	A340	0.0	4/ 3/80	10/ 9/80	R10/15/80	26.9	54.5			
A290	A340	0.0	4/ 3/80	10/ 9/80	R10/15/80	26.8	54.6			
A320	A330	0.1	8/ 3/80	10/ 9/80	B 8/ 3/80	9.4	72.0			
A330	A340	0.0	8/ 3/80	10/ 9/80	R10/15/80	9.4	72.0			
A340	A350	4.4	9/ 3/80	11/ 9/80	R11/15/80	9.4	76.4			
A350	A360	0.0	9/ 3/80	11/ 9/80	R11/15/80	9.4	76.4			
A360	A370	0.1	9/ 4/80	11/ 9/80	R11/16/80	9.4	76.5			
A370	A380	0.2	9/ 6/80	11/18/80	R11/18/80	10.4	76.7			
A380	A390	0.0	9/ 6/80	1/ 7/81	R 1/16/81	17.2	76.7			
A370	A390	8.0	12/29/80	1/ 7/81	B12/29/80	1.2	92.7			
A390	A392	0.7	4/ 6/81	4/15/81	B 4/ 6/81	1.3	106.6			
A390	A420	14.0	4/ 7/81	4/15/81	R 4/15/81	1.2	106.7			
A392	A420	0.0	4/ 9/81	4/15/81	R 4/15/81	1.3	106.6			
A350	A440	17.1	1/ 5/81	4/30/81	R 4/30/81	16.5	93.5			
A420	A440	0.2	4/ 8/81	4/30/81	R 4/30/81	3.1	106.9			

## Appendix L

The following glossary was selected from the PERT/Time Reference Manual (7).

## GLOSSARY

activity	A work effort of a program which is represented on a network graph by a line.
activity slack	The latest allowable end time minus expected end time.
backward pass	The portion of the program during which the latest allowable dates ( $T_L$ ) are calculated.
beginning event	An event which signifies the beginning of an activity. Syn: predecessor event.
critical path	That particular sequence of events and activities in a path that has the greatest negative or least positive slack; therefore, the longest path through the network.
dummy activity	A zero time activity placed in the network merely to show a dependent relationship.
ending event	The event which signifies the completion of an activity. Syn: successor event.
event	A specific definable accomplishment in a program plan, recognizable at a particular instant in time. Events consume neither time nor resources; they are represented graphically as circles or squares.
expected date ( $T_E$ )	The calendar date on which the completion of an activity is expected to occur. It is calculated by adding to the date of each start event, or completed event of the network, activity times along each possible path up to and including the activity under consideration. The latest of these computed dates is the expected date of completion for the activity.
expected elapsed time ( $t_e$ )	A statistically weighted time estimate or a single knowledgeable estimate for activity duration. If a weighted or mean time estimate, it incorporates an optimistic, most likely, and pessimistic estimate for the work to be accomplished.

forward pass	The portion in the program during which the expected dates ( $T_E$ ) are calculated.
latest allowable date ( $T_L$ )	The latest date on which the completion of an activity can occur without creating a delay in the completion of the program. The $T_L$ value for a given activity is calculated by subtracting the sum of the expected elapsed activity times ( $t_e$ ) for the activities on the longest path from the latest allowable date or scheduled completion date for the entire program.
most likely time estimate	This is the most realistic estimate of the time an activity might consume. When only one time estimate is given this one is used.
network	A flow diagram consisting of the activities and events which must be accomplished to reach the program objectives, showing their planned sequence of accomplishments, interdependencies, and interrelationships.
optimistic time estimate	The minimum time in which the activity can be completed if everything goes exceptionally well. It is generally held that an activity would have no more than one chance in a hundred of being completed on time.
pessimistic time estimate	The maximum time required for an activity under adverse conditions. It is generally held that an activity would have no more than one chance in a hundred of exceeding this amount of time.

## Appendix M

The following material was taken directly from Thornley (32).

## OUTLINE OF TRAINING COURSE

(A period is one or two days)

## Period 1. Introduction to project planning and control concepts.

The fundamental mechanics of networking:

1. Symbols and logic relationships
2. Diagram layouts
3. Time estimates and diagram analysis
4. Slack, float, and the critical path
5. Tabulated analysis for activity start/finish times for scheduling

Progressive exercise that illustrates:

1. Network manipulation
2. Laddering
3. Breaking down activities into more detail
4. Altering activity times and resource requirements
5. Taking account of external restraints
6. Simple re-allocation of resources

## Period 2. Practical networking projects (company-oriented):

1. First with a given list of activities (say 30-50)

2. Second, up to 100 to 150 activities - preferably without a given list of activities but with a full project situation description

Discussion periods on:

1. Getting networks started in practice
2. Project organization and the function of network specialists
3. Level of detail
4. Master networks and subnetworks, interfacing, etc.

Project control methods

Period 3. Using the computer

1. Input
2. Types of output
3. Programs available

Resource allocation - principles and methods

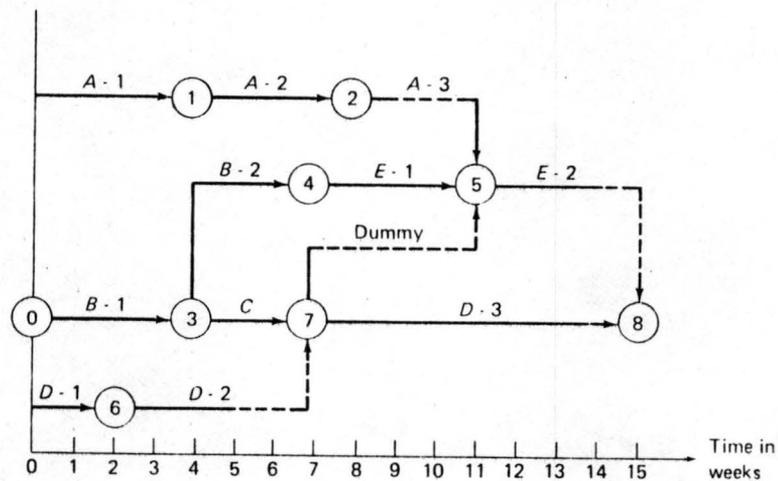
Cost analysis and control - principles and methods

A general discussion with an 'expert' forum

Period 3 might be considered too much to include in a basic instructional course and it is therefore suggested that this period could be left over until the trainees have had some practical contact with the technique.

## Appendix N

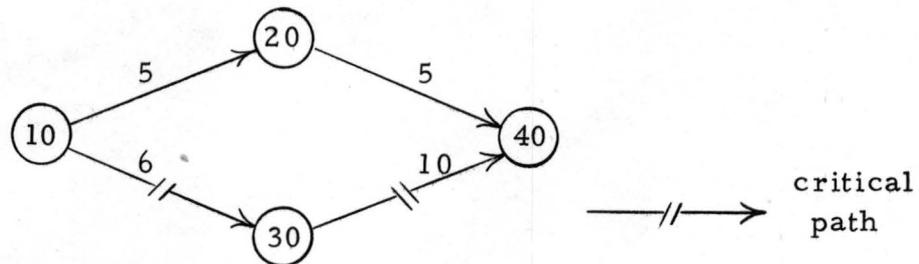
A time-scaled network is one in which the arrows, drawn to a time scale along a horizontal border, represent the activities durations. The location of the arrow represents its start and finish times, and the location of a node, the occurrence time. A dashed line is used to represent slack. Moder and Phillips (20) provide an example of a time-scaled network as well as a discussion on the advantages and disadvantages of using such a network.



## Appendix O

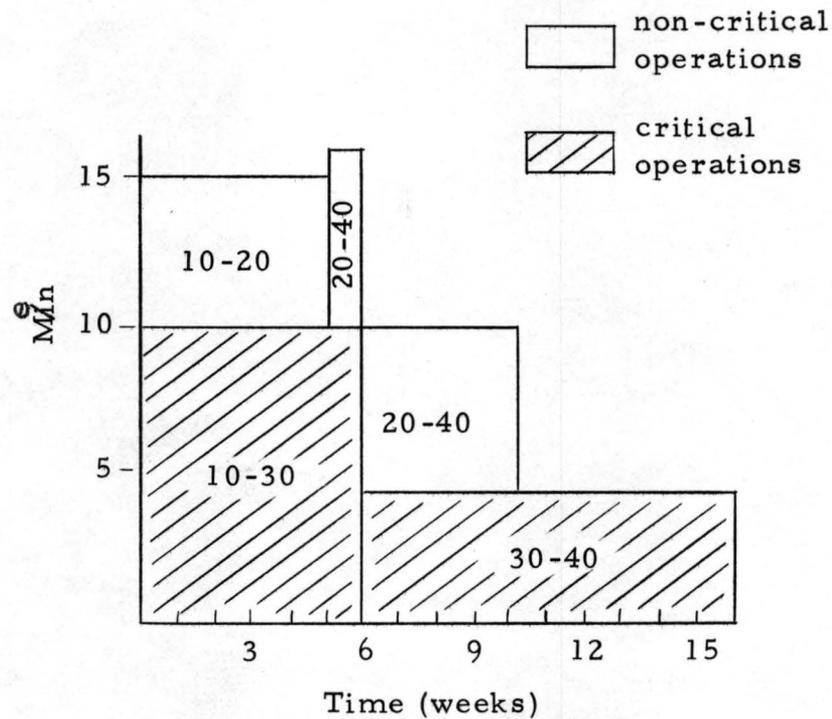
Resource allocation must be considered by management to avoid sharp fluctuations in manpower requirements and unnecessary hiring and training of personnel. A manpower leveling chart aids the manager in this task. The chart plots time on the horizontal scale and number of men on the vertical scale. Each operation is represented by a rectangle whose height is equal to the number of men needed and its length is equal to the duration of the operation. The duration of the activity can be taken directly from the network. The following procedure is suggested by Thornley (32) for manpower leveling:

1. Calculate durations and determine the critical path for the segment of the network which is being considered for resource allocation.

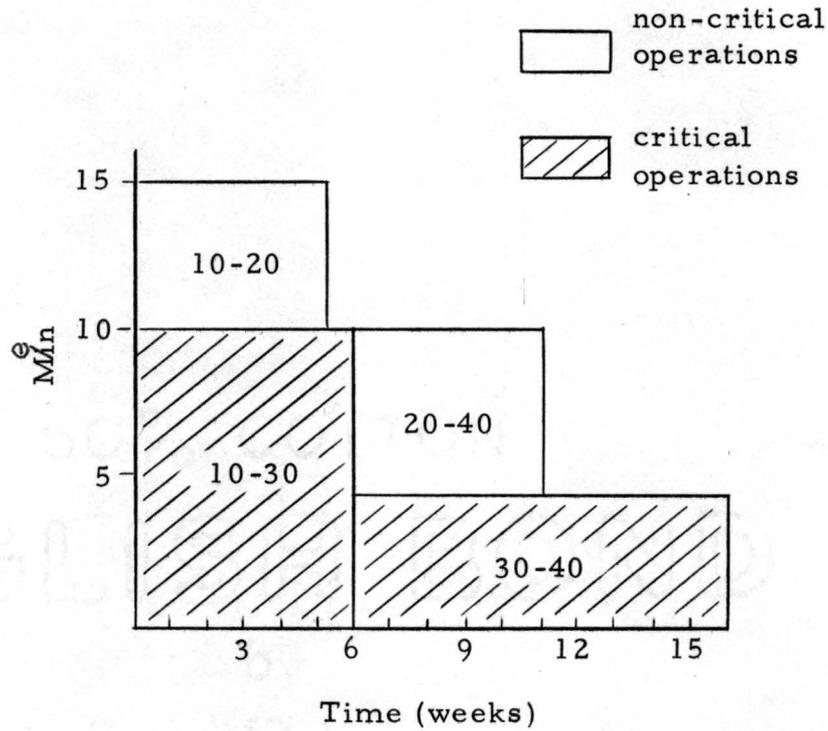


Operation	Duration	Crew Size
10-20	5	5
10-30	6	10
20-40	5	6
30-40	10	4

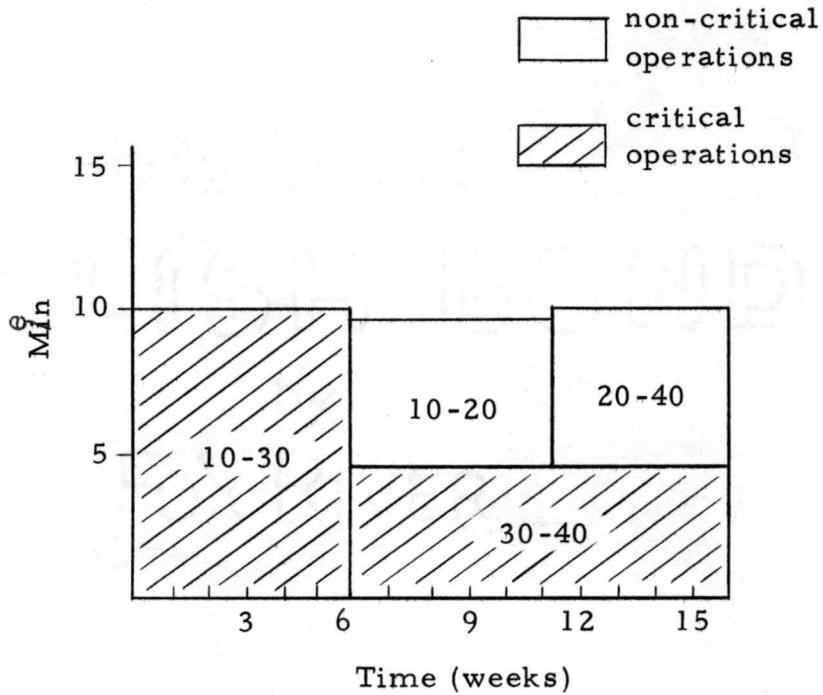
2. After the critical path has been determined, plot the operations on a graph. For the first trial a manager may desire to plot the non-critical operations as early as possible. This may result in a non-uniform use of manpower and in this example a peak results in the fifth week.



3. To eliminate this peak, operation activity 20-40 can be shifted within its allowable slack time (5 weeks).



4. If a more uniform curve is desired, both non-critical activities can be adjusted without affecting the critical operations.



This same approach can be used for scheduling and allocating equipment.