

Fred Emery

The Nine Step Model¹

Purpose of Model

This analytical model has been developed as a practical tool to help line managers implement the concept of joint optimization in their own departments or sections. It is hoped that it will enable managers to examine their existing technical systems and their existing organizations to gain insight into the technical and social systems, and to improve the level of performance.

The Model in Practice

As the model has been tried out on a number of different production systems, certain lessons have emerged:

- Care must be taken in selecting the appropriate area for analysis. Existing organizational boundaries are not necessarily the most appropriate ones. In practice, it is all right to select a production system as defined by current organizational boundaries, bearing in mind that one result of the analysis might be an indication that the boundaries should be adjusted. Departmental management should not select too large or too complex an area for analysis, at least initially. In

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most cases, a department is too large a unit for full study within a reasonable period of time with the resources available. Greater progress can be made by selecting smaller units, if possible.

- For analysis, it is helpful to concentrate on the production system as it is currently operating; otherwise, some confusion may creep in with reference to the way it "used" to operate or how it "might" operate in the future.
- A practical difficulty is the tendency to collect too much detail. An effort should be made to identify only key information under each step heading and to avoid getting caught up in an abundance of detail.
- To initiate and carry through an analytical process and to carry out an ensuing action program will require a high degree of effort and commitment. It will also require the participation of people at all levels in the production system concerned. It seems highly desirable, therefore, to set up a small action group headed by the production system manager, with representatives from various levels and with such outside help as may be required.

Analytical Model for Socio-Technical Systems

Step 1: Initial Scanning

The objectives of this step are to identify the main characteristics of the production system and of the environment in which it exists and to determine, if possible, the

main problems and where the emphasis of the analysis needs to be placed. This can be done through a carefully structured briefing of the action group by a departmental manager. The briefing should cover the following ground:

- The general geographical layout of the production system.
- The existing organizational structure and the main groupings within it.
- The main inputs into the system, with specifications where appropriate.
- The main outputs from the system, again with specifications where appropriate.
- The main transforming processes that take place within the system.
- The main types of variance in the production system and their sources, e.g., the nature of the raw material, the equipment or breakdowns.
- The main characteristics of the relationship between the production system and the department in which it exists.

Step 2: Identification of Unit Operations

The purpose of this step is to identify the main phases in the production operation.

Unit operations are the primary segments or phases in the series of operations that have to be carried out to convert materials at the input end of the system into products at the output end.

Each unit operation is relatively self-contained and each effects an identifiable transformation in the raw material. A transformation in this sense is either a change of state in the raw material or a change of location or storage of the material.

The actions necessary to effect the transformation may be carried out by machines or by people, but we are not concerned at this stage with either the characteristics or needs of the

machines (e.g., maintenance needs or operating characteristics) or the characteristics and needs of the people (e.g., psychological needs). Attention is entirely on the series of transformations through which the raw material goes. Where possible, the purpose of each unit operation needs to be identified in terms of its inputs, its transformations and its outputs.

Step 3: Identification of Key Process Variances and Their Interrelationships.

The objectives of this stage are to identify the key process variances and the interrelationships between them. A variance is a deviation from some standard or from some specification.

It is necessary to emphasize that, at this stage in the analysis, we are concerned with variance that comes from the raw material or from the nature of the process itself as it is currently or normally operating. We are not concerned with variance that comes from faults in the technical equipment or plant (e.g., breakdown or malfunctioning); nor are we concerned with variance that comes from the social system (e.g., maloperation or human error).

We also are not concerned with the total range of variance. From other studies it has been found that there are a large number of variances in any production system that have either no effect or a comparatively minor effect on the ability of the production system to pursue its objectives. It may be necessary, however, to take some such variance into account in subsequent attempts to reach a higher level of joint optimization, but at this stage we are concerned only with those "key" variances that significantly affect the capability of the

production system to pursue its objectives in one or more of its unit operations. The sequence of actions necessary is as follows:

- Identification of all variances in the system (arising from the nature of the raw material or from the nature of the process) that, in the opinion of the action group, are worthy of note. The main sources of information are the manager and supervisors of the system, who draw on their knowledge and experience. It is necessary to go through the process of identifying variances several times to ensure that all the main variances have been included.

- Drawing up a matrix of the variances identified. This matrix shows any clusters of variances--control problems--and also shows where information loops exist or are necessary in the production system. It will also help in the selection of key variances (e.g., variances that have an effect through a series of unit operations are likely to be considered key to the control of the process).

The identification of the key variances can be done in two stages:

- (1) The department or unit manager and appropriate assistants should make a list of what they consider to be the key variances, drawing on their experience and knowledge of the production system.
- (2) The action group should work with this list, checking it against the matrix of variances and against the following four criteria. A variance should be

considered key if it significantly affects:

- quantity of production;
- quality of production;
- operating costs (use of utilities, raw material, overtime, etc.);
- social costs (e.g., the stress, effort or hazard imposed on the employees).

The first three dimensions are concerned with the system's production objectives.

It is possible to move now to an analysis of the social system; to examine the way in which it contributes to control of variances and so to the attainment of the production system's objectives; and to examine the extent to which the social system's own needs are met.

Step 4: Analysis of the Social System

The objective of this step is to identify the main characteristics of the existing social system. Its complex sets of interrelations and groupings, both formal and informal, do not need to be described. By structuring the analysis carefully, it is possible for the analytical team to draw out sufficient amounts of the relevant information to enable it to begin to develop job-design proposals relatively quickly. The following steps are the minimum necessary:

- A *brief review* of the organizational structure where necessary, filling in a little more detail than was included in Step 1 on number of levels, social groupings and types of roles.

- Preparation of a *table of variance control* to show the extent to which key variances are presently controlled by the social system. It is possible to identify where key organizational and informational loops exist or are required by using such a table. It answers the following questions: Where in the process does the variance occur? Where is it observed? Where is it controlled and by whom? What tasks must the controller do to control it? What information does the controller have from what source to carry out these control activities? Hypotheses that are formed should be noted for subsequent discussion and possible validation.
- *Ancillary activities* such as descriptions of the workers' roles in the production system should be noted. Activities connected with the control of key variances will be listed in the variance control table. It is likely, however, that there will be a number of ancillary activities. Identifying these and trying to relate them to the control process may well lead to the identification of additional key variances. On the other hand, it could conceivably lead to the elimination of these ancillary activities altogether.
- *Spatial and temporal relationships* such as the physical or geographical relationships between the various roles in the production system (i.e., distance or physical barriers between workers) and their relationship over time must be mapped out.
- *Flexibility*, i.e., the extent to which the workers share a knowledge of each other's roles, can be identified on a mobility chart. It may be necessary to carry out this step in two phases: an initial analysis of rotation and a more detailed

analysis of the extent to which the workers carry out the essential tasks associated with the roles. The chart should cover a period of two or three months.

Therefore, it is good to start recording this information in the early weeks of the analysis process.

- The *payment system* and how it is related to various roles in the production system must be studied because it has an impact on job rotation, group working, etc.
- *The psychological needs* of employees can be tested to see if their roles meet these needs. An adequate/inadequate rating for each employee's main activities is sufficient. For this purpose, the action group will need to rely on management perceptions of the roles. To learn the workers' perception for their roles, it will be necessary to set up some machinery for the collection of their views.
- *Identify areas of maloperation* to establish causes, where possible.

Step 5: People's Perceptions of Their Roles

This step, although it is part of an analysis of the social system, is dealt with separately partly because of its importance and partly because of the method of carrying it out. Its purpose is to learn as much as possible of the people's perceptions of their roles, *specifically the extent to which they see the roles as fulfilling their psychological needs*. This can be accomplished by having a personnel worker in the action group, either for this particular purpose or as a full member.

Two interviews can be arranged with appropriate groups of workers, the first

within the first six weeks of the analysis and the second toward the end of the process, when job-design proposals are being finalized. Both interviews must be highly structured, designed with open-ended questions based on psychological needs and, in the case of the second interview, on the developing job-needs design proposals.

With this step, an analysis of the production system itself is complete, and it is to be expected that a number of redesign proposals or hypotheses will have emerged.

The analysis now considers the impact on the production system of a number of "external" systems, e.g., maintenance, supply and user systems, personnel policy, etc., that will influence any hypotheses that have emerged and that may well bring about further redesign proposals.

Step 6: Maintenance System

This step is not concerned with the examination of the maintenance system or organization as such but solely with the extent to which that system has an impact on the particular production system being analyzed and with the extent to which the maintenance system affects the capability of the production system to achieve its objectives. These objectives are to determine:

- the nature of the maintenance variance arising in the production system;
- the extent to which that variance is controlled;
- the extent to which maintenance tasks should be taken into account in the design of operating roles.

This analysis of maintenance variance is not in any way subordinate to the analysis of process variance carried out in Step 3. Both are necessary to an understanding of the characteristics of the production system. It may be that in some cases, variance of a greater order comes from the maintenance system than from the production system itself, in which case one would expect greater emphasis on this stage.

To collect information on maintenance activities, the analyst must begin with the first month of the project and continue for two or three months. The collection of additional data and the burden of collection placed on operating and maintenance staff should be kept to the minimum consonant with achieving the objectives of the analysis.

Step 7: Supply and User Systems

This step is not concerned with identifying the characteristics of the supply and user systems themselves, but with the way in which these environmental systems affect the particular production system. The objectives of this stage are:

- To identify the variances that are passed into the production system from the supply and user systems.
- To examine, where appropriate, the extent to which these variances could be controlled closer to their source, or their effect on the production system could be diminished.

In general, the analysis across the boundaries of the production system should be kept at a fairly general level initially and should go into greater detail only if there appears to be a

real possibility of effecting an improvement, e.g., a better control of variance or more appropriate flow of information.

The result of this step might be either a diminishing of the variance arising in the production system from across its boundaries or, in some cases, a redefining of the production system's objectives to ensure that they realistically take into account both supply and "marketing" constraints.

Step 8: Work Environment and Development Plans

The purpose of this step is to identify those forces operating in the wider departmental or work environment that either affect the production system's ability to achieve its objectives or that are likely to lead to a change in those objectives in the foreseeable future. It has two main steps:

- *Development plans.* The identification of any plans, either short or long term, that have a high probability of being implemented *for the development of the social or the technical systems.* These clearly would have to be taken into account in the development of any redesign proposals.
- *General policies.* The identification of any general policies or practices that impinge on the production system, if these have not been taken into account in the examination of the maintenance system and the supply/user systems. Examples are the general method of promotion, which affects the social system, or the

utilities supply and control system operating throughout the plant, which affects the technical system.

It should be emphasized that we are not concerned with the characteristics of these environmental systems as they exist in themselves, but only insofar as they affect the ability of the production system to pursue its objectives. In the analysis of most production systems, these environmental factors will constitute "givens" rather than areas to be included in proposals for change.

Step 9: Proposals for Change

The purpose of this step is to gather all the hypotheses and proposals that have been developed during the analysis process, to consider their viability and to make them the basis of a subsequent action program.

As was mentioned earlier, it is likely that hypotheses will be formed as the analysis of the technical system is being completed. These proposals will probably be expanded, eliminated or modified as further information is gathered about the social and environmental systems.

Those hypotheses that remain must be tested, as much as it is possible on a theoretical basis, against appropriate criteria before being developed into viable proposals. The actual criteria will vary and will require careful design, but these criteria must relate to the production system objectives and must cover:

- the production objectives of the system in terms of quantity, quality and general operating costs. This covers proposals specifically aimed at increasing the control over, or diminishing variance in, the production system.
- the social objectives of the production system, such as those aimed at increasing the extent to which psychological needs are met in role design or at diminishing the costs borne by the work force (e.g., stress, hazard or heavy labor).

Many proposals will, of course, lie in both areas. For example, proposals aimed at increasing the level of responsibility at the lower levels would meet psychological requirements and might lead to shorter lines of communication and more effective variance control. In addition, any proposals for the redesign of the social system must be tested against emergency and crisis needs. In the case of a process unit, this would entail the ability to shut the unit down in the event of a loss of power or feed, or of a major fire.

Organizational Objectives and Role Analysis

This model has been developed in conjunction with the socio-technical model as an alternative method of analysis for departments in which no continuous process exists, e.g., service or advisory departments. Like the socio-technical model, its purpose is to help managers analyze their existing organizations as they currently and normally operate, and to develop proposals for change when this seems likely to lead to improved performance. The model is still in the development stage.

Step 1: General Scanning

This step should provide a general introduction to the outputs, inputs and transformation processes in the department, i.e., its objectives, its work and its organizational structure and location within the organization, as well as to the geographical layout of the department. Scanning is necessary so that more detailed investigations at a later time can be seen against an overall background. In general, the amount of detail collected should be kept small. If this analysis is undertaken by an action group, it is probably useful for the departmental manager to describe each process itself rather than to explain its purpose.

Step 2: The Objectives of the System

It is important to arrive at a clear definition of objectives because this provides a rational datum against which to judge all activities in the department. In practice, the identification and statement of objectives pose difficulties because:

- the objectives stated may be too general;
- they may be multiple, but only one or two may be identified;
- they may be nonmeasurable;
- they may refer to several time periods;
- they may be partly derived from higher or other system levels;
- they may be outputs that the system wants to minimize rather than to maximize, e.g., waste;
- they may involve changes of the internal structure of the system rather than

outputs from the system, e.g., change in assets;

- they may not be well enough recognized to be formulated.

To cope with these problems, the following method of analysis is proposed.

Consider all major *outputs* of the department, whether they be processed raw materials, communications or workers. Then try to identify all inputs and follow these inputs to determine the steps they go through to become outputs. Make sure that no significant output has been missed. Then test outputs to determine whether they are objectives by presenting them to the manager of the next higher system level and asking him or her whether these are, indeed, the outputs required. Also, some inputs come into the department to maintain or develop the assets, and part of the objectives of a department will be directed toward these two activities. The assets of a department include its plant and equipment, the money over which the manager may have authority and the workers.

When considering a department's outputs, a problem may arise because it may not be possible to describe an output such as a communication (written or verbal) meaningfully unless some indication is given of its necessary contribution to an overall decision that is made outside the boundaries of the department. In such cases, it is useful to draw up a table with the following headings:

Description of output.

To whom sent.

Overall decision it was intended to support.

Required contribution of the department's output to this decision.

Consequences of substandard performance on the social and economic cost (both inside and outside the department).

This analysis will determine the resources that are within the boundaries of the department and those that the manager needs to bring in. Because departmental objectives are more clear, it should be possible to hypothesize the responsibilities, authorities, information/communication links with others and key methods and procedures that are appropriate and to match them against those that already exist.

Step 3: Analysis of the Roles in the System

An analysis must also be made of each role in the system to arrive at the role objectives and to relate them to the overall departmental objectives. This process should start with the manager's role and work down through the system.

Step 4: Grouping of Roles

This analysis will identify the necessary role-interaction links insofar as the current process exists and will lead to hypotheses about the clustering of these roles in respect to

their geographical and temporal distribution and status dimensions.

Step 5: Measurement of Roles against Psychological Requirements

After identifying the inputs, transformations and outputs of each role, it is useful to measure the manager's perception and the workers' own perceptions of how much each role meets the workers' psychological requirements. The workers' perceptions of their own roles can be learned through individual interviews, preferably conducted by someone outside the department.

Step 6: Development of Change Proposals

In the course of the preceding steps, various hypotheses for change will have emerged. These should be refined into proposals for the redesign of jobs or organizations, e.g., a change in authorities or methods of grouping, or it may be that by this stage analysis will have indicated a need for a reformulation of department objectives. Proposals for change will, of course, have to be related to the overall environment of a department.

Step 7: Management by Objectives

Once the objective of the department and its constituent roles have been determined, attention should be given to developing performance measures, to setting targets (either jointly with a manager or by oneself as consultant) and to feeding back these results to the person occupying the role. However, because important areas of role output may not be readily

measured, care should be taken to ensure that these areas are in some way included in performance targets so that role output is not distorted.