KERNFORSCHUNGSZENTRUM

KARLSRUHE

Mai 1967

KFK 593

Institut für Angewandte Reaktorphysik

Experience with Network Analysis and its Further Development for the Purpose of Planning Objectives and Time Scheduling within the Framework of the Karlsruhe Fast Breeder Project

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Experience with Network Analysis and its Further Development for the Purpose of Planning Objectives and Time Scheduling within the Framework of the Karlsruhe Fast Breeder Project[1][2]

by

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1) The report has been presented in this form to the Symposium on International Congress for Project Planning by Network Analysis, Vienna 21 - 26 May 1967

2) Work performed within the association in the field of fast reactors between the European Atomic Energy Community and Gesellschaft für Kernforschung mbH., Karlsruhe

I. Experience with Network Analysis in the Fast Breeder Project

About the year 1960 the development of power reactors quite generally entered into a new phase. That means it became more and more obvious that the long term objectives of an abundant energy supply could only be reached by introducing a new type of reactor. This reactor type is called FAST BREEDER on account of the use of fast neutrons instead of thermal ones and the capability of these reactors to breed more fissile material by converting uranium 238 into plutonium than they consume for the production of energy. Since the early sixties, the large industrial nations devote a great deal of effort to the particularly intensive development work concerned with fast breeder reactors. However, this amount of interest is focussed on these reactors not only due to the fact that they will solve the problems of a growing future energy requirement but also because they will surpass even the economy of the now proven and already highly competitive light water reactors. This economic attractiveness results also from the breeding effect of fast reactors. That means only the abundant and cheap U-238 has to be fed into these reactors and no expensive fissile material, as with the light water reactors e.g.

The development of fast breeder reactors requires greatly extended and much more complicated physical foundations than previous thermal reactors, a highly refined fuel element technology, entirely new technologies of the reactor coolant, and the technologies of a closed fuel cycle, since the plutonium produced, after chemical reprocessing, must constantly flow back to the fast breeder reactors. After this comprehensive preliminary work prototype reactors will have to demonstrate the technical feasibility, safe operation, and the economic potential of the new reactor generation.

The expenditure for the Fast Breeder Project, in which the countries Belgium and the Netherlands are engaged in addition to Germany, will be some 1.5 billion. The period of the project is schedulded to cover 18 years from 1960 on.

The execution of the project requires the collaboration, coordinated down to the details, of government organisations as the sponsors, utilities as the later reactor operators, research centers to elaborate the foundations, and large-scale industries for the project work and construction of the prototype and finally large commercial plants.

The objective of the project is to enable industry well before 1980 to build large competitive fast breeder power stations(about 1,000 MWe) and offer them on the market.

It is only natural that the execution of such a large and complex project includes modern network techniques of planning. However, it has emerged that in a research and development project the unreflected acceptance of the methods of time schedule control (CPM, PERT) is not sufficient. For the main burden of planning work gradually shifts in the course of an R.+D. project from recognition and fixing of the objectives, which shall mean mainly eliminating more and more less promising variants by studying extensively the technical and economical potentials according to rational decision criteria, finally to the coordination of the partial objectives and to the control of reaching the objective. To repeat:

1. stage: recognition and fixing objectives
2. stage: selection and coordinating objectives
3. stage: controll of objective accessment.

In our experience, present day network planning techniques can be applied succesfully only in the control of reaching an objective.

The process of recognition and fixing an objective in an R.+D. project cannot be formalized, since it should result primarily from human insight and imagination for the problem at hand. This manifests itself much more strongly in R.+D. projects than in standard industrial projects where, generally objectives can be set to a much greater extent on the basis of experience available.

By contrast, the process of setting an abjective is often an expensive process of searching in an R.+D. project. This is true, above all, of the partial objectives which also manifest themselves in an unequivocal way only during the course of the project and do not necessarily follow from the overall objective. Often, it is necessary to work with intermediate solutions in partial sectors, hence, the overall rhythm of time of a project in no way functions in the unequivocal PERT logic like "when job x is finished, job y may start". Since this has turned out in practice, it is not reasonable either in an R.+D. project to intent to represent the whole project in one single network. We rather adopt an iterative method of proceeding, i.e. an interaction between objective plans and time schedules on the one hand and CPM network analysis on the other hand.

The one type of graphs containing as well objectives as time schedules can be represented in the usual manner of a bar-graph with a time abscissa, in addition, the graphs contain the important interrelations of the partial projects, e.g. certain basic physical or technological investigations in relation to the planning and to the construction of the prototype reactors. Hence this plans can be taken as networks quite well. However, as was stated above, there are only very few basic investigations which are unequivocal conditions, say of the decision to build the prototype. In most of the other partial sectors it is true that the design of the reactors can be made the better and the more economical, the more accurate results were arrived at in the basic investigations. Thus, it is important to draw conclusions as precisely as possible at specific dates from the investigations carried out to this point and to communicate these to the other partial projects. These dates and their interrelation represent as said the networks in objective planning and time scheduling.

The network analyses of the partial sectors we carry out with our TERM-1 program in the second iterative step serve for the accurate determination of the partial results actually available at the desired dates. In this way, the objective plans and time schedules can be adapted to the reality of any situation by iterative methods.

Following the lines of the description given above one becomes aware of the fact that network techniques either for the representation of objective plans and time schedules or for the actual control of project performance are special features of the general communication process in systems engineering. Concerning this, network-graphs are only special topological realisations with a high degree of informational condensation, of generally related sets. The more basic phenomenon in the overall systems engineering aspect is, of course, that structures of related sets are to be found all over the parts of this quite general and new technique for describing and managing large and complex systems of men and machines whatever there purposes may be.

Having a defined objective one is able to define the system aiming at this objective, or even to create a proper system to reach the given objective. However the process of arriving at an objective ultimately means exchange of goods, money and information by acting persons. In this respect, the flow of information is guided by the tracks outlined by the systems engineering techniques which by themselves are meta-informations in the system, that means systems engineering information like network techniques create and demonstrate the relations in systems and are therefore the proper instrument of order in systems.

Because of the informational natur and the special function of the quite general set of systems engineering techniques of which network analyses is only a special example we exspect an enormous increase in importance of these managerial instruments once the next computer generation will be introduced which allow for direct communication between man and computer and for vastly extended storage capacity.

For reasons of this general philosophy the development of new computer programms in network techniques has to be specially directed to programm systems rather than to single refined programms.

II. The TERM Program System

Because of the practical deficiencies inherent in the PERT program available to us for our IBM 7074 computer we decided in 1965 to develop a program system of our own which we call TERM. As said above, a research and development program makes special requirements of the planning methods, at least after our experience. Therefore the program system was designed from the outset so as to be expandable in order to be able to follow the rapid development in the field of systems engineering methods and fulfill all requirements made by the project not to be recognized in their entirity in the beginning.

In our opinion it is often not emphasized sufficiently that the practical use of a computer program for network analyses above all should be as simple and easy as possible.

The first verification of TERM (TERM-1) therefore has some possibilities derived from practical wishes. First, there is an initial program phase in which the network fed in is scanned for errors. Uncorrelated activities, cycles from activities, unidentifiable correlations and double terms are registered in this scanning for errors and corrected preliminarily by the program itself for the rest of the search for errors. Hence, the phase of error determination with high probability will find all the errors of the network in one run and print them. For practical application this increases the turnaround periods of computer calculations quite markedly, because determination of errors will thus be possible as an express run with less than 3 minutes.

Moreover, TERM-1 offers the possibility of fixing certain intermediate dates within the network which, in our opinion, are more usefull and simpler for practical operation than, e.g., the cycles used in Metra Potential Method. The disadvantages of using cycles lie in their aggravating a closed and fast search for errors and in their making the input more complicated by multiple identical correlations which have to be fed in repeatedly. Anyway, an input carried out in several phases is impossible with our computer because the medium fed in is used as an intermediate storage in different phases. The advantages of using cycles, in our opinion, do not lie in the field of deterministic planning models but rather in the field of the stochastic ones. In a model with the two logical operators AND and OR e.g. which can be coped with by the stochastic model the introduction of cycles result in definitive advantages as is shown by S. Elmaghraby*). For the reasons mentioned below, however, we do not use a stochastic model. The intermediate dates already mentioned form the basis of the corresponding subgraphs and are treated by the program as if there were a special network extending from the beginning up to that intermediate date, i.e. critical paths may end also in intermediate dates although for instance the critical path to the ultimate date will lead over other activities.

Another practical possibility inherent in TERM-1 is the printing of the results. It is possible to print the dates of the activities and the bar-graphs grouped by departments in several copies with the calendar data leaving out all sundays and holydays, thus giving rise to more accurate date quotations. With this type of prints it is possible to achieve very quick return information to the partial projects, here, care has been taken to leave out all information not required for the partial project.

The free slack is distributed through the activities of a branch in the network so that these periods of free slack may really pass without endangering any successive activities. In our opinion, too,

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*) S. Elmaghraby: An Algebra for the Analyses of Generalized Activity Networks, Management Science, 10 (1964)

such linear allocation of free slack through the activities of a branch is but an approximation. For instance, it would be obviously possible to allocate free slack corresponding to the duration of an activity of the individual activities. However, even this is only an approximate solution. Finally, the solution of this problem can be found only if capacity distributions are considert at the same time, because a short activity which is critical with respect to the provision of capacity, obviously needs more free slack or freedom in the disposition than a longer one without any shortage of capacity.

Also some problems of network planning techniques of a more fundamental nature which are the subject of vivid discussions among the experts have been solved rather pragmatically for our case. TERM-1 is not based on the stochastic model like PERT, because it is difficult to obtain the data about the uncertainty of ultimate date of an activity and the networks are analyzed with new and more accurate estimates often enough anyway, which makes the statement of the ultimate date of a partial sector increasingly more accurate.

The problem of including the necessary input data and, respectively, the establishment of the first version of a network seems to us, to be rather difficult in the field of research and development projects. On the one hand, special efforts are required on the part of the network planner to reflect the frequently unsystematic ideas of the individual participants into a network logic which comprises only one logic function the AND. Moreover in our opinion, the inclusion of several estimated times of an activity with different probabilities of occurence would further complicate the already psychologically difficult situation of network planning within a research project and, since there is no possibility of referring to data from experience, it would give generation of phantasy numbers. Another point which we think might prevent the use of a stochastic model is the fact that in the solution of conflicts in the allocation of capacities no sufficiently unambiguous weightin criteria are possible. However, this problem might be circumvented by a-priori statements of priorities, but this would mean a considerably less flexible model. We think as already mentioned the advantages of stochastic models lie in the treatement of all network planning problems having more than one logical operator, where criteria of decision can be meaningfully represented by probabilities. However, in case it should show that the expenditure involved in procuring the data for a stochastic model is in reasonable relation to the advantage provided by the statement of the certainty of the ultimate date, we could introduce the stochastic step in later versions of TERM.

If the intention from the outset is to conceive a program system in a way to keep it adaptable, each activity initially is a set of information not closely limited. Seen in this way, the activities constitute the fundamental set of the networks and the set of correlations is merely a necessary additional information with respect to the topological assignments of the elements of the fundamental quantities. This approach turned out to be favourable for the computer algorithms in the case of TERM and leads to an activity graph. As regards the representation of the network, the graphical requirements of the users were allowed free play, except for a few fundamental conventions, because we do not think this to be a logical but rather an aesthetical problem.

Because of the limited facilities of our computer the processing of several network plans in TERM-1 is still uncorrelated, i.e. there is no central data library either as a magnetic tape or a disc. In case of changes the user himself has to change the cards of a stack of punched cards and, by means of guiding cards, he may call TERM-1 as a sub-program, so to speak.

However, for the further steps of development of TERM a central data library of the magnetic tape type is envisaged, for this is to implement automatic segmentation and correlation of networks. In our opinion automatic segmentation of network plans is desirable and particularly meaningfull in those cases where by the installation of optical displays segments of network plans may be changed on the display or have to be called in for purposes of demonstration and management. We think this will be possible. However, in what way networks would have to be read out graphically appears still to be unsolved.

The continued development of the TERM program system is carried out along the generally prescribed line, i.e., a particularly efficient program system must be expected to handle next the control of employment of capacities and budget control. This step of realisation will be finished this year; it will be called TERM-2

A third stage of TERM which is already the object of preliminary work finally will comprise calculations of the optimum employment of capacities. In this case, we do not necessarily start on the assumption that the cost time function of an activity must be given but rather that it could be calculated also from the employment of the required capacities in principle.

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