NETWORK ANALYSIS IN RESEARCH PLANNING:

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INTRODUCTION:

Forest research does not in general require sophisticated techniques and elaborate equipment. It does, however, more often than not require considerable time and considerable space. One of the effects of the sheer size of forest research projects is that the planning and scheduling of research procedures over time become important. It may also become a difficult task. In several fields of research it will be advantageous to have at disposal a planning method which ensures that:

The different phases of the experiment or trial are scheduled over time with information on the sequence and the interdependency of the operations.

The entire carrying-through of the experiment is visualized in a form which allows a comprehensive evaluation of the procedure, the timing, the priorities, the bottlenecks and the flexibility.

The plan allows current control of achievements measured against programme, making revisions easy when required.

The method briefly presented in this paper, Network Analysis, has for several years been employed with success in management, including research management. Its greatest advantages as a tool is that it is simple, can be reduced to a non-mathematical form, that it compels the researcher to prepare his project with realism, and that it is an effective information also for those not directly involved in the work.

This paper contains no theory and no discussion of advanced methods. There are good textbooks available for that purpose. The technique is demonstrated throughout by means of a simple, everyday example.

EXAMPLE:

Imagine that a certain species is expected to be worth considering in the country's plantation policy. It is not a well tried species with anything like a tradition for handling at the different stages of management, and the experiment attempts to test various methods of treatment in the nursery and early establishment stages.

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It is assumed that indigenous seed can be collected, and that the research unit has got some supply of suitable land, man-power, and funds . In the annual research programme the outlines of the project have been supplied, but a detailed research design has not yet been prepared . It is the main idea that a number of treatments at the nursery stage are combined with different planting (sowing) techniques, all methods employed judged to be realistic and relevant from a practical point of view .

<u>APPROACH:</u> The initial approach is to break down the objective of the project into activities, actual working level operations . Ideally these activities should contain one and only one homogenous and continuous procedure utilizing clearly defined resources and with a distinct beginning and end .

In the example chosen we might get the following break-down:

Project: Determination of suitable methods for raising XX species in nurseries and plantations .

Activities 1: Procurement and processing of seed .

1.1. Obtain seed of adequate quantity and quality.
1.2. Test seed .
1.3. Calculate seed distribution
(1.4. Pretreatment of seed) +

2: Design of experiment .

(2.1. Obtain relevant external information).
2.2. Design experimental lay-out .

3: Procurement of facilities .

3.1. Select and arrange land for plantation plots.
3.2. Select and arrange land for nursery plots.
3.3. Procure supplies and tools .
(3.4. Hire labour).

4: Nursery activities.

4.1. Prepare nursery beds and soil mix for containers.
4.2. Prepare containers for seedlings.
4.3. Sow in nursery beds.
4.4. Sow in containers .
4.5. Transplant from seed-bed to containers.
4.6. Tending and weeding of seedlings in nursery.
4.7. Prepare stumps and ball-root transplants.

+) Activities in brackets are not included in network analysis.

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5: Direct sowing activities .

5.1. Prepare field sowing plots, including protection.
5.2. Sow in plots.
5.3. Tending and weeding of direct sowing plots.

6: Plantation activities .

6.1. Prepare plots for planting, protection .
6.2. Plant stumps and ball-root transplants .
6.3. Plant container seedlings.
6.4. Tending and weeding of transplant plots .

7: Assessment of experiment .

7.1. Control of growth and mortality at seedling -stage .
7.2. Control of growth and mortality, direct sowing .
7.3. Control of growth and mortality, transplants.
7.4. Final analysis, evaluation and report .

It may seem a trivial exercise to list these various routine elements of something which is, after all, a pretty simple piece of work . But it is a useful exercise . It compels the project leader mentally to work through the whole procedure, safeguarding against mistakes, omissions and wishful thinking . Furthermore it allows a quantification of the requirements for the projects in terms of physical resources. And finally, most important , it provides the basis for a timing: Each activity needs a certain amount of time, depending partly on biological facts and partly on the quantity of labour and other resources put into each operation . In addition to the absolute time ; the duration of each activity, also the relative time, i.e. the position of an operation in the chain of activities , is defined ; one cannot let operations follow each other arbitrarily .

TECHNIQUE: THE BASIC NETWORK: Equipped with the estimates of time consumed in the different activities and an assessment of their logical sequence we can now construct Figure 1 (page 4), which gives the basic network .

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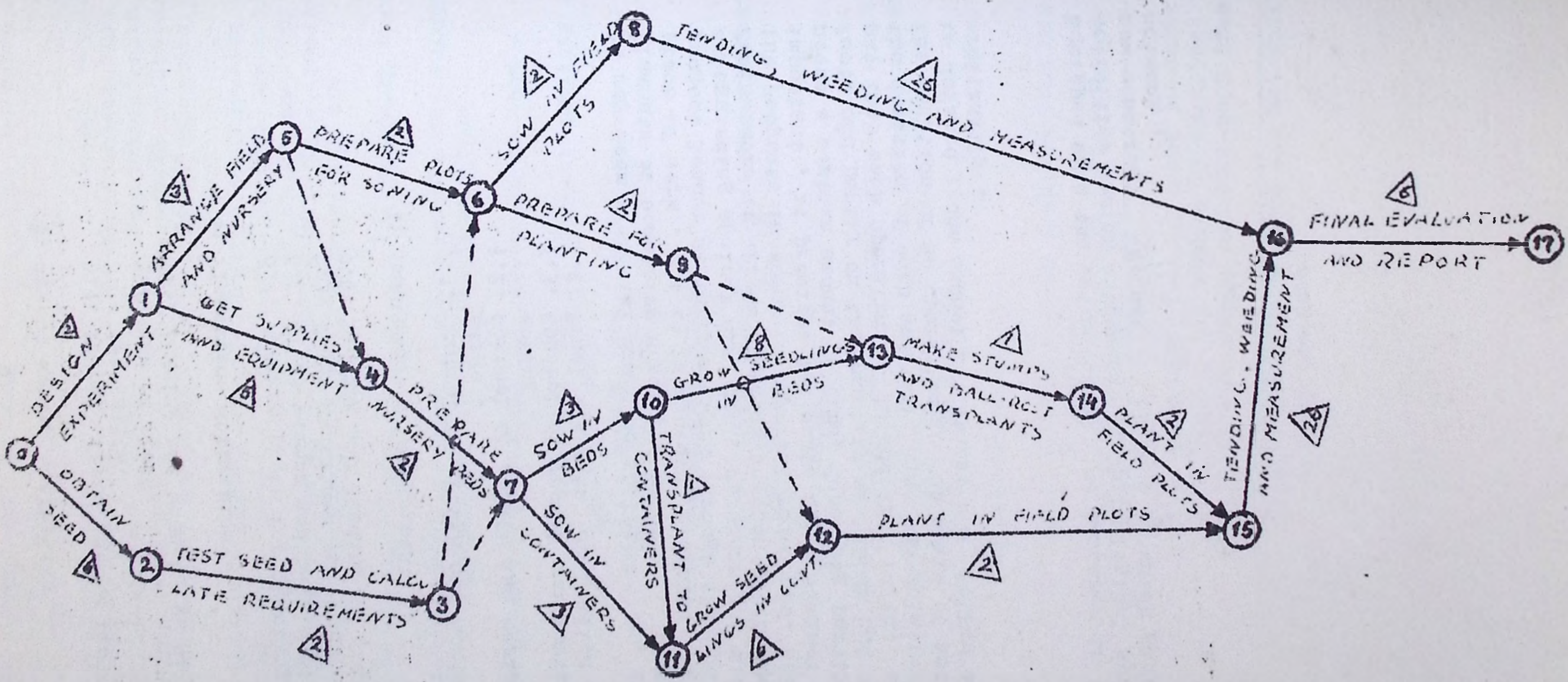
FIG. 1: THE BASIC NETWORK , activities and events in a planting experiment.



The network consists of arrows . Each arrow represents an activity as defined above . There is no quantitative measure attached ; for the time being the length of the arrow does not indicate the duration of the activity . The arrows start and end with circles, representing events , i.e. signifying that a certain result has been achieved by means of one or more activities (e. g. ground is ready for sowing, seedlings are prepared for planting). A small number in each circle serves to identify the individual events and activities (e. g. activity 5-6 is preparation of field sowing plots). Numbers in small triangles show the estimated time consumed in the activities .

It appears that even a relatively simple experiment as the one chosen is not a straightforward one-step-after-another . In that case the picture would have been one of an unbroken line . The interdependency may, as a matter of fact, look more complicated than suspected . - One feature of the illustration is a number of dotted lines or arrows . They signify dummy activities , not consuming any time, but signaling that a certain event must have taken place before an activity somewhere else in the system can start . Take , for instance, the activities starting from event 7 , i.e. sowing in beds and in containers . The start of these activities will principally depend on the event that nursery beds and containers have been prepared. But they are also dependent on the determination of seed quality and germination capacity and the subsequent calculation of the amount of seed per unit nursery bed . This means that event 3 is a precondition . The dummy arrow from 3 to 7 symbolises this dependency .

The basic network, starting with the decision to launch the experiment and finishing with event 17 , the final evaluation and write-up illustrates the logical structure of the experiment. It does not yet provide any quantitative measures ; but working to a consistent sequence of well defined operations the researcher builds a planning model, structurally in accordance with reality .

TECHNIQUE: THE CALCULATIONS:

The next step is the calculation of time required from the beginning to the end of the experiment . For this purpose Figure 1 is being equipped with a few devices that make it possible to do computations directly on the model .

This is illustrated by Figure 2.

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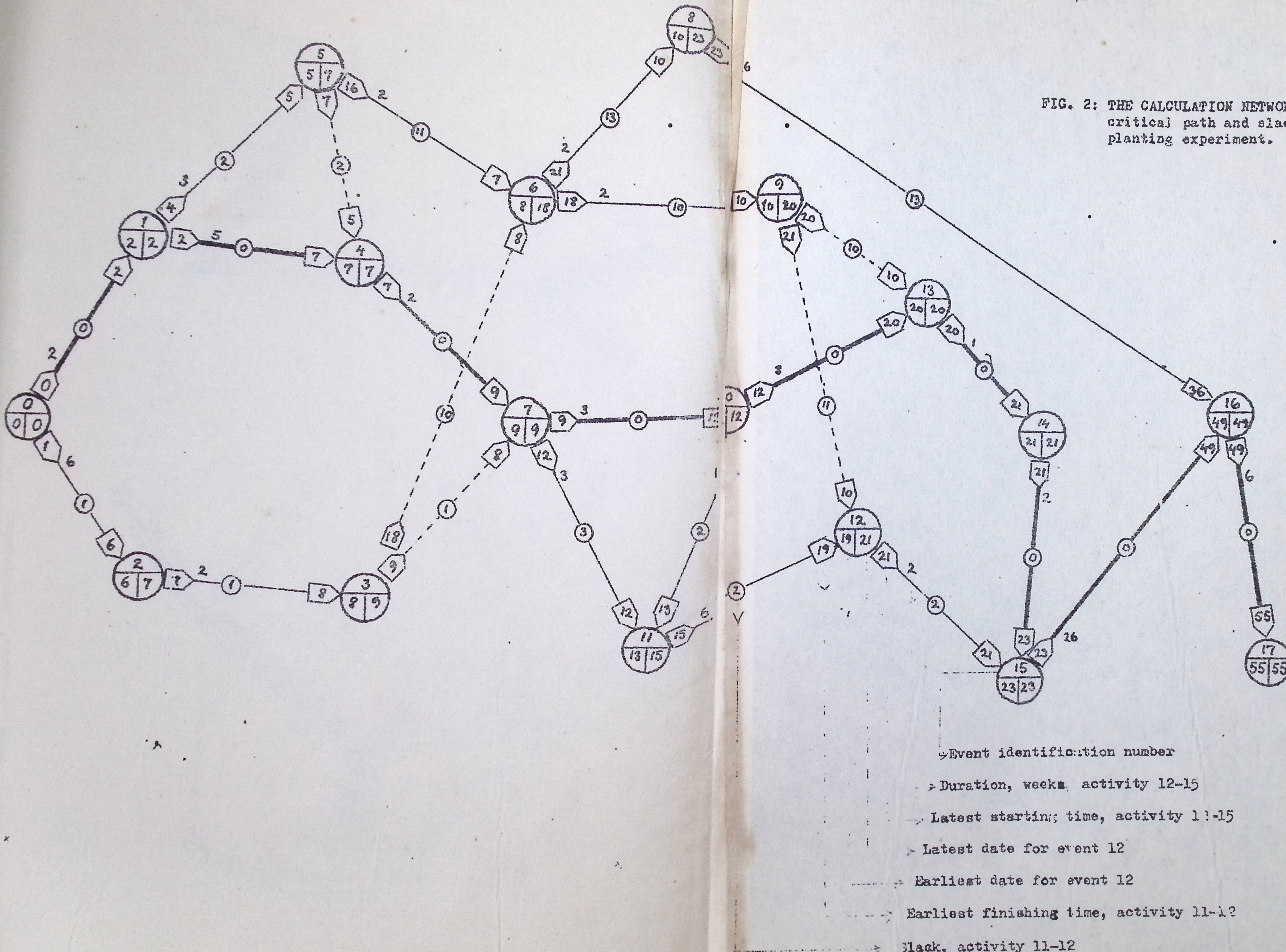
FIG. 2: THE CALCULATION NETWORK, times critical path and slacks in a planting experiment.



2a: PRELIMINARY NETWORK FOR MENSURATION PROJECT.

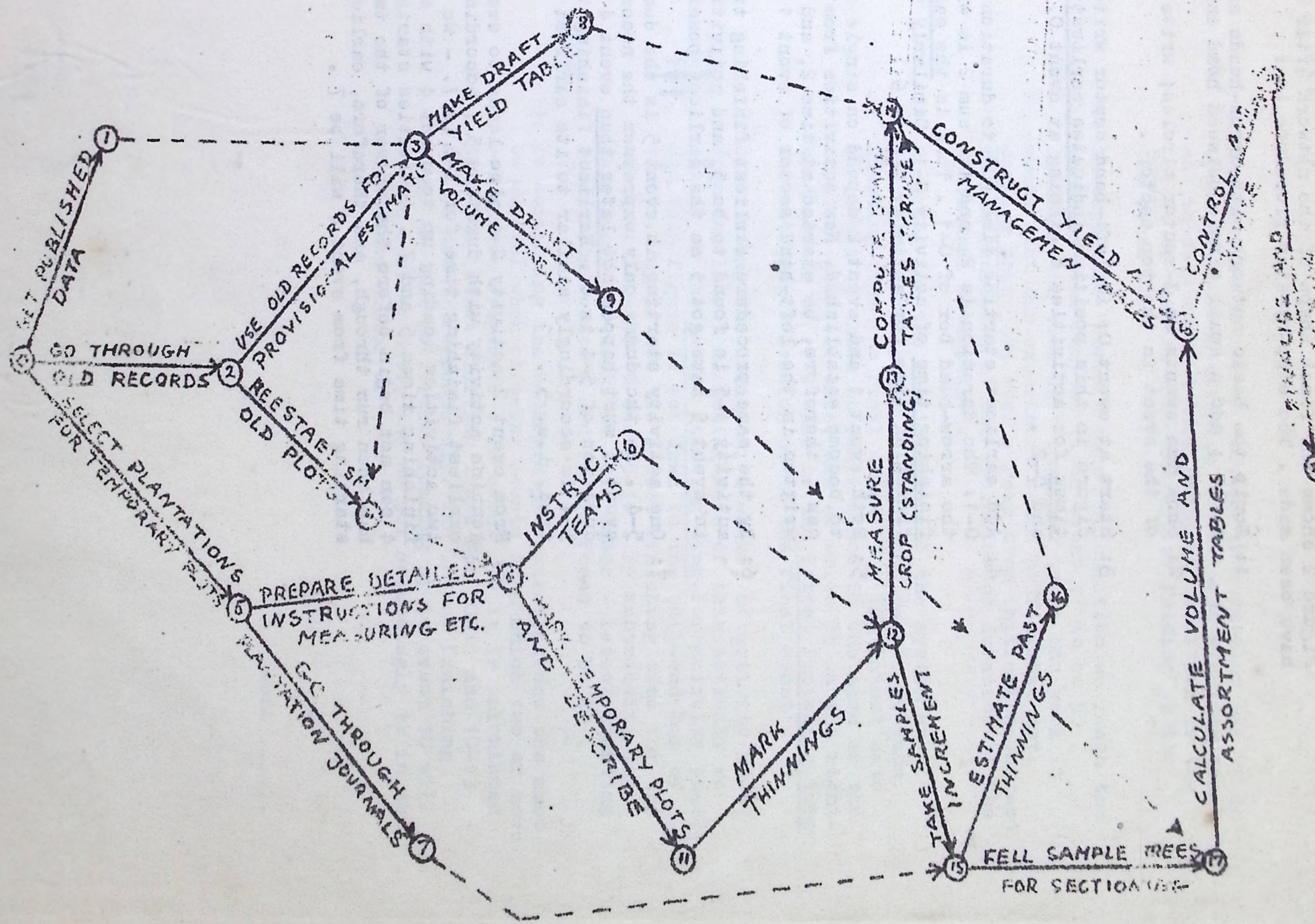


Figure 2 shows the final shape of the network after calculations have been made . The step-by-step procedure is :

1: Equip the basic network with arrow-heads and arrow-tails ; add a small circle between head and tail .

2: Show the events as 3-sector circles; write the number of the event in the top sector .

3: Start at event 0; in left-hand sector write o . The figure in this position indicates earliest starting times for activities beginning at event 0, i.e. 0-1 and 0-2 .

4: Add earliest starting time (0) to duration of activity 0-1. The duration is 2, and the sum 2 is written in the arrow-head box of 0-1 . This is the earliest finishing time of activity 0-1. Similarly the earliest finishing time for activity 0-2 is 6 .

5: Both event 1 and event 2 depend on single activities to become established. New activities from event 1 can , therefore, be started at time 2, and 2 is written in the left-hand sector of event 1 .

6: By the same procedure earliest finishing time for activity 1-5 is found to be 5, and activities starting in event 5 have got 5 as the earliest possible start.

7: One activity starting in event 5 is the dummy activity 5-4 . As the dummy only expresses the necessity that event 5 must happen not later than event 4 the duration of 5-4 is o . Earliest finishing time for 5-4 is accordingly similar to its earliest starting time, i.e. 5 .

8: From event 2 activity 2-4 also leads to event 4 as a genuine activity with duration 5 ; accordingly the earliest finishing time for 2-4 is 7. - We now have two activities leading up to event 4 with earliest finishing times 5 and 7 . Activities starting from 4 can not begin before the slower of the two paths has been run through, and therefore, earliest starting time from event 4 will be 7 .

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9: The network is worked through in a similar way up to event 17, adding duration to earliest starting time and in each event taking earliest starting as the latest of two or more activities leading up to the event .

10: Through this "forward pass" calculation we reach the earliest time for the final event 17 to be 55 . Assuming the time unit employed to be one week it means that our experiment could be finished not earlier than just over a year from initiation,subject to the precision of our estimates of duration of the individual activities .

11: To bring out the implications of the system an analogous computation, a "backward pass", is made, starting from the final event 17 . The latest date for event 17 which we shall allow is the same as the earliest possible date, and we write 55 in the right-hand sector of 17 . This is the latest finishing time for activities leading up to the final event .

12: Subtracting the duration, 6 weeks, of activity 16-17 from the latest finishing date of this activity we get 49 as the latest starting time for activity 16-17, and this figure is set down in the tail-end box of 16-17 . 49 is now the latest finishing time for the two activities 8-16 and 15-16 . By subtracting the durations - 26 weeks in both cases - latest starting times from events 8 and 15 are found to be 23 .

13: In continuing the backward pass calculations one must be careful when crossing events from which two or more activities originate . In event 10 it is calculated that the latest starting times for 10-11 and 10-13 are 14 and 12 respectively. The latest finishing times for all activities leading up to event 10 will be the earlier date, and we put accordingly 12 in the right-hand sector of event 10 .

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14: Reaching starting point 0 after working along all paths of the system the check on our calculations is that event 0 will happen at date o . - During the process it will be noticed that some events have the same figure in the right- and in the left-hand sector. This signifies that the earliest and the latest date of occurrence are similar, or that the activities connecting these events can neither be postponed nor advanced ; the activities are critical . If for some reason one of the operations along the path 0-1-4-7-10-13-14-15-16-17 is delayed the whole project is delayed for the same period . One of the important results of our analysis so far is the identification of this Critical Path (heavy line in fig. 2), which will determine the attention and priority given to the project components .

15: Activities lying along other paths are not openly critical but have some flexibility . They may be delayed for some time without affecting the termination of the experiment. This flexibility, or allowable delay, is called slack and is conveniently calculated on the figure .

16: An activity along the critical path has no slack : Its earliest starting time plus its duration is equal to its latest finishing time . Other activities, e.g. 2-3 ; have a latest finishing time which is later than earliest starting time plus duration, in this example 1 week . Slack is calculated in this manner for all activities, and the slack times have been written in the small circles .

17: It will be noticed that slack is different in different parts of the system. When the slack is small - as in path 0-2-3-7 this path will become critical if any of its activities are delayed for more than one week, or if there is more than one weeks saving of time along the critical path 0-1-4-7 .

At this stage, when the network has been constructed and quantified, it should be closely scrutinized. It is now a working model to be evaluated and if necessary restructured and revised. The realism of the timing can be judged on the basis of the available resources, and the more difficult or dubious phases of the procedure can be strengthened . But we still need to present the network on a true time scale, before it is presentable as a time schedule.

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Scheduling: One reason, the principal one, for giving the network a shape different from the one employed in figs. 1 and 2 , is that these models are difficult to interpret for those not already familiar with the details of the project and with this particular way of illustration. When transforming the network to a time schedule it is in a sense being distorted, and some of the information supplied by the original illustration is lost . For planning, reporting and control purposes, however, a re-drawing of the network is useful .

The scheduling is shown in fig. 3 .

The presentation in fig. 3 needs a few comments. A calendar scale has been introduced, and the earliest possible starting date of the experiment has been assumed. From start to end the events making up the experiment have been placed in the diagram according to their earliest date of occurrence (fig. 2). Activities are shown as unbroken lines dummy activities as dotted lines . The slack calculated in fig.2 is expressed in the same way . It appears that it is convenient to show some events in duplicate or triplicate in order to improve the readability of the figure .

One thing which it is necessary to take into account in an experiment of this kind is that some activities are season-bound ; they must be carried out at certain periods . In scheduling we must, therefore, be careful to observe critical dates or critical periods for certain activities (seed collection, nursery production, planting). If the scheduling is unrealistic, appropriate revisions will have to be made in the basic network . In the example we have, for instance, supposed that activity 6-8 (sowing on the site) can not be done before June . Thus it is possible to take into account directly because we are not on a critical path, and a 2 week waiting period is introduced after event 6 . Not directly visible in the diagram is another feature of minor importance: We only need 26 weeks for observation of the directly sown plots, but have, as a matter of fact, 37 weeks available (activity 8-16). It depends on the design of the experiment if one or the other observation period is employed .

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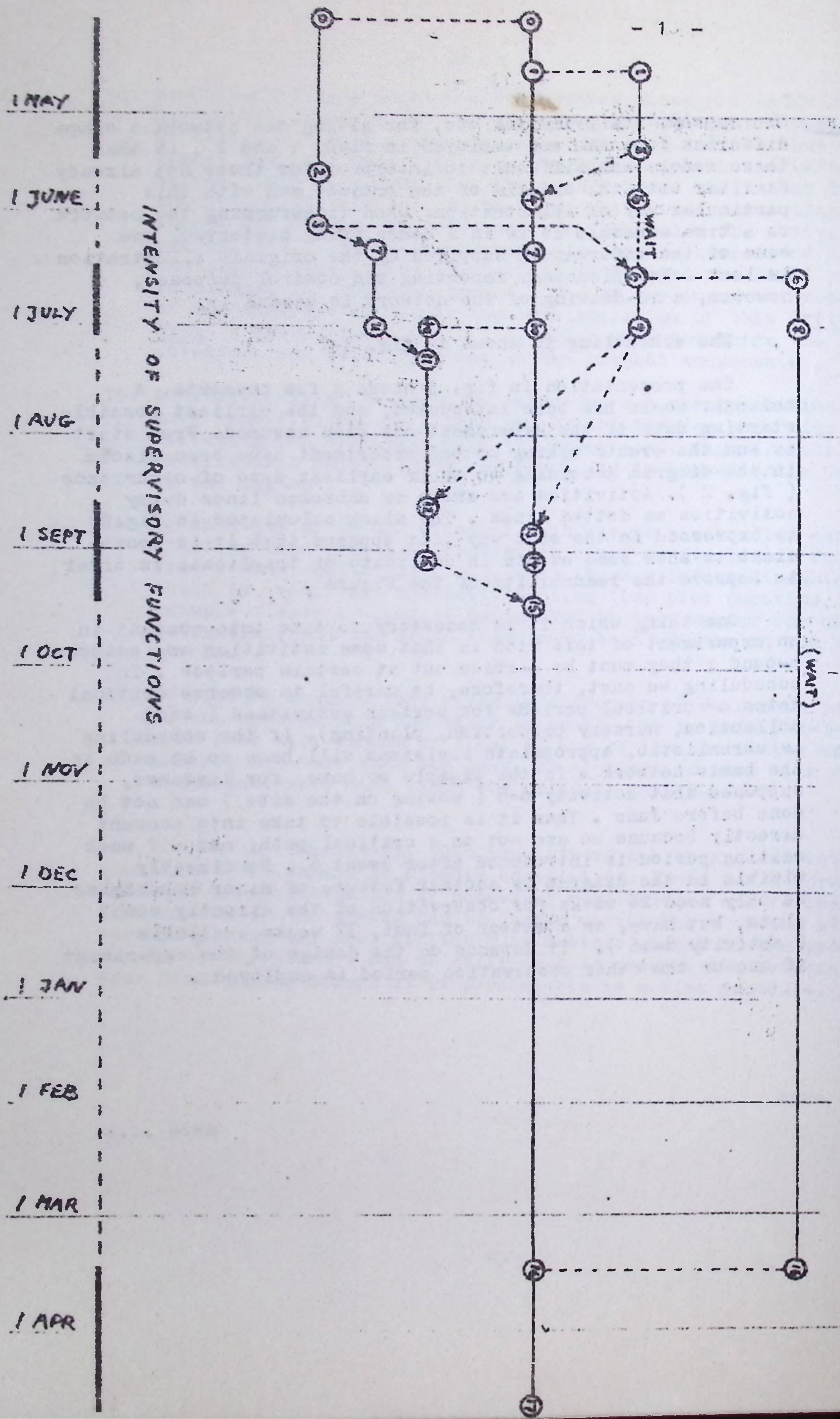

FIG. 3 : TIME SCHEDULE for a planting experiment.

It will depend on the kind of experiment contemplated and upon the facilities and resources available for research if and how scheduling in addition to the time scheduling demonstrated above is required or useful . Time sequence of operations is a crucial point in most cases, and our network so far allows an ordered and rational forward planning . But for carrying out the individual activities we need resources, a more or less predictable set of factors for each ~~i~~- operation: land, man-power, supervision, equipment, supplies, external services, transport etc. The time schedule diagram can be used for a presentation of these requirements . In fig. 3 only one factor is taken into consideration, namely supervision of activities by professionals, i.e. the project leader's involvement. It is then implied that we assume all other factors to be available, or at least that their supply is not a critical constraint on activities .

Applicability of network analysis in forest research planning: All concerned with forest research will be aware that realistic planning of research and - in particular- management of research projects in accordance with approved plans are not easy . It might be agreed that every possible tool which will bring the planning progress closer to the realistics, which the research leader must eventually face, are potential useful instruments. Equally useful is a technique which makes it possible to present the research project in an intelligible way to those who need to know about it, before starting and during execution. And to have a graphic model against which actual achievement can be tested and if necessary redirected is not a disadvantage .

The simple and straighforward technique presented- admittedly in a crude form - in this paper may meet some of the requirements, not meet them always, nor completely. There are no curealls to management from a superstitious belief in patent medicines. As a tool network analysis has been found useful. Like all good tools its applicability and efficiency increases with use. Particularly under conditions, common to all public agencies in this country, where quite elaborate and time-consuming paper plans are a precondition for starting of any activity, it may well be worth while to adopt a planning method which lets implementation be the centre of attention of the paper exercises .

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