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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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APPLICATION OF SYSTEMS ANALYSIS TO INDUSTRIAL PROJECT IMPLEMENTATION IN DEVELOPING COUNTRIES

Lecture Notes

August 1970

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I. INTRODUCTION[1/]

The following are brief lecture notes on the "Application of Systems Analysis to Industrial Project Implementation in Developing Countries", which is one of the components of the Training Workshops on Project Implementation being organised by UNIDO. The notes should be used in conjunction with other training and reference material related to both the basic network techniques, and on critical resource scheduling.

The notes discuss briefly and in a rather simple way, cost-duration analysis or time-cost trade-off, the general systems approach, and management information systems as applied to the implementation of an industrial project, with special reference to the problems encountered in developing nations. As regards cost-duration analysis it is recommended that in addition to these lecture notes, chapter 4 of the document "Procedures for Programming and Control of Project Implementation in Developing Countries" will also be considered. This document is reference number one of the list of training and reference material mentioned above.

1/ These notes have been prepared by Dr. M.I. Dessouky of the University of Illinois, consultant to UNIDO.

2. NETWORK ANALYSIS

Network analysis as applied to project implementation may be used to find answers to the following kinds of questions:

1. What-is type:

   Examples are, "What is the expected duration of the project"? and "What is the critical path" The answer to which may be obtained through CPM and PERT techniques. The statements provided are generally predictive statements.

2. What-if type:

   An example is, "What will the effect on total project duration be if the estimate of the duration of some activity was too low, or too high"? Answers to such questions may be obtained by sensitivity analysis, and again the statements are generally of a predictive type.

3. What-ought-we-do type:

   Questions of this sort are raised when choice is possible from among a set of alternative courses of action. Suppose that it is possible to select the duration of a particular activity from among different possibilities, at higher costs for shorter durations. It is meaningful in this situation to ask the question, "Which duration ought we choose for this particular activity, so that the total project duration is minimized, and a certain budget is not exceeded"? An answer to this question is a choice from among the set of alternative sections, or a decision.

The question raised in the last paragraph is typical of those directed to analyse the relationship of the project duration to its cost, or "cost-duration analysis". Only by investigating as wide a range of alternatives as possible, within acceptable limits of time, cost and effort, can economical programmes be set up for the implementation of industrial projects, and cost-duration analysis is one of the most effective tools for such programming.

3. COST-DURATION ANALYSIS

3.1 Introduction

Cost-duration analysis of projects aims at determining the relationship between the project duration and its cost, if reductions in the project duration are possible through added costs. The analysis is concerned with the minimum additional project cost to achieve feasible reductions in duration. This assumes that it is possible to condense the total project duration, through the shortening of some of its activities.

Two types of costs are to be observed:

(a) Direct costs: Those project costs which can be directly charged (imputed) to a specific activity.

(b) Indirect costs: Costs which cannot be directly charged to any specific activity, but are shared by more than one

Examples:

	Direct Costs	Indirect Costs
Material and Equipment	Connexion to machine to be installed; consumed tools. (Material completely used or consumed in the activity)	Compressor for vacuum cleaning machines and floors (Material shared by more than one activity)
Labour	Construction workers (e.g. masons, welders, etc.)	Supervisors, engineers, etc.
Services	Subcontracting for specific activities	Subcontracting for supporting activities such as food services for workers etc.

There are also certain types of indirect costs which are incurred by the project as a whole. The most important of these are the costs resulting from a delay in the completion of the project. Typical delay costs are:

(a) Penalty for delay (or loss of rewards for accelerated completion).

(b) Tied-up capital and resources.

(c) Lost production or profit.

(d) Lost market opportunities.

(e) Rising construction costs.

(f) Lost financing opportunities.

(g) Good will.

(h) Social costs: delays in other projects; threat to national security or prestige; delay in providing employment opportunities, etc.

In addition to delay, a project is subject to other costs arising from bad implementation of specifications. Examples of such costs are:

(a) Costs of correcting errors: material, labour, overhead.

(b) Cost of delay due to corrections (examples of which are listed above).

(c) Increase in maintenance costs due to erroneous building construction or faulty equipment erection.

(d) Production losses due to same reasons.

(e) Good will.

In any particular project, the costs incurred may be only some of those listed above, perhaps in addition to some others not mentioned here. The costs to be taken into account depend on the party for which the costs are calculated, whether it be a contractor implementing the project for another company which will operate it, the company operating the project, or a company establishing the industrial project and then operating it.

As the implementation of the project is accelerated, a higher risk of bad quality is faced, but rewards for speedy completion (the negative of the costs of delay) become available.

In cost-duration analysis, direct and indirect costs are treated separately. Direct costs tend to increase as the project duration is reduced, while indirect costs increase with project duration. The total of the two costs tends to have a minimum value similar to the one shown in Figure 1.

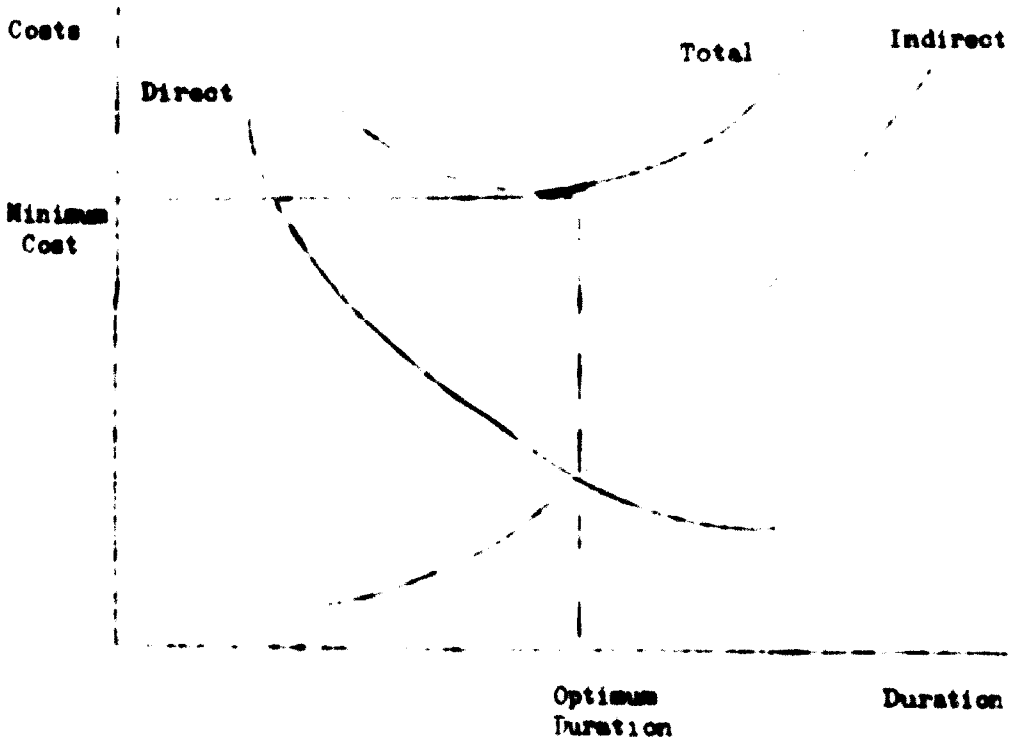


Figure 1. Typical Time-Cost Relationship

The cost-duration problem may be posed in the form of one of two questions:

(a) What is the minimum cost to reach a specific project duration (which may be the minimum duration)?

(b) What is the optimum project duration?

The answer to the first question requires the study of the project direct costs as they are related to its duration, since the indirect costs, which are mostly related to the total project duration are fixed. The answer to the second question requires considering the total of direct and indirect costs at every possible duration, and selecting that duration for which the total is minimum.

It is apparent that a project direct-cost-duration analysis is to be performed separately if any of the two questions were posed. A simple technique for performing this analysis is presented below.

3.2 Direct Cost-Duration Analysis

Suppose we define the normal duration of an activity as the minimum time for completing the activity at the minimum direct cost possible. Also define the crash duration of an activity as the minimum time for completing it at any cost. Any extension of an activity beyond its normal time without any reduction in cost is of no interest to us since this is merely a reflection of inefficiency.

An assumption will be made here about the relationship between the cost and the duration of all activities in the project between their normal and crash durations, in order that the simplified analysis presented here be valid. The assumption is that it is possible to plan the duration of any activity for any length between the two extremes, and that the increment in the direct cost at that length above that at the normal duration varies in proportion to the reduction in time from the normal duration. Therefore, if the activity normal duration is t_1 at a direct cost C_1, its crash duration is t_2 at a direct cost C_2, and its duration at some point in between is t_3 at a direct cost C_3, the following relationship exists:

$$\frac{C_3 - C_1}{t_1 - t_3} = \frac{C_2 - C_1}{t_1 - t_2} = c$$

where c is the direct cost slope of the activity in units of money per unit of time and it represents the rate at which cost increases as the activity length decreases. It is computed from the left hand side of the equation by dividing the difference in costs by the difference in times at the crash and normal durations of the activity. From the equation above the cost at duration t_2 is equal to

$$C_2 = C_1 + c\ (t_1 - t_2)$$

and since C_1 and c are constants, the equation is termed linear. In other words, we are dealing with linear cost-duration relationships for the activities. The following Figure 2 illustrates this point:

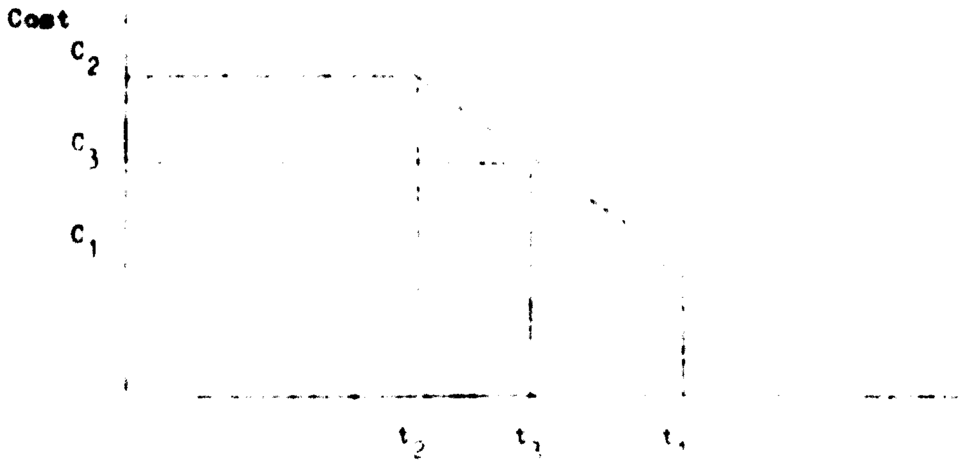


Figure 2. A Linear Cost-Duration Relationship for an Activity

Suppose that we start with an activity network which represents a project, with the time on each activity representing its normal duration. The critical path (or paths) in the network could be determined and also the total normal project duration. Also, since we are basically interested in incremental costs, that is, direct costs over and above those at the normal duration, we may indicate that we are starting with incremental (or marginal) direct costs of zero for the normal durations.

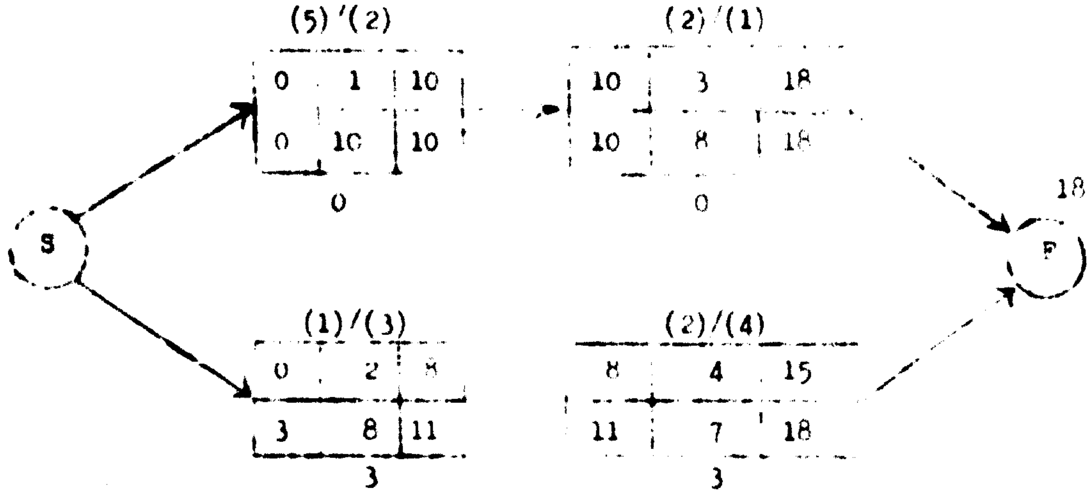
It is clear that in order to reduce the total length of the project from any given length, it will be required to reduce each critical path of the network by an amount equal to the desired reduction, unless a new subcritical path(s) becomes critical, as a result of the reductions, in which case the new path(s) will have to be reduced by the appropriate amount. Therefore, in order to conduct a cost-duration analysis for the whole project between its normal duration and its crash duration, we start from the normal duration of the project, and reduce the existing critical paths simultaneously until a new one becomes critical, and then the new set is reduced simultaneously until more critical paths are added to it and so on. The problem at every step is to select a set of activities such that when reduced simultaneously by one time unit, the project length will be reduced by one time unit. Such a set may be called a reduction set.

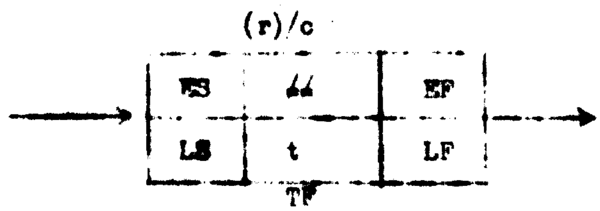
At every step, it will then be required to find the minimum reduction set, which is the reduction set for which the total of the cost slopes is minimum. The procedure to be followed here will be to determine the minimum reduction set after each reduction, and reduce each activity in that set by an amount equal to the maximum amount the set could be reduced without either causing a new path to be critical or exceeding the allowable reduction in any activity in the set. This procedure, although in many cases yields an optimum solution at every step of the reduction, will not guarantee such an optimum. This is so because sometimes an activity which has been previously reduced may at some later stage be available for increase as a result of its becoming a float activity after some reduction. The procedure described above will not allow for such increase, but improvements on the technique are possible and will be described later.

The procedure is repeated until the crash duration is achieved, or at least until the specified reduction (if any) is reached.

In the following Figure 5, the activity-on-node network represents a simplified project with all critical path calculations at the normal durations of the activities. The divided box below the network shows the meaning of the figures in the cells of each box, or node, representing an activity. The interpretation of the symbols is given below the box.

3.3 **Example**





= activity number
ES = earliest start
LS = latest start
(r) = maximum possible reduction
= normal duration-crash duration
(c) = cost slope
TF = total activity float (slack)

t = its normal duration
EF = earliest finish
LF = latest finish

Figure 3

It is clear that the project normal duration is 18 and that the critical path is 1-3. In order to reduce the length of the project one activity on that path will have to be reduced. Since activity 3 has the smaller cost slope, 1, we choose to reduce it first. (In other words the minimum reduction set at this step is activity 3). The maximum reduction of this activity in one step is the smaller of its maximum available reduction and the float in the other path. Since its maximum reduction is 2 and the float in the other path is 3, we reduce activity 3 by 2 units of time and thus reduce the total project by 2 units of time. We then recalculate the float in all activities. For activities 2 and 4, the float becomes 1.

In the second step we reduce activity 1 at a cost slope of 2. Although the maximum reduction for this activity is 5, we can reduce it only by one unit of time since the float in the other path is 1. After this step the float in the other path is completely absorbed and we have now two critical paths. The problem is to choose, in addition to activity 1, which has now 4 time units available for reduction, another activity from the second path, in order to form a minimum reduction set. Since activity 2 has the smaller cost slope, 3, it is selected for a reduction with activity 1 of one time unit, its maximum reduction. The total cost slope of this reduction step is 2 + 3 = 5, the sum of the costs slopes of activity 1 and 2, the members of the reduction set. Activity 1 has now a maximum reduction of 3 units and activity 2 has no potential for further reduction.

The final step is to reduce activities 1 and 4 for a maximum of 2 time units, the maximum reduction of activity 4, which is smaller than that for 1.

A summary of the reductions is given in Table 1 below, and the cost-duration relationship is depicted in the following Figure 4.

Table 1

Summary: Direct Cost-Duration Calculations

Step	Reduction Set	Cost Slope	Maximum Reduction at Step	Total Reduction	Total Addit-ional Cost
1	3	1	2	2	2
2	1	2	1	3	4
3	1,2	2+3 = 5	1	4	9
4	1,4	2+4 = 6	2	6	21

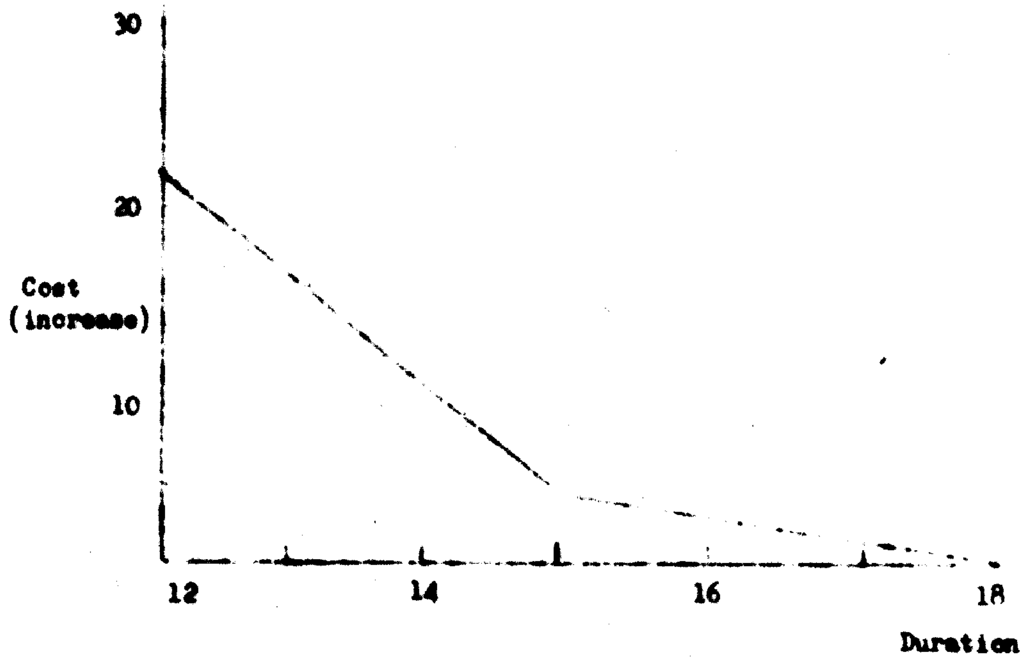


Figure 4. Direct Cost-Duration Curve

It is to be noticed that as the reduction increases, the cost slope tends to increase. This is a result of the linearity in activity cost slopes which was assumed before.

It will be noted that the choice of the minimum reduction set in this problem was very easy because of the small size of the network and due to the independence of its paths. In more complex problems several combinations of activities would have to be tried in order to find the minimum reduction set.

Although this procedure will not guarantee a minimum cost solution at any step except the first and the last, improvements on an unoptimum solution can be made by detecting any float activities which have been previously reduced. Such activities may be increased in duration until they become no longer with float, or until they reach their original length, whichever comes first, with a resulting reduction in cost.

Due to the complexity of cost-duration analysis of large activity networks, the use of computers often becomes more economical in performing cost-duration analysis. Several computer programmes have been devised for the solution of this problem for linear activity cost-duration curves. A computer programme has been devised at the University of Illinois, Urbana, Illinois which is very efficient in solving the problem for linear cost relationships, but which is also adaptable to solve the nonlinear case.[1]

There are, however, some methods for simplifying a complex network for the purpose of cost-duration analysis, which would make them more amenable to hand methods of calculation.

3.4 Network Simplification

Two methods of simplification may be used for a complex network:

A. Simplification by elimination

This is more important because it leads to the elimination from the network of most of those activities whose float is so large that even when the project is completely crashed, no reduction would be necessary in them. The procedure is as follows:

(a) Use crash activity durations, and conduct forward computations to determine the earliest start and finish times of the activities and the total project duration. This is actually the minimum or crash project completion time.

(b) Enforce the crash project completion time on the network as its latest finish of the last activity, use normal durations in order to compute the latest finish and start times of the activities.

(c) Compute the float of each activity by subtracting its earliest start time calculated in step (a) from its latest start time calculated in step (b). Some of the floats will be negative; these indicate activities whose float will

1/ The programme has been developed by W.J. Dunne and Mohamed I. Dessouky, Department of Mechanical and Industrial Engineering.

probably be absorbed before the project reaches its maximum reduction.

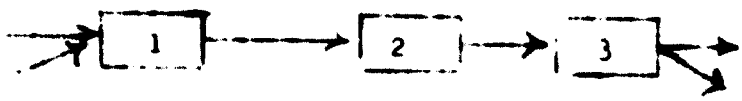
(d) The activities whose float is zero or positive may be eliminated from the analysis since they are activities which will never have to be reduced for any project reduction.

This procedure will eliminate most, but not all, the activities which are irrelevant to the analysis.

B. Simplification by grouping:

Activities which form a subproject within the project may be grouped together, and a composite cost-duration curve may be constructed for them so that they can be represented in the network as one activity. A subproject is a group of activities such that all activity outside the group precedes (not necessarily immediately) any activity in the group it will precede all others and any activity outside the group succeeding (not necessarily immediately) any activity in the group it will succeed all others. There are two types of subprojects and combinations of the two types. The two types are

(a) Activities in series (Figure 5):

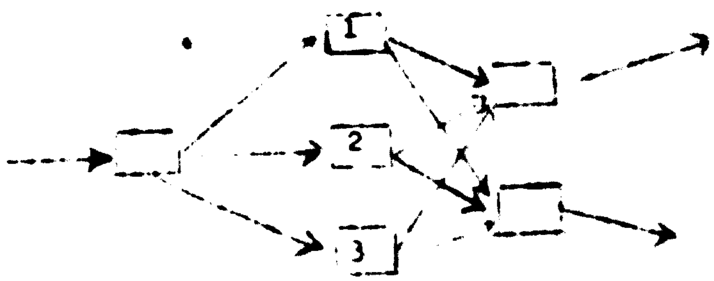


Activities in Series

Figure 5

Note that no other activity precedes 2 or 3 but the ones in the group, and no activity succeeds 1 or 2 but the ones in the group. The three activities may be combined into one and a composite cost function is constructed for them which uses the minimum cost slope for the first reduction and then the one next to it and so on until all reductions in all activities in the group are used. The maximum reduction of the group is then the total of the maximum reductions of its members.

(b) Activities in Parallel (Figure 6):



Activities in Parallel

Figure 6

Activities 1, 2 and 3 are in parallel. A composite cost cost function may be constructed for them by adding their cost slopes for any particular reduction. The maximum reduction of this set is the minimum of their maximum reduction.

4. SYSTEMS ANALYSIS

4.1 What is a System?

A system has the following characteristics:

(a) It is a collection of elements
(b) which are interrelated
(c) and serve a function.

In this category will fall planetary systems, machine systems and organisations. We are, however, interested in a system which in addition to the above:

(d) has an objective to attain.

Therefore our interest lies in those systems which include the human element. An organisation, as well as a project, fill all the four requirements for our definition of the system.

A system may be partitioned into subsystems, each consisting of a number of the original elements, or components. On the other hand, a system may itself be a component or subsystem of a larger system and so on.

For example, the fuel system of an automobile is a subsystem of its engine which is a subsystem of the automobile. The automobile itself may be considered a component in the system of traffic on a street which itself may be a component in a transportation network.

4.2 The "System" Approach

The "system" or "total system" approach is a way of problem-solving which came to the forefront scientific and technological progress in the 1960's. Basically, the approach requires the analysis of problems from all angles relevant to it, whether this problem dealt with the structure of an organisation, (or some other social unit) or the processes being performed by the organisation (or social unit).

4.3 Why the System Approach to Project Implementation?

The complexity of the process of implementation of projects, most notably industrial projects, is emphasized by several of their characteristics.

(a) They involve a large number of distinct activities, which are interrelated both sequence-wise and resource-wise.
(b) They require the deployment of a multitude of resources, human, financial and material.

The decisions involved in planning and controlling the implementation of an industrial project involve a wide variety of questions such as planning the sequence of activities, setting up the schedule of implementation, making an appropriate distribution of the resources over the activities assuming that the capacity of the resources is not exceeded by the demand on them, selecting appropriate equipment, processes and methods of implementation, and coordinating the efforts of many people and agencies.

This process of decision-making for industrial project implementation becomes more difficult in developing countries as a result of the scarceness of resources, the lower efficiency of personnel and the longer delivery times of goods and services. In addition, the problem is further complicated by the lack of managerial experience, the scarcity of technical skills, and the absence of the required industrial base. Furthermore, in most developing countries an industrial project is a part of an industrial plan consisting of several industrial projects. This implies that coordination for the utilization of available resources is required not only within the same project, but also among different projects. The process of coordinat on quite often involves scarce national resources for which the government needs to make important decisions.

The system approach and the different techniques of systems analysis can be very useful to planners, implementors and evaluators of projects and groups of projects in industrial organizations and governments of developing countries. They provide the managers and their staffs with tools which make them able to have a bird's-eye-view of the total undertaking and to coordinate the various factors operating on it.

4.4 Uses of Systems Analysis

It is worthwhile at this point to distinguish between two types of studies; strategic and tactical. The two types differ in several respects:

(a) In scope: strategy studies are broader. They involve wider territory and serve the needs of higher officials.

(b) In range: Strategy studies tend to involve longer-range plans. The consequences of the decisions or decisions recommended by the study generally extend over a longer time horison.

(c) In end-orientation: Strategy studies tend to be more involved with problems of formulating organisational objectives and policies rather than of finding means of reaching the objectives and making operational decisions.

(d) In weight: The impact of strategy decisions on the system as a whole is generally more pronounced in terms of money, risks, change, etc.

Systems analysis is most useful when applied to strategy problems. Cost-duration analysis and critical resource allocation of project networks are examples of techniques applicable to the study of strategy problems of industrial project implementation.

4.5 <u>What is the System</u>?

This is a very important question to be asked at the outset of any systems analysis study. As applied to industrial project implementation the system may be:

(a) A single project.

(b) A group of projects.

(c) An ongoing organization (a government agency, a part of a large corporation, etc.) involved in the implementation of industrial projects.

A system may be looked at with an emphasis on the relationship between its inputs (resources) and outputs (objectives), or with an emphasis on the relationship between its components (controllable variables), and environment (uncontrollable variables). Due to the need to incorporate these two points of view in any systems analysis study, the description of the systems we are dealing with will be made in connexion with their: (a) objectives, (b) components, (c) environment, (d) resources, and (e) management. The last aspect of the system is the one that coordinates the interactions of all others. A comparison of what these aspects look like for two types of system — a project and an organisation, is given in Table 2 below. It will be noted that by studying an organisation which implements industrial projects as a total system, we have defined a system which is in command of more resources, many of which are long-lasting. For example, whereas the management of a separate project may have to rent a piece of equipment for construction, an organisation in charge of project implementation may own such equipment and thus have more control over its use. Also, by being in charge of several projects running simultaneously, the management of a company will have a greater flexibility in allocating its resources.

While it is possible to define the elements of a project as its activities, a complete description of the project as a system requires the inclusion of other aspects involved with implementation such as the functions performed and the resources to perform them.

Table 2

The Project and the Organization as Systems

Aspect	Project	Organization
Objectives	Quality, time, cost, social value.	Survival, expansion, profit, social relevance.
Components	Activities, events, functions.	Projects or stages of projects, functions, departments.
Environment	Deadlines, resource limits and uncertainties, specifications, public opinion, government pressure, bidding price limits, random and unexpected events, uncontrollable costs.	Same as in project plus limits on profitability.
Resources	Manpower, materials, equipment, land information, money, foreign currency, time.	Same as in project but resources are more permanent.
Management (Functions)	Planning, directing, controlling and evaluating the implementation of the project.	Same as in project plus coordination among projects plus maintaining and developing the organization.

In fact one of the most difficult problems facing a systems analyst is to define the boundaries of his systems, in other words, the dividing line between the system proper (containing the components) and the environment. The factors affecting such a definition are:

(a) Position of client (of systems analyst): the higher the position of the client, the broader the definition of the system.

(b) Degree of interaction between variables immediately under the client's control and those outside of it. The higher the degree of interaction the more tendency toward including those variables beyond his immediate control and attempting to influence them, at least partially.

(c) Not all variables under the client's control are included in the system description nor all of those outside of his control and influencing the system are included in the description of the environment Only those which show some relevance to the problem at hand, expressed in the form of the objectives to be pursued. Parametric analysis could be used to test the response of the objectives to changes in the controllable variables and sensitivity analysis to test its sensitivity to variations in the uncontrollable variables. For example, a simple test may be conducted to investigate whether the project completion time will be affected by changes in the level of a specific resource. If the answer is negative, the resource may be disregarded from the analysis.

(d) The ability of the systems analyst also influences the scope of the problem he should tackle.

4.6 Decisions in Systems

Decisions are made in all stages of design and operation of systems. Such decisions may be strategic or tactical. The distinction between the two was discussed earlier. To sum up, a strategic decision defines general policies and long-range plans, while tactical decisions relate to short-range plans, detailed operational plans, and slight-modifications in the original plan. In other words, a strategic decision defines the direction and broad limits of movement and action, while tactical decisions define the actual lines of movement. With respect to project implementation as a system, decisions are faced when the initial implementation plan is made, when the resources are allocated and when situations are met where either modifications in the plan are required or detailed decisions are to be made. It is important at this stage to distinguish between planning decisions and control decisions. The first relates to the setting up of the initial plan of implementation including initial allocation of resources, and the latter to the modifications and corrections in the initial plan. The first type of decisions was discussed under resource allocation and cost-duration analysis, the latter will be discussed in the next section.

A decision is the choice of an alternative from among a feasible set of alternatives, according to an accepted criterion.

The criterion of choice is the measure of achieving the goals and objectives of the system, and some of these might be in conflict.

As mentioned before, the factors operating on and in a system are either controllable or noncontrollable. A decision is a determination of the values of some of the controllable factors, whether these values are expressed quantiatively or qualitatively. An example of a quantitative decision is that so much material X will be allocated to activity Y during a specified period of time. A qualitative decision may be that a certain team leader will be changed to a more forceful one.

In order to make a decision, understanding must be established about the relationships among the relevant factors operating within and outside of the system which are relevant to the [illegible]m at hand, and between all such factors and the decision criteria. Such relationships are described by a model. This model may be a simple verbal description of the relationships, or an elaborate mathematical model. In between, lies several forms of models, graphical descriptions (such as networks), solid scale models (of buildings, airplanes, etc.), and electrical circuits.

Regardless of the form used, a model is a simplified replica of the object of of study in the real world. In fact, every decision maker has a model of some sort in his mind while he makes his decision, whether he is aware of it or not.

By virtue of its simplicity and economy, a model may be adapted for experimentation in a way which is impossible to do with the real object of study. For example, it is possible to test the effect of an increase in the length of one activity on the completion date of a project through an examination of the network, while it is impossible to do that with the project without actually completing it.

A model may be used for experimentation, in which case it is a simulation model, or in deriving an optimum solution, in which case it is an optimisation model. In simulation, the model is fed different values of inputs in order to observe their effect on the outputs, which are the goals and objectives of the system. On the other hand, optimization requires precise mathematical definition of the objective function, or the decision criterion.

Techniques are available for finding optimum solutions for cost-duration analysis problems, while resource-allocation is largely done by experimentation, with reference to heuristic methods, in which the problem solver gains insights in the problem by the successes and failures he meets with, and thus improves his next trial for finding an appropriate solution.

Optimisation techniques, simulation models and heuristic methods can all be programmed on electronic computers.

It should be asserted here that since the best choice (decision) is no better than the best alternative considered, three elements are extremely important in a decision-making mechanism.

1. An effective information system providing the required information about the relevant variables and their inter-relationships. This subject will be discussed in the next chapter.

2. Ingenious and inventive decision-makers who probe new possibilities for the sake of reaching new and better alternatives. If the process of enumeration of alternatives is to be programmed (on a computer, for example) the programme should provide for scanning as many as possible of the feasible alternatives, and perhaps also generate new ones.

3. A tool, technique or mechanism for searching for the best alternative.

4.7 Control in Systems

System control is the assurance that the system operates according to plan. It implies the follow-up of the progress of operation and the comparison between actual performance and planned performance, and correcting any deviations in the light of the objectives to be attained.

The steps needed to administer effective control are:

1. Information collection and reporting of actual performance.
2. Comparison of actual and planned performances; determination of deviations, if any.
3. Communicating deviations to the decision-makers.
4. Decision-making for correction of durations.
5. Communicating decisions to implementors.
6. Action by implementors
7. Result of action to appear.

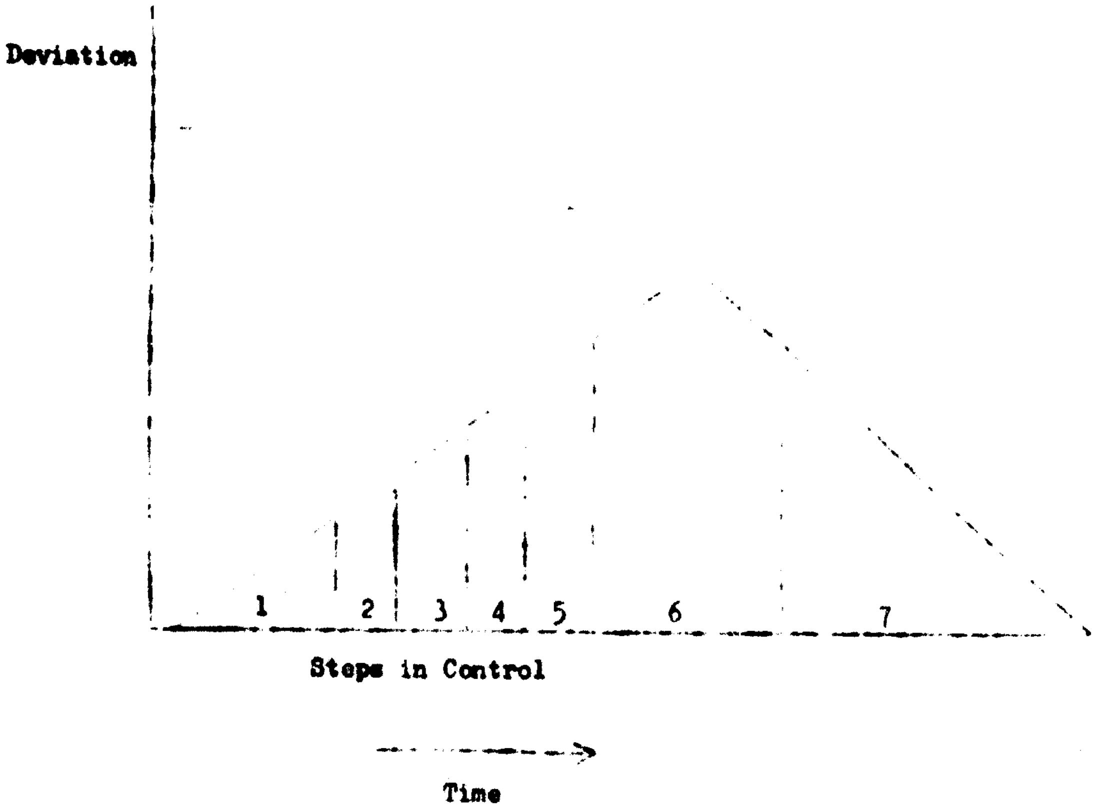


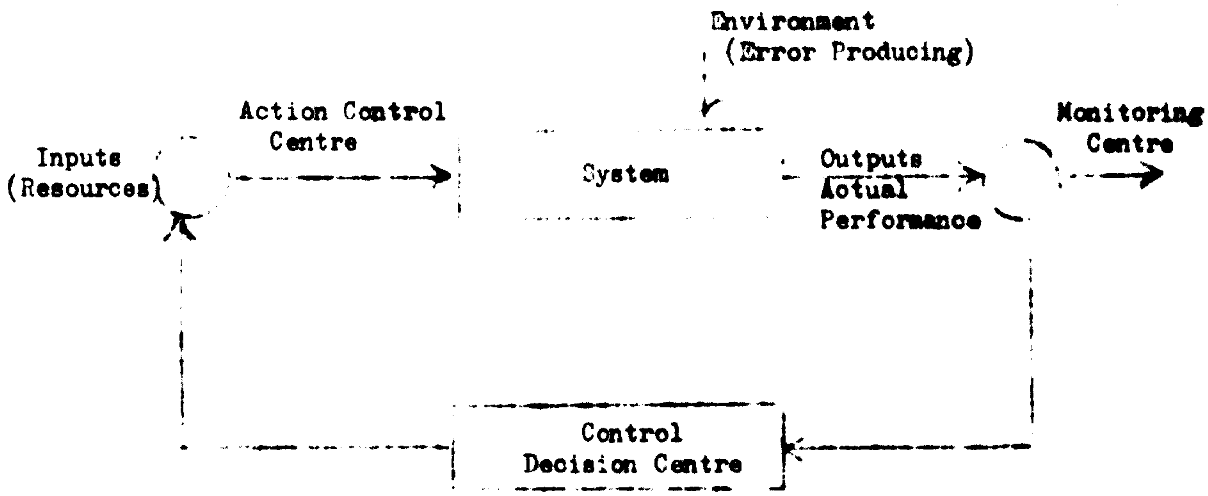
Figure 7. The Control Cycle

These steps are often called, "The Control Cycle" and their relationship to deviation from plan is shown in Figure 7 above.

Thus, control involved the following three main activities:

1. Information collection and communication.
2. Decision.
3. Action.

A control system relies heavily on the supporting management information system (MIS), which is the nervous system of the project or organisation under study. The main function of the MIS is to supply data about actual performance to a monitoring (reviewing or checking) centre in the control system, which makes the necessary comparison with the standard performance, to feed any errors back to a control centre which makes the necessary decisions, and to communicate the decisions to action centres so that action is initiated. Due to this movement backward of information the control process in systems is often labelled "<u>feedback control</u>", and is often portrayed with a diagram such as the one shown below in Figure 8.



A Feedback Control Process
Figure 8

The decisions made in feedback control need not be corrective decisions. The new information collected as the system operates in time (in a project, as implementation proceeds) may be used to reach detailed decisions (about resource allocation, scheduling, etc.) that could not be made as part of the overall implementation plan. In other words, contro involves making detailed, as well as corrective, decisions.

Feedback control becomes more complex when, as in the case of projec implementation, there is a lag between the time errors occurring and their complete correction. The problem becomes even more complicated if errors do not occur in one direction. For example, if at the beginning of implementation the efficiency of workers in the use of material is observed to be lower than estimated, a possible action may be to increase future orders of material. But then it may be that by the time the additional material is ordered and received, workers would have learned how to economise on the use of materials and consumption becomes drastically less, with the result that large quantities of material are left unused. In short, long lags result in larger deviations and higher costs of correction. The effects of lag may be reduced by reducing the lead time of control (reducing the length of the control cycle), and by anticipating errors and changes before they actually occur. The latter action requires effective prediction and forecasting mechanisms, which can be a part of the MIS.

Several methods can be resorted to in order to reduce the control cycle time: increasing the efficiency of the information system, placing decision centres as close as possible to action centres, and programming as many of the decisions as possible.

Decisions are made according to criteria, and as mentioned before, the criteria of project implementation are time, cost, quality and social value. Performance standards are made against these criteria, and control decisions are again guided by them. Control is required when deviation is observed in the progress of the project (the time criterion), the expenditures incurred (the cost criterion), and in the adherence to specifications (the quality criterion). Dissatisfaction of workers, the public, the government may also reflect serious problems to be considered by the management of the project (the social value criterion). Control may involve taking action to ensure adherence to the original performance standards, or failing to do that, modifying the original standards (e.g., revising completion dates, budgets, or specifications). This implies a higher order of control. A still higher order is to possess the liberty to change the basic criteria of project implementation.

The three criteria for project implementation mentioned above; time, cost and quality, may require three different, but interrelated systems to control. Thus, there may often be systems for progress follow-up (similar to production control in production systems), cost control, and specification checking (similar to quality control).

4.8 System Evaluation

The basic difference between monitoring and evaluation is that the latter is performed at considerably larger intervals than the former, thus allowing the management of the project enough time so that the results of their longer-range decisions are reflected on their performance. Thus, evaluation is made against basic project criteria, while monitoring is made against performance standards.

The above argument brings in the important question about how much time should be allowed between evaluations of the system, in our case, the project or the organization implementing projects. Before answering this question it is worthwhile to list four types of evaluation:

1. Periodical — Which is conducted after equal periods of time, at least a month, but may be done quarterly, semiannually or annually.
2. Stage — To be performed at the completion of specific stages of the project or all of it, or after the accomplishment of certain stages of an industrial plan.
3. Emergency — Which is initiated by observations of serious troubles in the completion of the project or by indications of mis-management or by complaints from employees, contractors, clients, government, the public or any important person or group. This may require a reassessment of the situation and the introduction of drastic changes.
4. Surprise — Unexpected evaluation which is conducted for the sake of assuring that records or appearances are not given which do not reflect the real situation; for example, sudden visits to the project site.

> Management which relies on this sort of evaluation probably counts as much on the threat of its occurrence as on the actual conducting of it to motivate people to work. Such evaluation would have more psychological effects than uses for collecting factual information about the status of the project.

The most important types of evaluation are the periodic and the stage, since information systems can be designed to yield the appropriate kinds of information at the time they are required.

The length of the evaluation period for periodical evaluation depends on several factors:

1. The importance of the project, the more important it is the more frequent evaluation is required.

2. The level of management to be evaluated, the higher the level, the longer the period.

3. The probability of occurrence of deviations, the higher the probability, the shorter the evaluation period.

The management of a project should have full knowledge of the evaluation criteria. Not only is this knowledge helpful in the evaluation process, but it is of utmost value as a guide to decision-making for better performance.

Evaluation of subsystems of the total systems requires a definition of what the subsystem is. A subsystem of the total project may be a grouping of activities according to any of the following criteria:

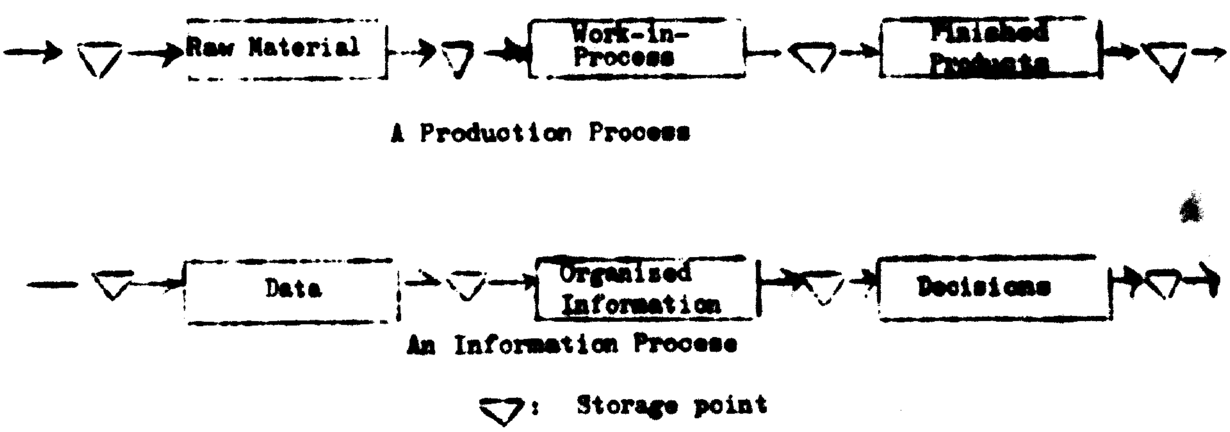
(a) They form a subnetwork of parallel and/or series activities.
(b) They serve the same general function.
(c) They utilise the same kinds of resources.
(d) They form a distinct stage in the project.

Evaluation of a subsystem of a project should be with reference to the criteria of the whole project, or to some intermediary criteria leading to them.

5. MANAGEMENT INFORMATION SYSTEMS

5.1 The Functions of a Management Information System

In the literature of management information systems (MIS), a distinction is often made between data and information. There is no common agreement about the distinction between the two, but information is generally regarded as data organized for the purpose of particular usage. The most important use of information is decision. To borrow an analogy from a production process, shown in Figure (8), which transforms raw material into work-in-process to finished products, with storage points in between, an MIS collects data, stores them, organises them into information, which is either stored or transferred (or both), for further use in decision-making. Decisions are then transformed into instructions which are communicated to the appropriate people.



Analogy Between Production and Information Processes

Figure 8

In any particular production system, it will be noticed that the flow of information moves in the opposite direction to that of material.

Much as a production process is designed around its final products, an information system should be designed around the final decisions to be made through the system. Knowing the kinds of decisions to be made, the information needed for them is organised for data which the system should be designed to collect. Many of the existing systems work in the opposite direction, they start with whatever data they have, and make the best out of them. Or else, they collec a large mass of data without particular regard to their use.

A very important function of an MIS is control. By following-up the systems performance, comparing it with planned performance (which is stored information) and providing the necessary information about the system resources and constraints proper control decisions can be made.

5.2 The MIS of Industrial Project Implementation

An example will be provided to show how an MIS could be effectively used to control project implementation. Suppose that the budgeted expenditures of a project, based upon given schedule of implementation, is that given by curve A in Figure 9 below. The planned project duration is T units of time. Suppose that after the elapse of some period of time t, the actual expenditure was given by some point Q instead of P. A superficial glance might convey the impression that there has been some cost saving in the project implementation.

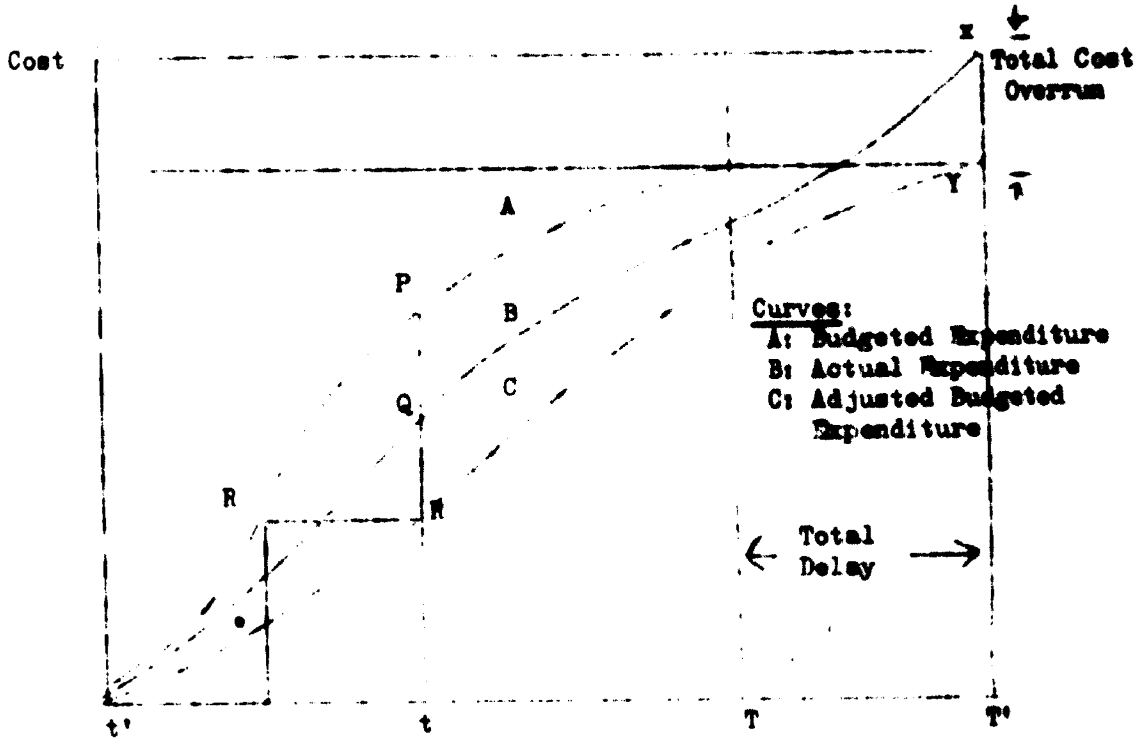


Figure 9. Cost-Control Curve

This view would be especially held if the cost information is not coupled with progress information. A proper MIS ties the two together so that in addition to furnishing data about the actual expenditures on a project, it provides a report on what the expenditure should have been, based on actual progress in implementation. Suppose that point R on the curve represents the revised or adjusted budgeted expenditure based upon actual implementation. Now, instead of finding a cost saving in implementation suggested by the difference in costs between A and B, there is actually an expenditure overrun given by the difference in costs between B and C. This cost overrun has been hidden by the slow progress in implementation given by the difference in time between points R and R', the latter being obtained by extending a horizontal line from R to meet curve A.

If curves B and C represent the values, over all the period of implementation, of actual expenditure and adjusted budgeted expenditure respectively, the two will end at time T', the actual project duration, with B ending at point X and C at point Y. The total delay in the project is given by

T' - T, and the cost overrun is given by the difference in costs between points X and Y.

It should be remembered that the costs here do not represent cash flows, but usages of other project resources such as material, labour and equipment. Cash could be disbursed before or after the activity.

5.3 The Project MIS and the System Structure

The MIS of a project is tailored around the following considerations:

1. Planning and control decisions and evaluations to be made.
2. The system hierarchies.

The first consideration has been mentioned and slightly discussed. The second is also important because it furnishes a general constraint on the way data are organised into information. It will have to be remembered that decisions are made at several levels in the organization, and that data are usually collected from the field, at a lower level in the organisation. These data are organized for a higher level, which condenses it to some degree for a still higher level, and so on.

Again, since the organisation of the forms and the files must be oriented to the ultimate use of the information, such organization will depend upon whether information is needed about all the resources needed for a certain activity, or about all the activities using the same resource. Here the analogy with a production system is obvious, information may be needed about the costs incurred in a cost centre, or about all the costs incurred by a particular job.

The knowledge of all expected uses of information will help in designing the forms, the files and the flow of information. Such flow should allow for minimum delay in conveying information to where it should go, and should provide for a sufficient capacity to process the information quickly and efficiently. A most important tool to perform this function is electronic computers. Electronic Data Processing (EDP) helps in organising the data, updating it, processing it, and providing the required outputs all at high speed and large capacity. Besides, it can assist in decision-making by computing optimum solutions to decision problems, simulating the system and conducting sensitivity analysis and parametric analysis. However, since the cost of EDP equipment and programmes is usually high, it has to be justified in terms of use before they are procured.

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