A PRODUCTION SYSTEM AND ITS CONTROL

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TITLE OF RESEARCH: A PRODUCTION SYSTEM AND ITS CONTROL

SUMMARY

Originated in my own experience, this research is concerned with the problems of effective operation and delay in the adaptation of the Production System in manufacturing companies.

The aim of this research is to establish a coherent framework to analyse the problem of Production Control.

We started with a review of the literature. In the Operational Research literature, we found many techniques for specific applications but not a framework we could use. In the Production literature, we found several approaches and points of view but again without coherent basis for unification. Careful attention had to be given to methodology in order to bring the Systems Theory and Operational Research together in a synergistic way. Based on the Systems Theory and Cybernetics, we built a model of the relationships which are necessary to regulate the operation and the adaptation of the production system and its management.

By comparing the mechanisms in our model with those currently used in industry, we found out that there was a need for improving the speed and precision with which the company perceives the failure of the short term regulation because this may dangerously delay the start of the adaptation process.

We then developed a technique intended to produce effective diagnosis of the adequacy of the control of the production system so as to initiate the process of adaptation earlier than usual. Our technique points out the need for adaptation; but for adaptation to take place, it is also necessary that the organisation produces practical solutions which ensure the restoration of control over the activities of production.

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KEY INDEX TERMS

PRODUCTION CONTROL
REGULATION
MATERIAL FLOW
PRODUCTION SYSTEMS
ULTRASTABILITY

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CHAPTER ONE

AREA OF RESEARCH AND METHODOLOGY

1.1 THE AREA OF RESEARCH

This research is about some of the problems of control of the production system in manufacturing companies. Here we pursue the detection of a particular type of control failure - that caused by the inadequacy of the control system itself.

1.1.1 THE MANUFACTURING COMPANY AND THE PRODUCTION SYSTEM

Most of the organisations created by man have the common characteristic of transforming the conditions of life to his favour. In that sense these organisations have many similarities. For instance they have to develop the ability to produce the transformation which identifies more clearly the organisation. Similarly they have to be able to integrate correctly the elements that participate in that transformation as well as to procure by themselves the resources which are to be used.

It is the transformation they perform that defines and differentiates more clearly these organisations. Because of this they also have many differences.

A very common classification based on the type of transformation is that which distinguishes between organisations producing goods and organisations producing services.

The companies producing cars, electrical appliances, chemical products, clothes and even agriculture offer some form of goods. On the other hand, the Post Office, the educational system and the Health Service offer services.

The manufacturing company is one of the commonest organisations of our society. From its results, the welfare of society depends in a proportion that cannot be neglected. This type of organisation can be considered as one that offers products and whose transformation is highly technical. In the manufacturing company, the main transformation is carried out by the production system.

The production system, in the manufacturing company, consists of the industrial machinery, the plant, the labour force and the industrial processes of production. An industrial process is a sequence of operations which enables the production of a specific final product from raw materials, consumables and parts. Generally, the operations are carried out using the industrial machinery and equipment under the supervision and control of the operators.

The plant is considered to be the set of all machinery and equipment, either electrical or mechanical, that intervenes in the operations and also in the transportation of semifinished products from one stage of the production process to another, as well as the physical location of the operations.

The transformation of raw materials, consumables and parts into final products making use of plant and labour requires the realisation of very well defined interactions between the elements of the production system. These relationships are of two types. Some derive from the technological precision of the physical and chemical processes affecting the materials while transforming or integrating into the final product. The others are related to the procuring and allocation of the physical and human resources which are necessary to carry out the more technical processes earlier mentioned.

In this research, we are concerned with some of the problems which arise in the administration of resources which intervene in the production process.

1.1.2 MANAGEMENT, CONTROL AND PERFORMANCE

The problems we are refering to are the problems in the control of the production process. In the fabrication of products, a number of resources have to be made available in the quantity, quality, place and time required. Resources such as plant, labour, raw materials, consumables and parts have to be used in precise proportions and at the time that best suits the process of production. To make that possible is the task of Production Management. The complexity of this task requires planning and control as a process parallel to that of production.

The fact that the volume required of these resources is considerably large and that such resources are scarce implies that the courses of action leading to their utilisation have to be selected carefully and beforehand. At the same time, and due to the fact that the decisions related to the use of these resources are not independent from each other, they have to be integrated within a coherent framework in order to support effectively the activity of production. All this lead us to the need to plan the activity of production as well as the ancillary processes which support production.

Nonetheless, because of the complexity of the production process and also because of the high probability of unexpected events taking place, the results may be different from what was intended in the plan. The differences between what is aimed at and what is finally obtained happen to usually, and seriously, damage the development of the production process.

Knowing these deviations would allow the reformulation of the courses of action still to be implemented and even the correction of those already in practice with the purpose of reducing the consequences these may have upon the outcome of production.

From the high uncertainty which is a characteristic of production stems the value, as well as the necessity, of controlling the production process and those processes which support production. Although control can be defined in a more comprehensive manner, in evaluating and reviewing plans, it refers to the detection of differences between expected and actual behaviour of the Production System.

If we concentrate on the detection problem, we see that it is necessary to compare the actual behaviour with the expected behaviour of the production system. The expected behaviour is that being sought in the plans while the actual behaviour is the result of the action of the production system. There are two conditions which have to be present for the detection to be successful.

First, for the control system to be able to perceive diffe rences, it is necessary that the measurements of the results of production can be compared with the references which are based on expectations; these references need to be shown in the plans. Secondly, it is necessary that the control system is able to detect the differences which are critical to the functioning of the production system.

If we were to have a complete knowledge of the way in which the production system works and only expected events were to take place, there would be no need for control, simply because the actual behaviour would always be the expected. That is, of course, very rare in production.

Sometimes it may happen that the knowledge about the internal functioning of the production system is good enough as to predict with accuracy its outcome in the absence of disturbances. The uncertainty over the result of production may then lie only in the occurence of unexpected events and control may be transfered specifically to the detection of differences between the expected events and those which actually take place. Knowing this, it should be possible to infer the deviations that these differences will cause in the outcome of production. Even in this case we also need the two conditions for the success of detection that we earlier mentioned although with a modification. This time the relevant differences are those between the real and the expected behaviour of the environment rather than that of the production system.

In more general terms, the first part of the problem of control can be stated as that of determining the situations which are critical to the functioning of the production system and to develop methods which enable its detection.

The measure of the functioning of the production system is its performance. This is defined in two aspects. On the one hand, the accomplishment of the transformation of production. By this we understand the finishing of the production orders in their specifications of quantity, quality and time as the demand requires. Secondly, to achieve an appropriate level utilisation of the resources necessary to that transformation. In this sense we mean that plant, labour and capital are combined to the best advantage for the purposes of the stability of the manufacturing company. Those disturbances which happen to keep the level of performance away from the expected are the ones to be controlled.

The cause of an inadequate performance can be internal or external to the production system. Internal causes are, for instance, the lack of adequate instructions to conduct the process of production - such as making it unnecessarily expensive. That is a poor production plan. The occurence of stoppages in the production system which delay the outcome of production also falls into this category. On the other hand, external causes are, for instance, changes in the demand in the market being served by the company but which puts the company in a difficult position to respond. In both cases, nonetheless, the result is an increase in the difference between the real performance and that which is required.

One important objective of the control function is that of the generation of information leading to the restoration of the level of performance required and hopefully information to anticipate the failure in performance.

The relevance of the methods to detect deviations during the course of production is related to the fact that the earlier the detection and the precise its definition the easier it will be to formulate and implement corrective courses of action. Depending on how soon the failure is detected and the precision of its identification, the sooner the adjustments could take place in order to restore normality. This is relevant even more when the adjustments in this case are of a known nature and the major proportion of the response time is spent in the implementation of solutions.

So far we have been refering to the functioning of the controlfunction. That is, problems of control assuming that the control function is able to cope with the complexity of the situation. There is another situation which is most relevant to the problem of control. The controlling system can cease to be effective without failing to function. This happens because the complexity of the situation to be controlled has increased beyond the limits with which the control system can cope.

This deviation is one the control system is not prepared to detect. This is a control problem of a different order. Nonetheless, also in this case the speed to detect this type of failure is crucial. This is the detection of the inadequacy of the control system. Such failure is extremly dangerous to the running of production because there is no longer control over the outcome of production.

1.1.3 THE AIMS AND JUSTIFICATION OF THIS RESEARCH

The detection of the inadequacy of the control system is extremely important since it is concerned with the overall success of the activity of production. Without a suitable control system, the activity of the production system could rapidly endanger the viability of the company.

Solutions exist for most of the specific failures detected by the control system, but when the control system itself becomes inadequate general solutions are not known. Applications from Operational Research into the problems of controlling production such as scheduling of activities, inventory control, allocation of resources, product-mix decisions, are answers to problems the controlling system can detect. However, these techniques are not applicable to the problem of detecting and solving the inadequacy of the control system.

The need for a development in that direction is evident from the fact that there are not good answers to this problem. The way in which organisations realise the inadequacy of its control function usually takes a long time and causes a great deal of strain in the organisation because it is easily confused with a failure in the internal mechanism of the control system.

This research aims to find a way to monitor the effectiveness of the control system and detect its inadequacy in a quicker way than it is currently done. By doing so, we expect to help the production system to generate solutions to the control problem without causing unnecessary risk to the viability of the company.

1.2 METHODOLOGY

1.2.1 CHECKLAND'S METHODOLOGY

Our problem is one that can be regarded as ill-structured according to Peter Checkland's view (1977) since the way in which Production Management develops awareness of the presence of a control problem as well as the way in which courses of action taken in response to those problems finally take shape are not possible to describe with analytical precision as it does in the case of exact sciences because of the uncertainty of human behaviour.

Therefore a 'soft' methodology has to be followed in contrast to the methodologies applicable in the exact sciences. Checkland (1976,1979) developed a methodology which is applicable to ill-structured problems; this is summarised below in Figure 1.1

In relation to the steps of that methodology, we could say that although we will come back later to these points, we have already presented the first two stages identified as the 'finding out' stages. However, it is necessary at this stage to present a root definition of the problem of controlling production.

We can define the production control system as the part of Production Management which ensures that the production system satisfies the demand for final products both in the

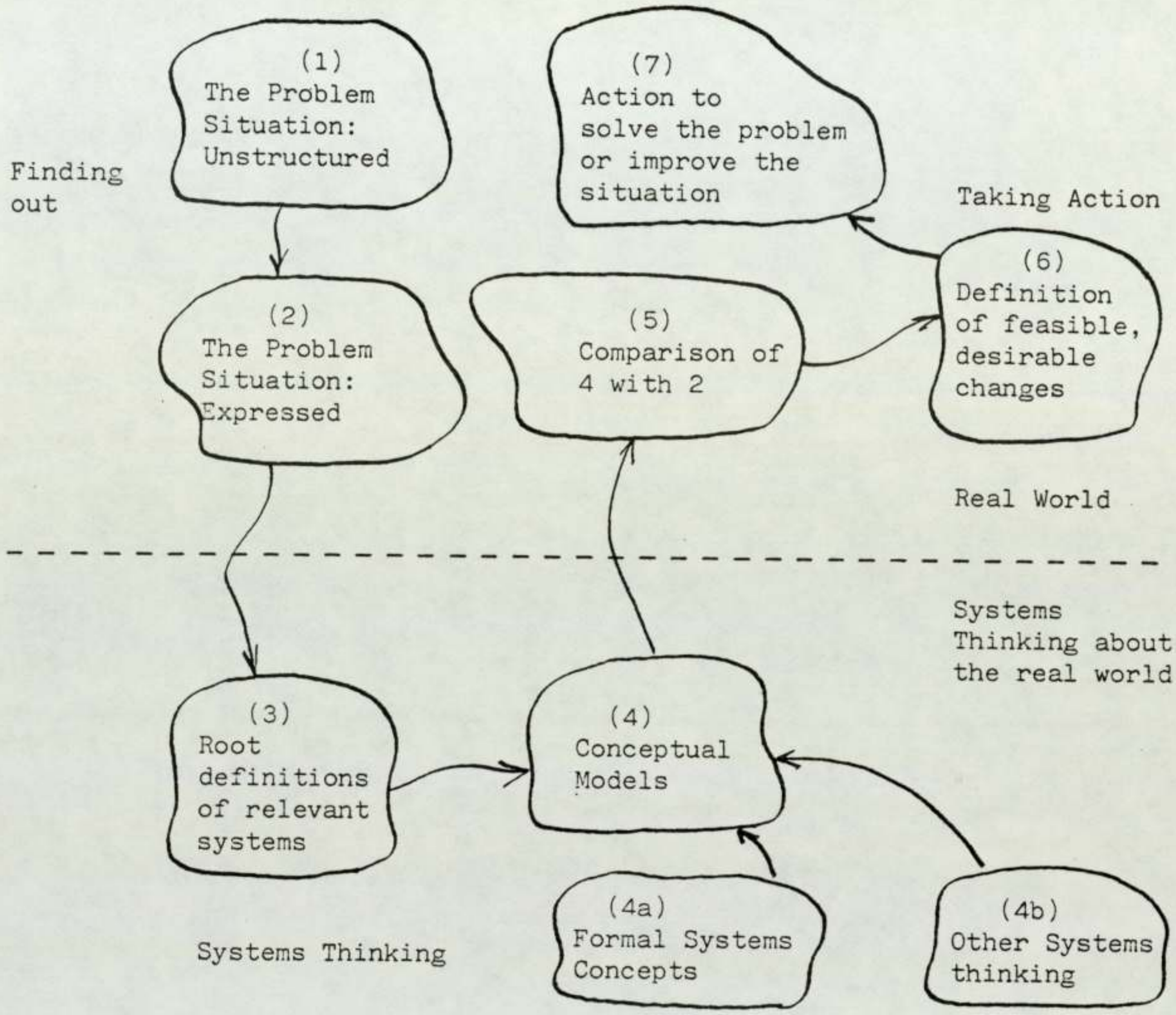


FIGURE 1.1 THE STEPS OF CHECKLAND'S METHODOLOGY

short and long terms, making use of resources so as to help in keeping the company viable.

In this sense the problem of controlling production is a problem of Production Management where the controller is a set of functions within Production Management and the controllee is the Production System. The latter has to be controlled because the disturbances acting upon it may result in the deterioration of the viability prospects of the company either by obstructing the satisfaction of demand or by forcing the use of resources in ways that the company cannot afford.

Our work follows by modelling this situation and referring to a more formal theory on control to continue with a comparison of this model with the situation as analysed from the real world. From here we state some desirable changes to improve the possibility of control over the production system.

Unfortunately, this thesis does not cover the last stage of Checkland's methodology; nonetheless, it provides a technique to make these changes possible.

1.2.2 THE SOURCES

This being a problem of control, we see the need for a coherent theory of control from which guidance has to be sought in the search for a solution.

The paradigm of cybernetics is seen to be appropriate to play that role because of the universatility and coherency with which it treats the problem of control.

The problem is also essentially related to interaction between different parts of the organisation; hence, a systems approach is seen to be essential.

Production control is a common practice in today's manufacturing companies and a great deal of experience has been accumulated during the last decade. In order to learn about this area, we have referred to specialised literature as the main informant of that experience. Our own experience from direct involvement in industry is also considered to be a legitimate source of ideas.

1.2.3 THE METHOD

From the methodological point of view, what we do is to compare the mechanisms for control, generally in use in the manufacturing industry, with those required according to the cybernetic principles of control. From this comparison; we find some characteristics that are necessary according to the cybernetic model of control but missing, or poorly developed, in manufacturing industry. Relying on the cybernetic principles of control, we assume that the development of these characteristics will help to improve control. Finally, from the analysis of the functioning of the production system, we formulate a technique which identifies the missing parts in the control system of the manufacturing companies.

We describe some work of the control function in the short term. We realise that the complexity of its task increases with the heterogeneity and variability of the demand. More exactly, this complexity depends on the ability of the production system to respond to the characteristics of the demand. The problem of the effectiveness of the control of production thus is no longer exclusive to the Production Control function and its short-term scope, but it also involves some other functions of Production Management in-charge of making the production system suitable for the task it has to perform.

We proceed by identifying the problem of control as that of controlling a complex system facing changing requirements both in the short term as well as in the long term. This changes the scope of the study of the problem of control, and in order to tackle it, we discuss the need for an approach, able to relate the activity of the Production Control function with that carried out by other functions in Production Management with reference to the problem of control.

From cybernetics we recognise the value and relevance of the concepts of Variety, Regulation and Ultrastability to treat the problem of control. With these concepts, we develop a model able to exercise control over a complex system facing changing requirements. Its main characteristics are to produce regulation in order to absorb the changes in the short term and produce adaptation to absorb the changes in the long term whenever the short term regulation fails to achieve control over the production system.

The characteristics of this model are compared with the mechanisms generally applicable and available in the manufacturing companies. We find that the more serious deficiency is in the detection of the failure of the short-term regulation. That is, failure to recognise the inadequacy of the control system. Since this inability is important, as it does not permit the initiation of the adaptation process, we intend to improve this ability.

Finally, we present a technique for monitoring, and also a diagnosis, of the regulatory process based on measurement and analysis of the continuity of the material flow, idle time and set-up time. This technique makes possible the detection of the regulatory failure in the short term due to changes in the environment which require not only the adaptation of the control system, but also eventually the adaptation of the production system. This technique is believed to be able to detect the regulatory failure much quicker than it is currently done and with a greater degree of detail at least as required in the early stages of the process of adaptation.

1.3 Presentation of chapters

In chapters two and three, we present the way in which the Production Control function works and discuss the causes which affect the complexity of its task. This highlights the fact that the problem of performance is the concern of several functions of Production Management and that therfore an approach is necessary which is able to integrate them in connection with the problem of performance.

In chapters four and five, we present several principles and concepts from cybernetics and integrate them into a model able to exercise control in the case of production. We map into this model the different functions of Production Management concerned with the problem of performance finding that some important aspects of the model remain uncovered in practice.

In chapter six, we discuss the necessity to provide the Production System with those characteristics and discuss and present a solution able to provide the missing features.

Finally, in chapter seven, we discuss the importance of the involvement of the organisation for the success of the solution and also of the methodology. This we then follow by the more important conclusions of our work.

CHAPTER TWO

THE PRODUCTION CONTROL FUNCTION AND THE PROBLEM OF PERFORMANCE

2.1 Introduction

The purpose of this chapter is to review the literature on the Production Control function in order to identify gaps in the approach to the key problem of control. This then forms the basis of the following chapter which relate the Production Control function to its context.

In this chapter we examine how the action of different functions of Production Management affect the performance of the Production System. In particular, we concentrate on the Production Control function since this is the most relevant function to performance in the short term. We devide its study into the basic activities it performs, followed by how these activities relate to the different stages of the production process.

2.2 Performance and Production Management

The concept of performance is to be applied, in our case, to the transformation of production. Performance is the measure of how well production is carried out from the point of view of the organisation as a whole.

From that point of view the production system can fail in two ways; it can fail to produce what it is aimed for or it can fail to produce in a way which is acceptable for the survival of the organisation. In this sense the measure of performance should be an account of the attainment of production targets, as given by the demand to be met, as well as of the way in which resources are to be used in the production process.

These two aspects are complementary in the account of the result of production. On the one hand the degree of actual satisfaction of the demand tells us to what extent the transformation required has been accomplished. And the other the way resources have been utilised tells us whether or not the process of transformation itself has been carried out in a satisfactory way, to the organisation.

These two aspects of performance are also contradictory in the sense that in most cases, the courses of action to ensure the satisfaction of the demand oppose the possibility of achieving a good use of resources, and vice versa. A common case is that of the holding of large amounts of stocks. This usually helps to respond better to demand; nonetheless, as it introduces additional costs, it also makes the use of resources less convenient.

In the general case, it is not possible to disregard any of these two aspects and since they are mutually dependent, the desirable performance is bound to reflect some level of compromise between the satisfaction of the demand and the way to use the resources. Plans in production usually represent the desirable compromise between these two aspects. The plans state what is to be produced and how so that the demand could be met and the use of resources kept within what is acceptable for the company.

The concern for these two aspects permeate the action of most of the functions in Production Management. Let us discuss very briefly how some of the functions of Production Management are related to the performance.

The planning of physical means of production, for instance, deals with providing machinery, equipment and storage within the plant so as to be able to produce the volume of products required according to the demand expected and its variations in the long term. The task is mainly related to the problem of satisfying the demand in the sense that this ensures that production capacity will be available when required. Nonetheless, this also affects the way to use resources because it is here where technological changes are introduced and with them the way resources are used in the long term.

Product and Process Design is another function of Production Management connected to both problems. On the one hand, it designs new products, for which it is believed that there will be a demand and on the other, it devises production processes for them and also modifications to the processes of others already in production. Since changing the production processes usually changes the way to use resources, the concern for the latter is usually present in the aims of both the design of a process for a new product or in the modification of a present industrial process.

Plant location and lay-out is also a function which relates directly at least to the problem of how to use resources, in this case resources such as space and handling equipment. Since good flow of materials and semifinished products is desired and it depends considerably on the characteristics of the lay-out, the way to use resources such as handling equipment and space depends to a great extent on the type of lay-out.

Machine replacement, although can be considered as a part of planning of physical means of production, in some cases constitutes a function in its own right. Since a machine is replaced when it becomes an obstacle rather than a contribution to the production process, in the decision to replace it, one of the main criteria is that of efficiency of the machine. The machine itself is the resource in this case and it has to be replaced if it does not serve the purpose of production.

Recruitment and Training of the Workforce is a very important function in the area of the planning of resources. It refers to labour and it cares for its renovation and preparation. One of the starting points in this area are the requirements of labour in different areas and skills so as to enable reallocation and promotion in order to use it to the best advantage.

Another activity, usually seen carried out by the Industrial Engineering Department, is that of Productivity Improvements. This concerns directly the way in which resources are utilised. Productivity is in a way a measure of the outcome that can be obtained using one unit of some resource. Improving the productivity then means to obtain more output using the same amount of input, usually by introducing some changes to the way in which the input is transformed into the output.

Quality Control is a function related to the satisfaction of the demand as the demand is not only to be satisfied in terms of quantity and time but also in terms of quality.

All these functions are in one way or another related to the problem of performance. Later we will develop an approach to bring them into the problem of control.

2.3 THE PRODUCTION CONTROL FUNCTION

There is though one function in Production Management which is specially related to the problems we have been looking at. The Production Control function combines these two aspects closer than any other in the short term and for that reason it is given special attention in this section.

2.3.1 THE SCOPE OF THE PRODUCTION CONTROL FUNCTION

Although it is clear that planning and control are two inseparable elements of management, the function of doing planning and control in the field of production operation is called Production Control.

Reinfeld (1959) defines Production Control as follows:

" Production Control is the task of predicting, planning and scheduling work, taking into account manpower, material availability and other capacity restrictions and costs so as to achieve proper quality and quantity at the time it is needed and then following up the schedule so that the plans are carried out using whatever system prove satisfactory for the purposes".

Let us examine another definition, this time given by the Department of Trade and Industry Working Party in 1972:

" Production Control is the function of ensuring, by issuing instructions, monitoring their execution and correcting them if necessary, that work station capacity and parts are available of the desired nature and quality at the desired place and time for completion of the final production by the date required, having regard to technological constraints".

We can compare these definitions by making specific reference to their aims, the methods to achieve those aims and the resources and elements in the production field which are to be used and handled by those methods. In Table 2.1 we are presenting that comparison.

These two definitions have a fundamental similarity in that both are referring to the management of the operation of production systems by using the methods of planning and control in pursuing the fulfilment of the requirements of the demand. Nonetheless, they have also dissimilarities.The more important is that related to the methods. In that respect both definitions partially agree on what one can call control; that is the 'following up', 'monitoring' and 'correcting' of plans and instructions but they are completely different in what could be classified as planning.

	REINFELD	DTIWP
AIMS	Achieve proper quality and quantity at the time is needed	Ensure that work stations and parts are available, of the desired nature and quality at the desired place and time for completion of a final product by the date required
METHODS	Predicting, planning and scheduling work as well as following-up the plan as to how it is carried out	Issuing instructions, monitoring their execution and correcting them if necessary
FACTORS	Manpower Material Capacity Costs	Technological Constraints

TABLE 2.1 COMPARISON BETWEEN DEFINITIONS OF THE PRODUCTION CONTROL FUNCTION

Reinfeld's definition is involved in predicting and planning ahead as well as scheduling the present activities whereas the TIWP's definition seems to be only prepared to deal with the present situation while issuing instructions. That is a difference which affects the scope of the function where we shall concentrate the rest of this section. This difference is even more apparent when we compare how control is considered in the two definitions: the second elaborates more in this particular aspect than the first does.

In general, we can perceive that the balance between future changes and readiness for internal adaptation to those changes has been shifted from prediction to adaptation in the last definition.

In fact the area without a clear agreement is that of the making of the production programme. The definition made by the Department of Trade and Industry Working Party tends to neglect some steps in the making of the Production Programme.

2.3.2 THE PRODUCTION PROGRAMME

The making of the Production Programme is the highest level of planning within Production Control. One major input to the making of the Production Programme is the knowledge we can gather about the future demands on final products. Other important inputs are the actual state of the work in progress as well as the production capacity and availability of production facilities.

Very often the gathering of that information is not explicitly considered an activity of production control and it is placed in the intersection of production and sales. Quite commonly even making of the Production Programme is regarded as an activity more in the interface between Sales and Production than belonging to the Production Control function.

It seems that this view derives from the fact that on the one hand the information on future demands is gathered at sales, in the natural course of selling to a market, dealing with present orders and customers, and on the other hand, because information about the actual and future engagement and, therefore, availability of production facilities is brought about by Production Control function.

Apparently there is another reason for making the Production Programme the result of a joint activity by production and sales and this is that the interest of sales and production are, to some extent divergent. In many cases it could not be possible to produce the Production Programme required by sales department and conversely there would be many difficulties in selling the Production programmed by the production people. Because of that, the Production Programme usually constitutes a compromise between the needs claimed by the sales department and the difficulties raised in the area of production.

Although there are other parts of the organisation involved, the making of the Production Programme, the control and correction of its performance as well as the gathering of all necessary information should be an activity of the Production Control function.

The purpose of the Production Control function is to ensure that the production system will respond to the needs of the organisation in its particular area. In order to achieve that, the Production Control function needs to be self-sufficient and therefore capable of obtaining the information it needs from anywhere it is generated. The fact that it is necessary to use information from different sources than the field of production cannot mean that the activities needing such information had to be allocated in the different functions producing the information. If we were to allocate an activity following its various sources of information it would not be possible to allocate the activity in any function in most of the cases. The most important factor to bear in mind when allocating activities is to determine the user of the information being the one that transforms the information into a course of action rather than looking at the sources of information.

In this sense, we emphasize the inclusion of the making of the Production Programme in the Production Control function. This is not evident from the literature.

2.3.3 THE ACTIVITIES OF THE PRODUCTION FUNCTION

In order to fix a framework we will discuss here about the set of activities which should belong to the Production Control function according to its definition.

To start, it would be interesting to look at the findings of a survey carried out during the late fifties in the United States (Reinfeld, 1959). From a very large sample of manufacturing companies, to the question of which activities did they have in their departments of production control, a long list was obtained.

These activities can be divided into two groups. In the first place, activities that perform the aims of the Production Control function and secondly, activities that being indirectly related to Production Control are in fact ancillary to the first group. The first group has been named the inherent activities of the Production Control function and the second the ancillary activities.

(a) Inherent Activities

Scheduling
Determination of shop personnel requirements
Planning
Requisition
Material Control

Forecast of material requirements
Warehousing
Forecast of production and sales
Master scheduling
Inventory control
Despatching
Expediting
Loading
Receiving
Semi-finished stores

(b) Ancillary Activities

Customers' service
Determination of job-personnel requirements
Estimating (cost of production)
Engineering (Design of products)
Industrial Engineering
Process Improvement
Purchasing
Quality Control
Routing
Shipping
Supervision of actual work
Time Studies
Tool control
Training
Transportation
Work Simplification

We can attempt to organise the inherent activities by grouping together those activities dealing with problems in the same area of production.

In fact there are several ways in which areas can be defined and therefore several ways in which the inherent activities of Production Control could be grouped. Here we are going to group them according to the order in which they have to be sequenced over time. Following that criterion, we have the following structure:

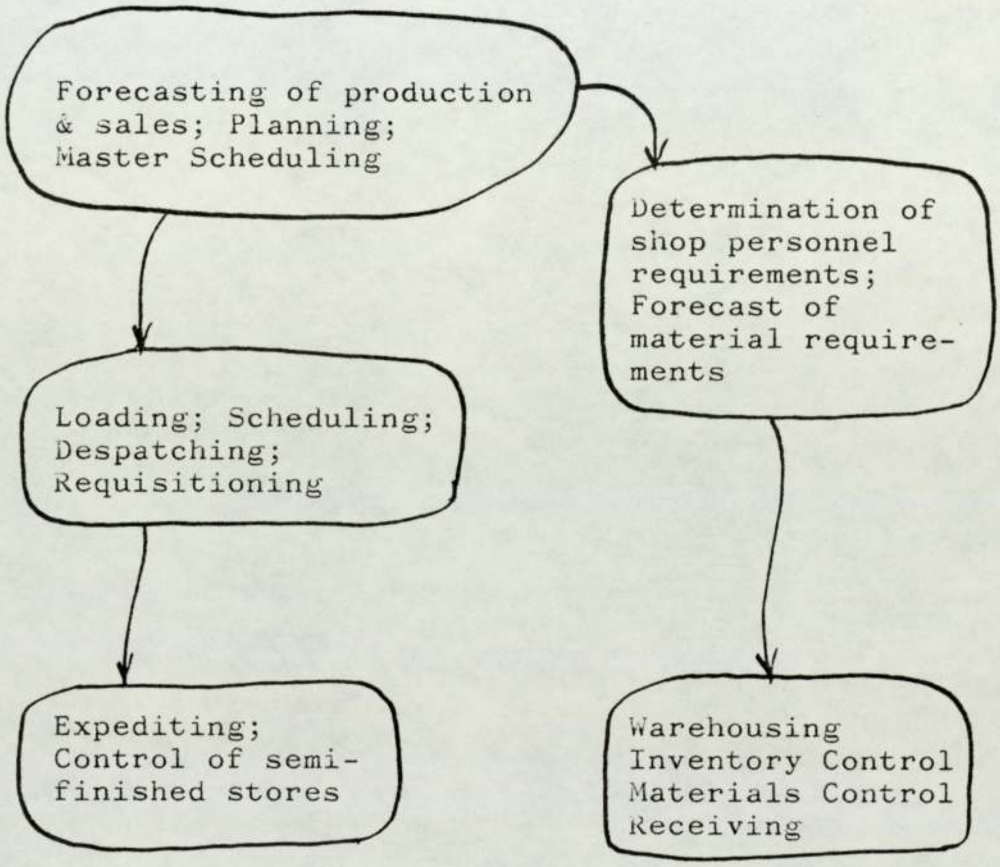


FIGURE 2.1 AGGREGATION OF ACTIVITIES FOR PRODUCTION CONTROL

We have allocated in the same box those activities which have some relevant degree of overlapping. We can group the activities now, considering alike those that, taking place very close in the sequence, are also overlapping. From that point of view we can identify the following groups:

(a) Forecasting of sales and production
    Master Scheduling
    Planning

(b) Inventory Control
    Material Control
    Warehousing
    Receiving

(c) Loading
    Scheduling
    Despatching
    Requisitioning

(d) Forecasting of material requirements
    Determination of shop personnel requirements

(e) Control of semi-finished stores
    Expediting

We can compare this classification with another more recently proposed for the activities of Production Control by Hall (1973).

a) Order analysis
b) Purchasing control
c) Stock control
d) Loading and Scheduling
e) Work in progress control
f) Sales Control
g) Planning and performance analysis

Comparing those two lists, at first sight we find some differences. It appears, for example, that at least purchasing and sales control (belonging to the second list) are not in the first. Nonetheless, at a closer look we find that, according to the definition which is given to these activities, it is reasonable to assume that it is possible to include purchasing and sales control in the area covered by inventory control, in the first list. Sales control is understood as the monitoring of actual sales in order to provide good bases for further forecastings of sales. Purchasing control is described as the monitoring of the purchasing order through the lead time, that means, between the time the order is allocated to a supplier and the time at which that order is received in stores.

The activities in both lists can therefore be considered very much alike. We can see the correspondence of these activities in the table below:

TABLE 2.2

COMPARISON OF ACTIVITIES FOR THE PRODUCTION CONTROL FUNCTION FROM TWO SOURCES

Reinfeld	Dep. of Trade & Industry Working Party 1972
Determination of shop personnel requirements Forecasting of Material requirements Planning	Ordering Analysis
Expending Semi-finished Stores	Work in progress
Warehousing, Inventory Control, Material control, Receiving	Inventory Control: Purchasing Control Stock Control Sales Control
Loading, Scheduling, Despatching Requisition	Loading, Scheduling
Master Scheduling, Forcasting of Sales & Production	Planning of Performance Analysis

We can note that in the list derived from Reinfeld (1959) there is not an activity related to the analysis of performance like the one we have in the lists from the DTI working party (1972). On the other hand the list from working party does not include some activities, that Reinfeld's does, such as receiving. Even though those activities are not considered in either lists we are assuming that they are performed in both cases. Why were they given the status of activity in one case and not in the other is something we cannot answer with precision here. Let us say, nonetheless, that this may be a consequence of the change that planning and control of production has suffered during the last twenty years. Before, in Reinfeld's time, receiving must have been a decisive activity and therefore many efforts should have been granted to do it properly. Nowadays this problem is certainly solved in an easier way and therefore it is more a routine process than a day to day challenge.

The analysis of performance, on the other hand, is a more recent activity. It seems that although evaluation and analysis has always been carried out to the progress of schedules only recently has it been generalised as to do it in a more quantitative manner. Only recently computer facilities and software of various kinds have been made available to the Production Management.

In other authors' views, like Burbridge (1978) and Lockyer (1975), similar lists of activities have been found to describe the concern of Production Control. From the previous discussion we can say that it is more useful to describe the area of management covered by Production Control by analysing its activities than by reconcilling definitions.

We are in a position to define the main activities of Production Control as follows:

a) Forecasting and Programming

This activity is related to the making of the production programme as well as to the gathering of all relevant information considered necessary to the purpose.

b) Ordering

This is the activity concerned with translating the production programme into orders to production shop and buying offices as well as with the allocation of those orders.

c) Loading, Scheduling and Despatching

The activity of prescribing when and where each operation necessary to the making of an order is to be performed taking into account the relationship between loan and capacity and instructing accordingly to the work centres.

d) Work in Progress

This is the activity of Production Control associated to the monitoring of the development on the Production Programme at the level of the plant, the level covered by the orders as well as at the level of the individual operations reporting at appropriate level of management whenever the situation fails to be the expected.

e) Inventory Control

The activity of keeping the quantity and/or monetary value of raw material consumables, parts semi-finished and finished goods to be kept in stocks within limits regarded as convenient both from the financial and the operational point of view as well as the updating of those criteria if changes in the system or its environment advise to do so.

2.4 The structure of the Production Control function

The part which plans and controls production, being part of a larger system, can also be regarded as a system and as such it should have parts and relationships between those parts. This is the planning and control system of the production system.

Of course, as any system it needs parts which may not have a physical sense but a functional sense. Most of those parts were described as the activities of the Production Control function, in the previous section. The way in which those activities should be organised and related to each other is the point we want to explore in what follows as this is central to determine the structure of the Production Control function.

In establishing those relationships, we will follow the relationship which exists between the planning and control system and the production system. Since the aims of the production planning and control system are, to a large extent, given by what it is expected from the production system; that dependency is central to the definition of relationships inside the Production Control function.

2.4.1 LEVELS OF AGGREGATION IN THE PRODUCTION SYSTEM

Production processes are made of production operations and most of the operations are taking place at the production centres. Although this is true, the description of production would not be clear if only looking at individual operation because there are features of the production processes which are not easily shown for us at the level of the production centres.

There are relations between production centres and also between groups of production centres which cannot be perceived looking at the production centres in isolation. There are, for instance, common resources to several production centres, there is dependency between a number of machines when engaged in the production of the same product, there are also families of products sharing the same route. There are as well assembly points receiving components from different production centres and also equipment used in the handling of material for several production centres.

To make sense of those relationships we need, in addition, a more aggregate view of the process of production using some criteria to group the operation centres. Burbridge (1978) identifies three levels at which aggregation is relevant to the planning activity.

The first level is the level of the production centre. That could mean a machine or a machine plus some ancillary equipment or even no machine at all but the location for a production operation if it is mainly manual. This level is referred to the most elemental transformation taking place inside a factory which has organisational sense as it can still be directed individually.

The second level Burbridge (1978) identifies is the level of the production line or technological stage. In this level of aggregation, he is grouping a number of operation centres characterised by a high level of dependency between them. That is plain in the case of the production line, where there linkage is the common product and the sequence of operations that is necessary to its manufacture. In the case of what has been called the technological stage, the association is not given by a product or a necessary sequence of operation centres but some kind of similarity which is more in technological field than in the operational. That is the case of the functional departments which are characterised by housing operations alike from the point of view of technology and even from the point of view of the machinery and equipments involved.

The third level is the plant level. The plant level includes all production centres engaged in the production of the range of products offered by the factory. Although it varies from one industry to another, it could be said that the range of products of a particular factory or plant will have some similarity from the point of view of the technological processes being used in its production. The technological branch, a plant belongs to, is one major feature of a plant.

There are more complex production systems where a fourth level of aggregation could be envisaged. It is the case where several plants are used in the production of a range of products, e.g. British Leyland. Nonetheless, it seems that in these cases the relationships between production facilities in different plants are very weak as a great deal of autonomy seems to characterised the operation of each plant. For that reason, this fourth level will not be analysed in connection with the Production Control function.

2.4.2 LEVELS OF AGGREGATION AND THE ACTIVITIES OF THE PRODUCTION CONTROL FUNCTION

Burbridge (1978) has defined as well a set of activities for the function of Production Control which bears a great deal in common with the activities we have put forward as it is clear from the picture below:

<table>
<tr><th>BURBRIDGE'S</th><th>OURS</th><th></th></tr>
<tr><td>PROGRAMMING</td><td>FORECASTING & PROGRAMMING</td><td rowspan="3">PLANNING ACTIVITIES</td></tr>
<tr><td>ORDERING</td><td>ORDERING</td></tr>
<tr><td>DESPATCHING</td><td>LOADING, SCHEDULING & DESPATCHING</td></tr>
<tr><td>INVENTORY CONTROL</td><td>INVENTORY CONTROL</td><td rowspan="2">CONTROLLING ACTIVITIES</td></tr>
<tr><td>PROGRESS CONTROL</td><td>PROGRESS CONTROL</td></tr>
</table>

TABLE 2.3 THE ACTIVITIES OF PRODUCTION CONTROL

For Burbridge (1978), the three levels of aggregation identified in the production system are levels for planning. Consequently the activities of programming, ordering and despatching are meant to be doing planning correspondingly at the levels of the plant, production line or technological stage and production centre. For the controlling activities, Progress Control and Inventory Control, those levels of aggregation are not followed in the same way.

In the case of Progress Control, it is recognised that there is a particular expression of it at each level and therefore the activity does not belong to any particular level. In the case of Inventory Control, again the activity is not associated with any of the levels in particular since the span of its activity covers the three levels as we will discuss later.

The need for controlling the progress of production differently at each level, can only mean that what is planned at one level has to be controlled partially, at least, at that same level of the production system. From the picture below, showing the principle aims of the Progress Control activity for each of the planning levels, we can see that Progress Control is in fact controlling a great deal of the outcome of the planning activities at each corresponding level.

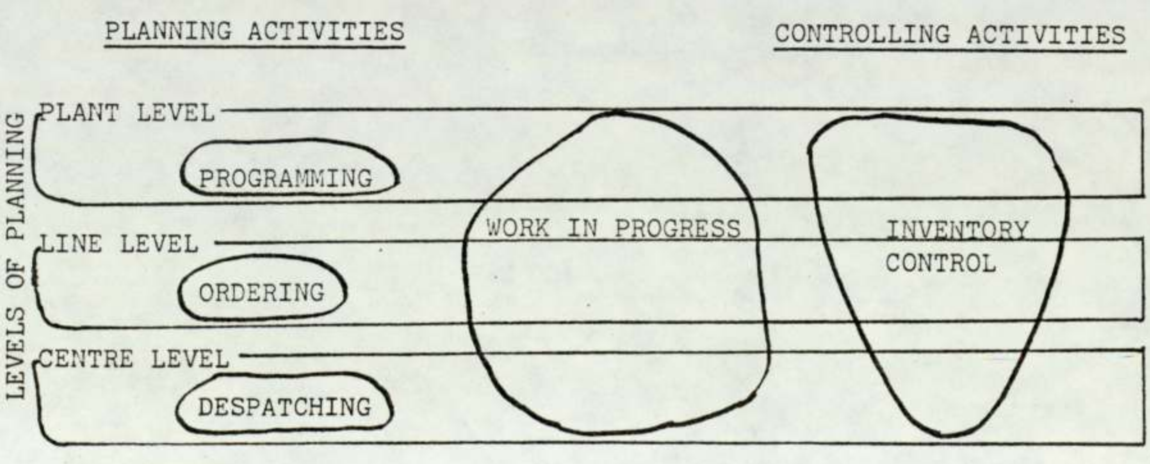


FIGURE 2.2 THE ACTIVITIES OF PRODUCTION CONTROL IN RELATION TO PLANNING LEVELS

However this structure of three levels of aggregation suggested by Burbridge (1978) is a structure where not only planning activities can be allocated but it is also useful for the allocation of controlling activities. Considering that in this structure it is possible to allocate most of the activities of Inventory Control it follows that the structure suggested by Burbridge (1978) is useful not only to allocate planning activities but also the controlling activities of the Production Control function. Those allocations have been made in the table below.

Level	Planning	Controlling
PLANT LEVEL	FORECASTING PROGRAMMING	i) Inventory Control of Raw material and finished Products (I.C.) ii) Monitoring of different Production lines leading to an assembly point or stages performing sets of operations which are in the same route iii) Monitoring the availability of resources of general use (like material handling equipment) (WIP)
LINE OR STAGE LEVEL	SCHEDULING ORDERING LOADING	i) Stock Control of work in progress (I.C.) ii) Monitoring the output of the production centres in relation to their engagement with the schedule of orders iii) Monitoring the availability and usage of resources to be employed only in this particular concern (WIP)
OPERATION CENTRE LEVEL	LOADING SCHEDULING DESPATCHING	Monitoring the time and resource consumption by each operation with reference to the schedule and standards of consumption (WIP)

TABLE 2.4 PLANNING AND CONTROL WITH REFERENCE TO LEVELS OF AGGREGATION OF PRODUCTION FACILITIES

At this stage, we can conclude that the levels of plant, line of production and operation centre are levels for planning and control and therefore it is a structure suitable for the Production Control function.

2.5 Connective Summary

In this chapter, we have shown that the performance of the production system, in the short term, depends on the Production Control function as in any other function.

Using the available literature, we have analysed how this function organises the resources already available to respond to the present demand for final goods. But as we discussed at the beginning of this chapter, we concluded that the performance, in the medium and long term, depends on the action of some other function of Production Management.

In the next chapter, we will identify the gap between the problem of performance in the short term and the problem of the performance in the long term for the Production System.

CHAPTER THREE

THE GENERAL PROBLEM OF PERFORMANCE

3.1 INTRODUCTION

In the previous chapter, we discussed that the Production Control function was responsible for the performance of the Production System in the short term. The Production Control function organises the present resources to adjust the production system to the day-to-day changes of the demand of the current range of products affecting, therefore, the performance of the Production System in the short term. But performance also depends on the action of other functions within Production Management as it was also discussed earlier. These other functions affect performance in a different way because they modify the resources available to the Production Control function while adjusting the production system to more profound changes of the demand such as changes in the range of products.

What the Production Control function can do in relation to performance is therefore bound by what is available to it. In this sense, the Production Control function works within a context. As a result, there is also a context to the problem of performance in the Production System which defines a more general problem once that context is included.

In this chapter, we analyse the problem of performance in its context and discuss how that context determines the complexity of Production Control.

3.2 THE CONTEXT OF THE PRODUCTION CONTROL FUNCTION

We define the context of the Production Control function as the Production System which it is controlling and the demand it is trying to satisfy.

Here, we analyse the relationship which exists between some characteristics of the demand and the Production System with the Production Control function.

In addition, we discuss the concept of Type of Production in relation to the context of the Production Control function.

3.2.1 THE DEMAND

One of the more important features of production that depends on the environment and particularly on the market is whether production is to be made to stocks or to orders. Mize et al (1971) says: *"Production systems are commonly divided into two broad classes: 'make to stock' and 'make to order'. The distinction is based upon the degree of certainty of knowledge of the demand and the length of a production run. It should be noted, however, that a particular company could engage in both types of production".*

Characteristics of the demand such as the variety of products, the volume of production needed, and variability will decide whether a product is to be considered special or standard. It follows that if the product is standard, it will be more likely produced to stocks and if special, it will be produced to customers' orders.

There is a broader set of effects of the type of making over the activities of production control as Mize et al (1971) summarises: *"The several functions of operations planning and control have varying degrees of pertinence to the two types of production. While it can be dangerous to generalise, and while exceptions can surely be found, the primary differences are summarised in ..."* Table 3.1

FUNCTION	PERTINENCE TO MAKE TO		DISCUSSION
	STOCK	ORDER	
	I	II	
Forecasting	Extreme	Little	I) Routing are fixed. Little flexibility in process. High equipment. Rigid operations plan. II) Usually not possible to forecast. More responsive to sudden change.
Operations planning	Extreme	Moderate	I) With this function, much of the control is built into the production process. II) Little detailed planning is possible.
Inventory Planning and Control	Extreme	Moderate	I) A highly structured process depends upon availability of materials, components and assemblies. II) Must maintain more kinds of materials because of uncertainty of orders. Little concern with finished goods inventory.
Operations Scheduling	Moderate	Extreme	I) Performed in operations planning function II) Must continually fit new orders into existing workloads
Despatching	Moderate	Extreme	I) Little despatching. Only exceptions important in progress control. II) Close control of high variable processes is needed

TABLE 3.1 PERTINENCE OF FUNCTIONS OF OPERATIONS PLANNING AND CONTROL TO THE TWO MAJOR TYPES OF PRODUCTION
(SOURCE: MIZE et al, 1971)

The effect that the type of making (to orders or to stock) has on the type of Production Control is fairly evident. According to Reinfeld (1959), it is more difficult to control a situation where a large number of small orders is produced than in the case of a small number of large orders. The number of different ways in which production can be organised is larger in the first case than in the second, and that alone makes more complex the decision of selecting a particular course of action.

3.2.2 THE PRODUCTION SYSTEM

So far we have been examining factors from the environment of the production system which are considered relevant to the Production Control function. Now we want to look at factors of the production system which may have an impact on the type of Production Control function to be used.

Within the production system, there are two structural factors which are particularly important to Production Control: The type of organisation of the direct labour and the type of arrangement used to organise the production facilities.

Referring to the ways in which the direct labour force can be organised, Burbridge (1978) says:

> *"The two main methods of dividing the direct labour force into organisational units are: 1. Division by process*
> *2. Division by product".*

The type of organisation for the direct labour which is predominant has a clear implication for the activities to be carried out by the Production Control function. In that respect, Burbridge (1978) says:

> *"This question of how the direct labour force is divided is of great importance to Production Control because:*
> *1. It affects the complication and cost of control*
> *2. It affects the degree to which efficient use of labour, plant and capital are possible".*

He analyses two major ways to divide the direct labour force:

1) Division by product or 'vertical organisation'; where all labour working in one product will constitute a separate group and

2) Division by process or 'horizontal organisation'; where all labour engaged in technological operations of a similar kind will constitute a distinctive group.

There is a strong relationship between the type of organisation of the direct labour force and the type of layout since the two extreme types of arrangements for production facilities are also organisations based either by product or by process. In general three types of layout are identified:

i) Line layout: A method of plant layout in which machines and other equipment required for a series of operations are arranged in the order in which they are used to make a part or family of parts.

ii) Group layout: A type of layout in which the plant is laid out in groups, each group containing sufficient plant to carry out the operations planned for all items in a given family of parts.

iii) Functional layout: A method of plant layout in which machines, equipments and areas for performing the same operations are grouped together. (For example, all welding is done in one area, all painting in another, and so on).

A correspondence can therefore be found between the type of layout and the type of organisation for the direct labour. The line type of layout organises production by product and generally the type of organisation of the direct labour which results more suitable in this case is the organisation by product. On the other hand, the functional type of layout, which organises production by processes has its natural organisational counterpart in the organisation of direct labour by process.

Apart from this strong relationship with the type of organisation of the direct labour force, the type of layout has a great deal of importance to the organisation of the Production Control function. In this direction, Burbridge (1978) says: *"Differences in layout have an important effect on the efficiency of production control ...."*

> *".... it is necessary to say again that line layout can be controlled more effectively and cheaply than functional layout".*

There is also an organisational correspondence for the group type of layout within the concept of group technology where direct labour is organised for the purposes of performing the operations required for the production of a particular sub-assembly or stage of a final product where several functions will eventually combine.

Commenting about the third type of layout, he says:

> *"Group Layout is, in a sense, a transitional stage in the change from Functional Layout to Line Layout ...."*
> *"Group layout comes some way between line and functional layout when considering its effect on the efficiency of Production Control".*

It is fair to mention here that during the last decade or so, it has been argued - for instance, by Wild (1975) - that the organisation of the direct labour cannot be discussed exclusively on the grounds of production efficiency. As he says, in experiences like Saab Sweden, Volvo Kalwar Sweden, Phillip Holland, Norsk Hydrò Norway, etc., the organisation of the direct labour force has been selected trying to combine production efficiency with job satisfaction as the lack of the latter is considered to be the major cause of the high labour turnover rate and absenteeism. This criterion has been adopted though in cases where manual assembly operations are a high proportion of the production process thus changing from the traditional assembly line to groups of workers in charge of production a complete assembly without imposing from the top a particular assignment of work to each member of the group. The experience has shown to be successful in cutting down absenteeism without damaging production efficiency.

3.2.3 THE TYPE OF PRODUCTION

Under the concept of Type of Production, the characteristics of the Production System are combined with those of the demand providing a more clear understanding of the context of the Production Control function.

For the purposes of distinguishing differences in the requirements to be fulfilled by the production control function, the type of production seems to be the appropriate concept as Bennett (1981) expresses:

> *".... However, for the purposes of analysing the design of production systems and the planning and control of operations, perhaps the most simple yet useful classification is that based on the concept of job, batch and flow."*

Wild (1972) comes to the same point but expands it further:

> *"A classification which is, perhaps, more useful for our purposes relies on the division of production systems into three broad and overlapping groups, namely Jobbing, Batch and Mass. These three classes lie on the same continuum of repetitiveness evolved above, i.e. pure jobbing production equates to pure intermittent production, while pure mass production is equivalent to continuous production".*

Each type of production is in fact a combination of characteristics of both the Production System and the demand. That is also clear from Willmore's (1973) definition of jobbing, batch and flow type of Production:

> *"In the special order concern, the major part of the work on every order, including the design of the product, or the adaptation of a*

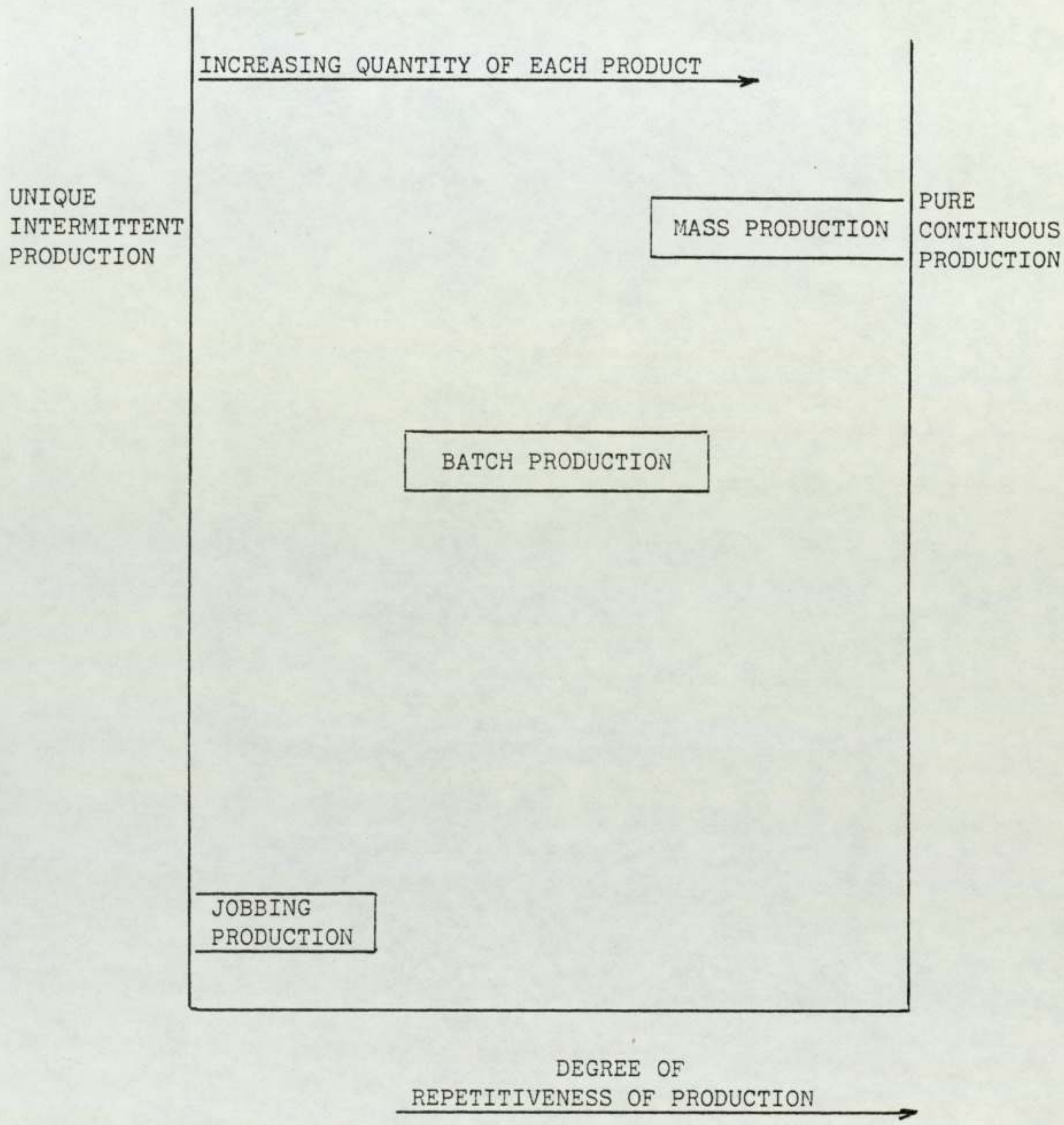


FIGURE 3.1 CONTINUITY OF THE OPERATIONS AND TYPES OF PRODUCTION

standard design, is performed separately for each order. There is no finished stock, or stock of finished parts; material flows through the factory intermittently, from process to process, with possibly, a wide difference in the order of flow of successive jobs. On the other hand, in the flow repetitive type of manufacture, instead of moving in intermittent lots, the material flows in a steady stream, whose volume may increase or decrease with fluctuations in demand, but is seldom interrupted. The factory comprises closes articulated units of specialised machines, as opposed to the group of general machines arranged for the best economy in handling varied orders." "....Between the two extremes is a variation of the special order type of industry, manufacturing with methods of batch production or repetitive lot. As demand increases for certain of the patterns which a concern had previously been making only to special order, it becomes profitable to put work through in large lots. The unsold portion of the lot is carried in stocks to fill future orders, being replenished by further manufacturing orders before the earlier lot is completely exhausted."

In these definitions of types of production, each of them blends the concepts of type of make, continuity, type of layout and general organisation of production. Nonetheless, some authors prefer to combine those characteristics differently.

In the following classification we found that along with the type of production, the type of layout has been stressed. Burbridge (1978) suggests seven types of production which are:

i) Line production: It uses a line layout and it is for particularly large batches

ii) Line batch production: It uses a line layout and it is for medium size batches

iii) Group batch production: It uses group layout and it is for medium size batches

iv) Functional batch production: It uses a functional layout and is for medium size batches

v) Continuous batch production: While it is continuous (although the rate may be varied), the items are allocated to specific customers' orders prior to completion

vi) Group jobbing production: It uses a group layout and is for small batch or orders

vii) Functional jobbing production: It uses a functional layout and is for small batches or orders.

Following the types of production, it is apparent that different types of demand do not combine at random with different types of production system. In fact, for each type of demand, a particular set of characteristics is chosen in the Production System thereby making production more efficient. For instance, if there is a large variety of products to be produced in small quantities, the production will be organised by customers' orders and plant and labour will be organised by process rather than by product. Something similar can be seen with the continuous type of production where a small number of products ordered in large quantities are best produced by means of a production line, organised by product rather than by process.

The reason for choosing the organisation of plant and labour in the way mentioned when the demand is characterised as we said is that these choices are the more appropriate for the purpose of achieving a higher level of performance in the production system. The choice in either case allows the best use of resources and at the same time the possibility of satisfying the demand. Therefore, in the correspondence between demand and production system, the criterion of performance is present.

We have established that the more general statement of the problem of performance should recognise the correspondence between the demand and the production system. There is a connection between the part played by the production control function and the part played by the correspondence between the demand and the type of production system. Failure to provide the production system required will make more difficult to achieve a good level of performance and will make specially difficult the task of the Production Control function.

3.3 The relevance of the Continuity of operations

In order to understand the nature of the relationship which exists between the Production Control function and its context we have found useful the concepts of continuity and intermittence of the operations. This concept is presented by Moore (1959) as follows:

> *"Intermittent and continuous production differ in the length of time the equipment set-ups can be used without change. Industry and product are not important as far as our distinction is concerned. If you use a machine set-up for only a short time then change it to make a different product, you have intermittent production. Perhaps you are able to use the machine set-up for only a few minutes of possible hours before the required quantity is produced. Such short runs, consisting of a great variety of products, characterise intermittent production. But if you set up equipment and use it for months without change, we call that continuous production. You need an enormous volume of highly standardised products for continuous productions".*

Continuous and intermittent production differ in some other respects as well, as Meredith and Gibbs (1980) point out:

> *"An organisation that desires to produce a wide variety of individualised outputs (reading, eating, playing) will probably utilise an intermittent production process to gain Flexibility. To gain the flexibility required to produce the large variety of outputs, general purpose equipment and broadly skilled staff are necessary."*

"An organisation that produces, or plans to produce, a high volume of a small variety of outputs such as pencils or car washers will probably organise the operations on a continuous process basis"

".... Since outputs and operations are standardised, specialised equipment can be used to perform the necessary operations at low per unit cost while the relatively large fixed costs of the equipment are distributed over a large volume of outputs".

It is apparent that the continuity of production has a great deal of connection with the factors both from the environment and from the production systems that we have been analysing. It is clear, for instance, that standard products are associated with high volumes of production, with small variety, with production to stock, with line layout, with direct labour organisation by product and with continuity in the operations. Whereas special products are related to a large variety of products, small volumes of production, direct labour organisation by process, functional layout and a high level of intermittence in the production operations.

On the other hand, the effect of the degree of continuity of the operations on Production Control is of great importance. High level of continuity in the operations is the consequence of a small number of orders and therefore a better chance to organise production and therefore a better use of plant, labour and capital. The degree of complexity of activities such as scheduling and machine loading is lower than otherwise and as a result control can be achieved in a simpler way.

As it is shown in FIGURE 3.2 the distinction based on the degree of continuity of the operations seems to be able to differentiate among production situations from a number of angles which are relevant to the problem of production control.

At the same time, the degree of continuity can be regarded as proportional to the skills required in the Production Control function.

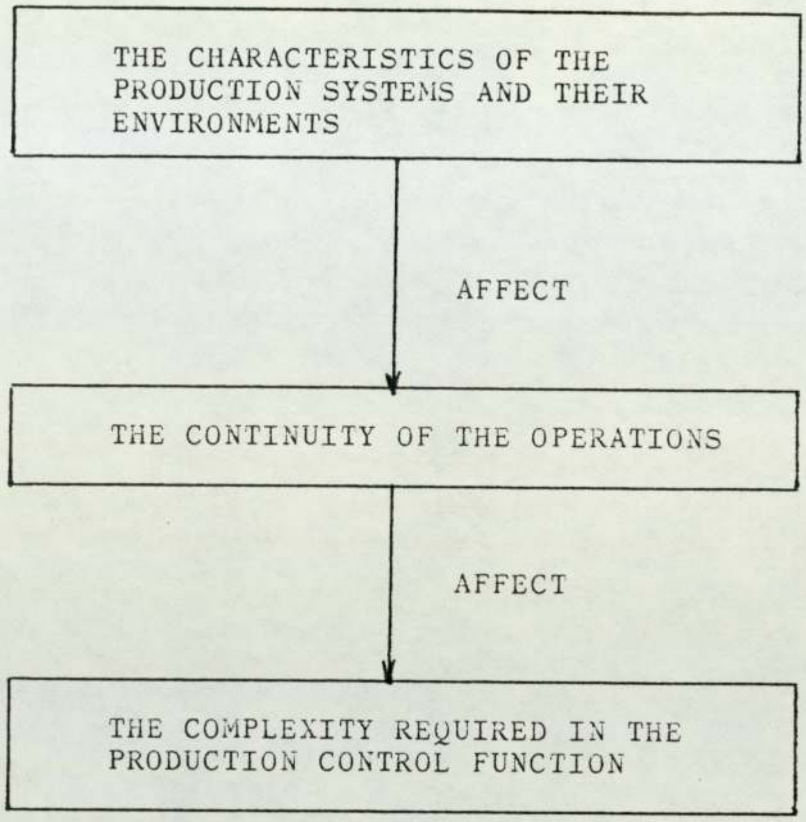


FIGURE 3.2 CAUSE-EFFECT RELATION OF THE CONTINUITY OF THE OPERATIONS

Although it could be argued that most real production situations would lie somewhere between the two extremes of continuity and intermittence, the degree of continuity of the operations is a good criterion for relating production situations and the Production Control function. This implies that the more continuity is provided by the production situation itself, the less complexity is necessary to be dealt with by the Production Control function and vice versa.

3.4 THE PRODUCTION CONTROL FUNCTION AND THE TYPE OF PRODUCTION

The analysis of the context of the Production Control function would not be complete without looking into the effect of the different types of production on the Production Control activities.

3.4.1 THE EFFECT OF THE TYPE OF PRODUCTION ON PRODUCTION CONTROL

3.4.1.1 The effect on the planning activities of Production Control

Scheduling is present in all planning activities of Production Control. Scheduling is particularly sensitive to the types of production as classified by Bennett (1981).

Lockyier (1975) looking at this effect classifies types of scheduling using the type of production as the distinction. He says: *"Types of scheduling situations:*

1. *Quantity and rate of production and resources are adjustable. This type is exemplified by Flow Production.*
2. *Only one project is undertaken (Critical Path Method).*
3. *Quantity and production rate and delivery dates are fixed and limited resources have to be used as effectively as possible. This type is characterised by Batch Production.*
4. *It may be a choice either in the resources or in the quantities of the various products to be produced (Linear Programming)".*

Here two of the major types of production have been identified (flow and batch) as particular cases of the problem of scheduling. The case number two is generally considered a particular case of the jobbing type of production and case number four does not make much sense unless to mention the particular technique used.

Quantity, rate of production, delivery dates and whether or not resources are fixed or there is some room for the production controller to adjust them. Reinfeld (1959) compares the three major types of production in relation to the activity of scheduling under a broader set of elements. His comparison table is presented here as TABLE 3.2 in which we see that elements of control, scheduling, principles and the functions are used while also the points of difference in degree and complexity are emphasized for each type of production.

Certainly those factors would affect scheduling in one way or another though it should be said that some of them such as 'quantity', 'inventory policy', 'time allowed' and 'work measurement' would affect more than one activity in Production Control.

Colley (1977) discusses the point from a slightly different angle. Rather than identifying differences of several activities within planning under different types of production, he defines the problem of scheduling under different production types:

> "*Continuous process: The problem in scheduling continuous production processes are to ensure a high rate utilisation of the expensive facilities and to sequence products through the Job Shop. The problems in scheduling job shops are twofold. First, to set the work-in-process level in such a way that a given order release rate (into production) provides as optimum or idle cycle time (through interval). With this accomplished, the second problem is to sequence the separate tasks effectively on a minute-by-minute basis within the framework established previously.*
>
> *One-Time projects: The problem in scheduling one-time projects is to ensure the completion of all tasks involved in the project in the least possible time for a given level of effort. The approach consists of making a list of all the activities in the project, setting down the precedence relationship (in a diagram showing the order in which the activities must be accomplished), and the longest path through the network. The longest path, called the critical path, determines the time which will be required to complete the*

FACTORS	(FLOW) PRODUCTION SHOP	(BATCH) JOB PRODUCTION SHOP	(JOBBING) JOB SHOP
Time Allowed	Days or months	Days or months	Usually less
Methods	Detailed	Detailed, semi-detailed	Loose
Tooling	Very often special purpose	Special purpose and standard	Sometimes make shift
Engineering Data	Detailed prints, B/M's (Bills of Materials) etc.	Mixed; some detailed, others not so well defined	Often incomplete
Quantity	Usually long runs or combination of short runs	Mixed from 1 - 100.00	Usually 1's & 2's; sometimes one run of a sizable quatity
Inventory Policy	Parts made against forecast for stock	Some parts made for stock	Few if any parts made for stock; purchase may be for stock
Dollar Investment in control	Heavy; tight controls requiring considerable indirect labour	Medium; tight controls required in some areas	Light; elaborated controls usually not required
Shop Supervision	Detailed knowledge of all operations not required	Some detailed knowledge required	Detailed knowledge required
Work Measurement	Tight; usually standard cost system	Medium; combination of measured work and day work	Loose; often all day work basis
Possibility of error in calculation of workload resulting in over load	Little	Some	Considerable

TABLE 3.2 TYPES OF PRODUCTION AND THE FACTORS WHICH AFFECT SCHEDULING (SOURCE: REINFELD, 1959)

	PROCESS SCHEDULING	JOB SHOP SCHEDULING	ONE-TIME PROJECT SCHEDULING	ASSEMBLY LINE BALANCING & SEQUENCING
KEY ATTRIBUTES	Facility Utilisation Throughput Continuous Operation Sequencing of products	Shop load Capacity Network of Facility Lines Sequencing of orders Priority Rules Multiple measure of effectiveness	Activities Events Precedence Diagram Critical Path Slack PERT/CPM	Precedence Diagram Standard times Station Assignment Open or Closed Stations
EXAMPLES	Oil Refineries Chemical Plants Food Processing Steel Mills Plastic Plants	Print Shops Machine Shops Computer Centres Hospital Operation Rooms Job-order Manufacturing	Shipbuilding Building Construction Opening of a new Plant Installation of a new Computer	Appliance Manufacturing Automobile Manufacturing Electrical Components Furniture Assembly

TABLE 3.3 TYPES OF PRODUCTION, ATTRIBUTES AND EXAMPLES
(SOURCE: COLLEY, 1977)

project. It follows that management pressure or action will hasten the completion of the project only if it shortens the critical path.

<u>Assembly Line</u>: Balancing and sequencing assembly lines is a two-level problem. First, the total workload must be determined by summing the work-content for the number of units to be built in a given time period, such as a day. This provides an estimate of the number of workers which will be needed. Next, a tentative notion much be reached as to the number of work-stations which will be established along the line. Finally, the total work-content must be sub-divided apportioned to the work-stations in such a way that the workload is balanced among the stations to the extent possible. There is no direct mathematical solution to the assembly line problem. There are common-sense heuristic approaches which largely involve trying various allocations in a search for the best attainable balance. This balancing problem is complicated in the real world by the fact that there are almost no single-product assembly line in operation. Most assembly lines are mixed-model lines, in which the work-content varies from unit to unit, making the balancing problem even more difficult."

As we can see, the classification of production systems which is relevant to the problem scheduling varies from one author to another. In the latter by Colley (1977), the batch production type was not considered but, instead, the assembly line type was included. Nonetheless, in general, the complexity of scheduling seems to be larger in the case of jobbing production and to some extent, simpler in the case of continuous production.

When looking at another planning activity, the ordering activity, the direction in which the complexity increases turns out to be different. Referring to the activity of ordering, Burbridge (1978) identifies three major groups of ordering systems:

"1. Make-to-order systems: In the case of jobbing production, the batch quality and the 'leadtime' are both fixed by contract and ordering is simply a matter of ordering on the shops that which has been ordered by the customers...."

"...First, 'contract-scheduling', covering the control of ordering in big single-product manufactures, such as ship-building and large scale civil engineering. Second, 'job-loading', covering the control of ordering of job-lots in general-purpose jobbing shops. A third type of make-to-order system is 'base stock control'. It is used to control ordering in factories making standard products where there are a number of stores between the factory and the final customer.

2. Stock-controlled Systems: With these systems, the release of purchase and shop orders is based on the level of stocks in stores. New orders, for a selective batch quantity, are issued each time the stock drops to a specified order point or re-order level.

3. Flow-controlled Systems: The third group of ordering systems contains those in which ordering is directly based on the production programme. Four different types are described in the book, known as 'component batch scheduling', 'period batch control', 'standard batch control' and 'maximum control'.

The stock-controlled and flow-controlled ordering systems and also 'base stock control' are used for the continuous manufacture of established products".

It is also apparent that 'contract scheduling' ordering system is mainly oriented to the project type of production, as defined by Meredith and Gibbs (1980), and that the 'job loading' ordering system is oriented to the jobbing type of production.

Therefore according to Burbridge (1978), the activity of ordering which also undertakes a considerable amount of scheduling, is affected by the type of production. Since breaks down, the general Production Programme into sub-programmes for specific parts of the Production System, ordering is bound to be realised differently if the Production System is divided into parts following different criteria as the different types of production do.

3.4.1.1 The effect on the controlling activities of Production Control

If we concentrate now in the area of the controlling activities of Production Control, we will also find that these activities are affected by the type of production.

Burbridge (1978) identifies two types of controlling activities. He says: *".... the two main controls used in production control are progressing and inventory control".*

Meredith and Gibbs (1980) describe:

> *"Control systems in organisations are of two major types: Preventive Control Systems and Feedback Control Systems. Preventive control systems operate to prevent the occurence of deviations from plan." ".... In a feedback control system, a plan or standard is adopted, the actual performance of the system is monitored and measured, and the system status is fed back to a decision-maker".*

Later they put forward the principle that the controlling activities need to be different for different types of production in the following way:

> *"As discussed in chapter .. there are basically four primary ways of organising operations: intermittent, continuous, batch and project. Specific means of controlling each of these forms, as well as operations characterised by special problems (such as bottlenecking), have been developed".*

By intermittent we should understand jobbing production and by continuous we should understand flow production.

Referring to the specific way in which each type of production should be controlled. Meredith and Gibbs (1980) say:

"Order Control derives its name from the fact that in intermittent operations, most output is 'made to order' ...."

"Order Control is made up of a rather large number of specific preventive and feedback controls which attempts to ensure that the operations are coordinated to produce the desired quantity of the product, delivered to the appropriate location by the desired due date at the agreed-upon price".

".... Flow Control, on the other hand, is used in continuous and semi-continuous operations. In semi-continuous operations, the volume of production seldom changes drastically, and output is of a similar type day after day. The major control method in flow control is feedback." Expanding these ideas, they add:

".... The basic principle behind flow control is that jobs started into a system will progress most efficiently if work-in-progress is kept low. To do this, the organisation must know its capacity limitations and release jobs to the operations area on a due date priority basis. From a practical side, clear reporting of finished jobs and jobs waiting to be started, along with reports on delayed or late jobs, are necessary to keep the system moving".

Referring to batch operations, they say:

"Although batch operations frequently use both flow and order control, on occasion block control is more appropriate. Block control is a modification of flow control used in operations which produce the same output and require the same steps or processes, but which processes the output in batches or 'blocks'. That is, for operations for which the output do not cause significant variations in the transformation process, block control is used".

Finally, for the project type of production, they say:

"Project Control is used to ensure that the combination of tasks necessary for 'project completion' by a given due date are accomplished."

".... Project controls are essentially of a feedback variety, comparing actual accomplishment with planned deadlines".

Therefore in the case of the controlling activities of Production Control, the type of production also makes a difference to the procedure in which the operations are to be controlled. The fact that production orders are generated and programmed differently under different types of production imposes the need for different procedures to control their execution. In the jobbing case, for instance, the control is to be exercised over the production orders as this is the only thing which can be traced. In this case, control over machines is not practical since they can perform a number of operations belonging to different production orders in every production period and usually there is a great flexibility to assign products to specific machines. On the other hand, in the continuous type of production and because of the rigidity of the assignment of products to machines and the lower number of orders, effective control can be achieved by monitoring the accomplishment of operations at the production facilities themselves. That is particularly evident in the case of a production line where due to the constraints imposed by the fixed sequence of production facilities, the progress of production can be measured by monitoring the first and the last machine in the line.

In the case Inventory Control, there is also a difference derived from the type of production. Depending on the type of production control, for instance, of semi-finished stocks can or cannot be important. In batch type of production, the control of stocks is extremely important whereas in jobbing it is not. This also extends to the control of semi-finished products in the same way since usually the connection between production lines is a stock of semi-finished products their control is a must whereas in the jobbing type of production this control is an option.

3.4.1.3 Summary: Type of Production and Production Control

We have seen, through some examples, how the characteristics of production systems and those of their environments do affect the way production control is to be performed. Even at the level of particular activities of production control, the effect can be easily perceived.

At a more general level, the differences introduced by the type of production for the purposes of production control can be recognised in the summary presented by Bennett (1981):

TABLE 3.4 THE EFFECT OF THE TYPE OF PRODUCTION ON THE ELEMENTS OF PRODUCTION CONTROL

(SOURCE: BENNETT, 1981)

	(FACTORS)	JOB	BATCH	FLOW
PHYSICAL FACTORS	LAYOUT	FIXED	FUNCTIONAL	PRODUCT LAYOUT
	TYPE OF MACHINE AND TOOL	GENERAL PURPOSE	GENERAL PURPOSE	GENERAL PURPOSE & SPECIAL PURPOSE
	MATERIAL HANDLING			
PLANNING AND CONTROL FACTORS	ROUTINE OF WORK	LITTLE IF ANY PRODUCT DOES NOT MOVE	EXTENSIVE MOVEMENT OF MATERIAL	CONSIDERABLY LESS THAN IN BATCH
	QUEUES	DEPEND ON SCALE OF THE PROJECT	EXTENSIVE	REDUCED TO A MINIMUM
	WORK IN PROGRESS	DEPEND ON THE TIME SCALE OF THE PROJECT	CONSIDERABLE	REDUCED TO A MINIMUM
	TIME SPENT IN SYSTEMS		LOW RATIO: PROD.TIME/THROUGHPUT TIME	HIGH RATIO: PROD.TIME/THROUGHPUT TIME
LABOUR & ORGANISATIONAL FACTORS	RATIO OF MANAGERS TO OTHER GRADES	1:23	1:16	1:8
	No. OF MGT LEVELS	3	4	6
	RATIO:SKILLED/ SEMI-SKILLED	67/14	-	18/55

3.5 THE PROBLEM OF CONTROL AND THE NEED FOR A NEW APPROACH

The context of the Production Control function relates to the problem of performance of the production system in a more fundamental way than just setting the conditions of operation for the Production Control function. It opens the possibility to improve performance by modifying that context enabling, in that way, the Production Control function to do a better job.

For the performance of the Production System it is very important to use the appropriate techniques to carry out the activities of the Production Control function. That is one half of the problem of performance. The other half is that of ensuring that the characteristics of the Production System match the requirements of the demand thereby setting a good basis for the achievement of a higher level of continuity in the operations.

There is then a second correspondence relevant to the problem of performance. That is the one established between the requirements of the demand and the characteristics of the production system. We could say that the more suitable the production system for the type of demand it has to serve, the less effort has to be spent in the production control function to ensure the required level of performance.

That leads us to the point that in improving performance, both correspondences are relevant and therefore improvements to performance will have to be sought by combining courses of action to adjust the production system to the demand it serves and/or adjusting the Production Control function to the context where it exercises control.

In the diagramme below, FIGURE 3.3, are the elements and relations which are relevant to the problem of performance in its general form.

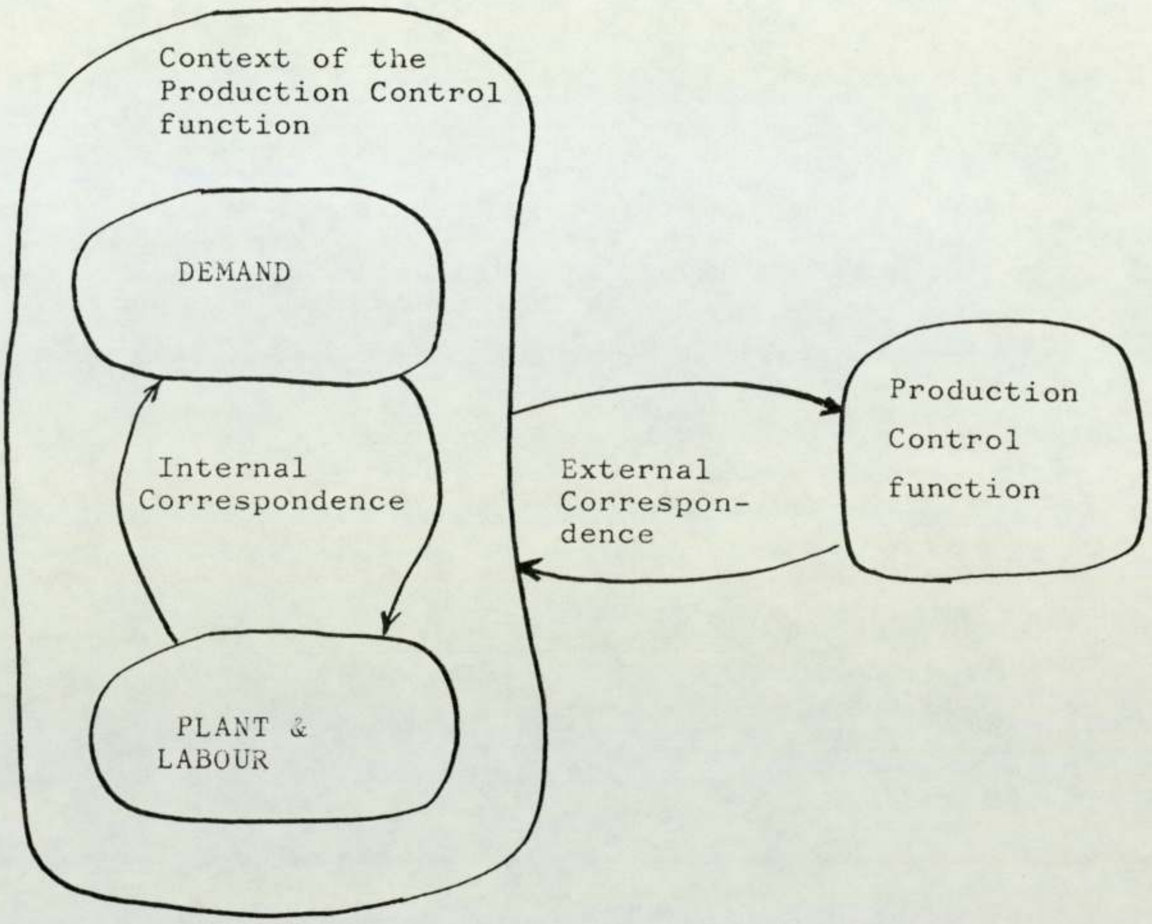


FIGURE 3.3 THE TWO TYPES OF CORRESPONDENCE WHICH ARE RELEVANT TO PERFORMANCE

The problem of performance does not deal exclusively with the Production Control function but also with those functions within Production Management which can modify the Production System to improve internal correspondence between the production system and the demand. Since performance also depends on how suitable the production system is, the functions of Production Management which take care of that have to be related to the problem of performance.

In relating those functions to the Production Control function and the problem of performance, we see the need for an approach able to integrate them and at the same time providing a consistent theory of control.

The prevailing approach in the functions of Production Management does not satisfy those conditions since all of these functions relate to problems more or less in isolation from the rest of the functions and they treat control at only one of the levels mentioned above.

In the next chapter, we are discussing the relevance of Systems Approach and Cybernetics to express and analyse the problem of control.

CHAPTER FOUR

REGULATION AND PERFORMANCE

4.1 INTRODUCTION

In previous chapters, we have shown that the performance of the production system ultimately depends on two main aspects. One is the suitability of the production system to the requirements of the demand, which we describe as the consistency of the production situation. The other is the adequacy of the Production Control techniques to the Production situation.

In that respect, we have also shown that the more suitable the production system is to the requirements of the demand, the easier it will be to find appropriate techniques for Production Control and therefore to achieve better performance from the Production System.

These are, in general terms, the factors upon which the complexity of the problem rests.

In this chapter, we will concentrate on the specific problem of control which underlies this situation. With that purpose, we will discuss our problem from the point of view of cybernetics and, in particular, in terms of regulation.

4.2 THE RELEVANCE OF CYBERNETICS AND SYSTEMS

Control is the theme of this chapter. In order to understand the principles of control, a solid theoretical framework is essential. Cybernetics is regarded as a coherent theory which provides the treatment of control at the level of generality which is required in this research.

"Cybernetics is the science of communication and control. The applied aspect of this science relate to whatever field of study one cares to name - engineering, or biology, or physics, or sociology, ..."

"The formal aspects of the science seek a general theory of control, abstracted from the applied fields, and appropriate to them all."

(Beer, 1959)

In applying the principles of control to the field of production it is necessary to understand control as a relationship established between systems since the production process is made possible by the interaction of several parts which are related and therefore constitute a system.

"Control is an attribute of a system. This word is not used in the way in which either an office manager or a gambler might use it; it is used as a name for connectiveness. That is, anything that consists of parts connected will be called a system."

(Beer, 1959)

If the concept of a system helps to understand the fabric of the production process, the principles of cybernetics help to understand the nature of relationships which hold the components of the production system together. At this stage, and according to our methodology, we need to model the problem situation. The relevance of the systems approach and cybernetics is central to this stage since they provide the possibility of building and working with models.

Models are useful in complex situations because they permit us to handle that complexity. As Starr (1971) puts it:

"By simplifying reality in a systematic and organised fashion, it is possible to study systems that are too complex to be understood by intuition. Then for such systems, we can diagnose errors to bring about useful remedial changes. The idea of a model is crucial to this reasoning, because a model is a simplified representation of

reality. It is constructed in such a way as to explain the behaviour of some but not all aspects of that reality. The reason that a model is employed is that it is always less complex than the actual situation in the real world. It must, however, be a good representation of those factors or dimensions that are strongly related to the system's objectives; otherwise, it will not be a useful model, and, therefore, it should not be used."

Here we will introduce some concepts to develop a language to build a model in order to control production.

4.3 VARIETY AND REGULATION

For the purposes of our study, perhaps the more relevant concept developed by cybernetics is that of regulation.

In fact, the attainment of the appropriate level of performance in the Production System can be understood as the result of a process of regulation present in every interaction within the Production System. Let us define two very useful concepts from cybernetics. These are Variety and Regulation.

4.3.1 VARIETY

The Variety of a system is defined as the number of states that system can assume. In this definition, the way a 'state' is understood is extremely important. For instance, if a door is to be considered a system, one could say that it has two states - open and closed. Nonetheless, it is clear that some other states could also be envisaged for this same system. For instance, 'half open', 'one third open' and also the infinite number of different angles that the door can describe between 'completely open' and 'completely closed'. In any case, the variable which has been used to define the states of this system is the angle between the door and its frame.

It is also clear that in the definition of the states of a system, we could introduce as many variables as we possibly can. In a system called 'room', we could define its states making reference, not only to the position of its door, but also to its temperature, pressure, intensity of light, type and position of the furniture, time, colour, percentage of oxygen, etc.

As a consequence, the variety of a system can be assumed to be depending on the degree of detail and precision we use to define the generic state. In logical terms, we have to accept that there is something like 'absolute variety' where every single dimension of the system is been considered and also an appropriate metric has been provided to measure the value of each variable. In only this case every single change in every aspect of the system will produce a new state.

Something which makes more sense to our problem is the idea of the 'relevant states' of a system. These are a subset of the absolute variety.

The relevant states are those defined in a space made of dimensions which are variables considered relevant to the behaviour of the system from the point of view of the observer. The set of variables which are relevant for an observer are exactly those which are necessary to define the state of the system which is desirable from his point of view. That is so because the desirable state will change only if some of the variables used in defining it happen to change. Changes in other variables, not used in the definition of the desirable state, are not going to change the state and therefore are not required to define the relevant variety of the system.

It is perfectly possible then for different observers to define differently the relevant variety of a system if they define in a different way the desirable state. If the observer of the system is a casual user of the room it might be enough for him to distinguish between cold and warm and clear and dark. If, on the other hand, the observer was a painter having to paint the room he may be concerned, in addition, with the position of the furniture, the dimensions, colour and smoothness of the walls and probably the time before deciding how to proceed with the painting. The room is the same in both cases and the same absolute variety but both observers would also be right to assess the relevant variety differently.

In the more general case, the observer is a second system. The interaction of a system with another gives that necessary frame of reference to the concept of variety. It is only in the interaction that the changes of a system have the possibility to be relevant to another system. It is the second system that qualifies the relevance of the changes in the first and therefore determines whether or not there is a difference in the system before and after a change, from its point of view.

4.3.2 REGULATION

The concept of regulation is the appropriate context to make use of the concept of variety.

Regulation is essentially a process of interaction between systems by which one system has its behaviour affected by the action of two other systems. One of these two systems is the environment, or source of disturbances. It generates a behaviour which affects the behaviour of the system in such a way that is seen undesirable by another system. This other system, the regulator, interacts with the system with the purpose of inducing a desired behaviour in the system. Regulation is successful when the regulator manages to induce the desired behaviour in the system irrespective of the disturbances the environment might be exercising upon the system.

Let us expand this explanation making use of Ben-Eli's (1978) insight on Ashby's (1970) work:

"For a given situation, there is a set Z of all possible events which may occur whether regulation is applied or not; of these, subset G defines desired outcomes, those which correspond to a condition of stability for a system under regulation. In addition, there is a set R of events in the regulator, a set S of events in the system which is being regulated and a set D of disturbances. Events in D produce condition in S which cause outcome to be driven out from G. Effective regulation is achieved if for a given value of D events in R and S relate such that the outcome is bounded by G."

Let us go step by step following this explanation.

D: Set of disturbances

S: Set of events in the system

Z: Set of all possible outcomes

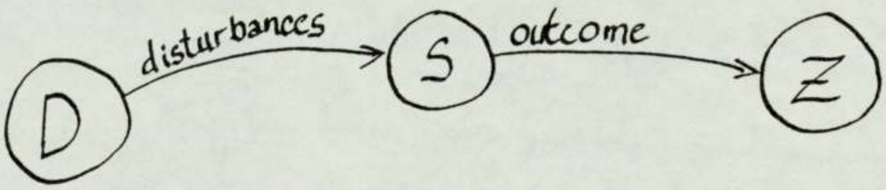


FIGURE 4.2 SYSTEM WITHOUT REGULATION

Outcomes are bounded by Z whether or not regulation is applied.

G: Set of desirable outcomes; G is a subset of Z.

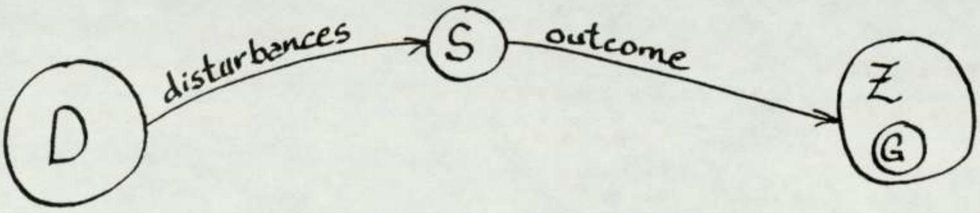


FIGURE 4.3 A SYSTEM WITHOUT REGULATION BUT WITH AN EXPECTED BEHAVIOUR

R: Set of events in the regulator

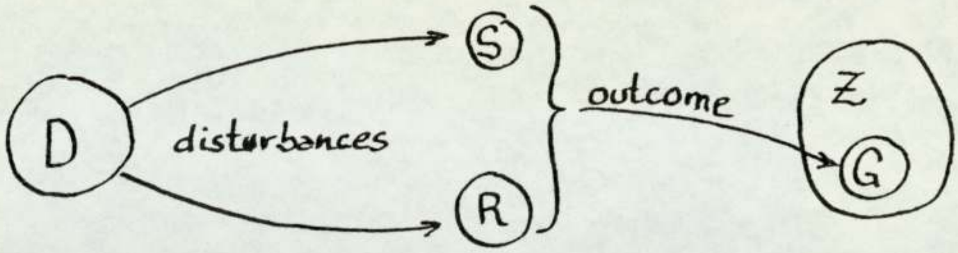


FIGURE 4.4 A SYSTEM UNDER REGULATION TO ACHIEVE A PURPOSE

Events in R and events in S should combine such that the outcome is bounded by G, under any disturbance.

The relationship between the regulator and the reguland is crucial to the success of regulation. One major consideration in that direction is that the way in which regulation is to be realised depends on the characteristics of both the system and environment. Ashby (1970) commenting on some conclusions on the paper 'Every good regulator of a system must be a model of that system' says:

> *".... In this regard, the theorem can be interpreted as same that although not all optimal regulators are models of their regulands, the ones which are not are all unnecessarily complex..."*
>
> *".... Second, it shows clearly that the search for the best regulator is essentially a search among the mappings from S (the set of events in the System S) into R (the set of events in the regulator R); only regulators for which there is such mapping need to be considered. Third, the proof of the theorem, by avoiding all mention of the inputs to the regulator R and its opponent S, leaves open the question of how R, S and Z (the total set of events may occur, the regulated and the unregulated; all possible outcomes of the system) are interrelated".*

The need for some kind of mapping between the regulator and its reguland is also implicit in the definition of regulation when saying that effective regulation is achieved when events in S and events in R relate such that the outcomes are bounded by G. It is fairly clear that the action of the system and the actions of the regulator should complement each other, so that the outcome of the combination belongs to a predetermined set of results. Furthermore, the events in the system and the events in the regulator are to be trigerred by the same event belonging to the set of disturbances, that means that having the same input as the system, the regulator has to be able to produce some kind of event that combine with the natural reaction of the system will produce an outcome belonging to the set G. For doing that, the regulator not only has to know how the system would react but also has to know how to behave itself in order to make it react otherwise. There is a transformation to be performed by the regulator on the events coming from the environment which is based on how the system would behave under its own actions combined with those from the environment. That is a mapping. That mapping is the regulator in the logical sense.

The outcome of the reguland is in fact a product of its interaction with the regulator. This mechanism is called extrinsic control in the sense that the controller is external to the reguland. In this case, regulation means ensuring that the regulator is able to move the reguland to the desired state (that which produces the expected behaviour) from whatever state it is found after its interaction with the environment.

4.3.3 FEEDBACK LOOP BETWEEN REGULATOR AND REGULAND

The mapping between the reguland and the regulator is present in the case of production. Identifying the reguland as the Production System and the regulator as the Production Control function, it is particularly interesting to see that the structure of the production control function maps into the structure of the production system.

From our discussion in the section 2.4 (The structure of the Production Control function), we have seen that the three levels of planning in the Production Control function map into the three levels of aggregation of the Production System. In order to analyse how this interaction works, it is helpful to use the concept of feedback.

Ashby (1976) defines feedback as follows:

> *"In the case ...., where each affects the other, a relation that may be represented by* $|P| \rightleftarrows |S|$. *When this circularity of action exists between the parts of a dynamic system, FEEDBACK may be said to be present."*

In the case of production, we can identify two transformations related in that way. One is the production process and the other is the one applied to information coming from that process by the Production Control function. The output of the Production Control function is an input to the Production System and the output of the Production System is an input to the Production Control function. Although production orders are another major source of inputs to both the Production System and the Production Control function, the existence of the feedback loop situation still remains and it is this feedback loop that makes control possible.

We can see an application of this concept in the diagram below (FIGURE 4.4). What comes out from the production process will have an influence on the transformation applied to the monitoring information and at the same time the monitoring information will reflect the modification applied to the production process by the controller.

As it is shown, the output of the transformation is monitored and a comparison is made using values which are reflecting a measure for effectiveness. If the result is an undesirable state the controlling information will say so but if, on the other hand it is a more positive situation it may not even be necessary to inform this to the adjustor as presumably no adjustment would be necessary. Depending on the controlling information received by the adjustor it will follow some kind of intervention in order to modify the input to the transformation so that a more desired outcome could be approached.

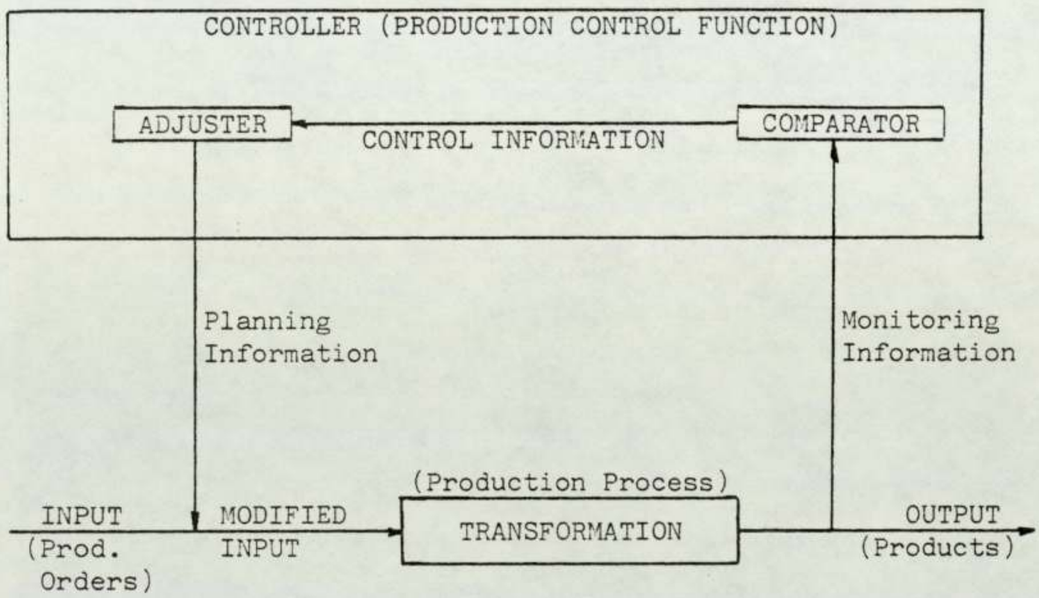


FIGURE 4.4 PLANNING AND CONTROL WITH REFERENCE TO THE FEEDBACK LOOP MECHANISM

We have called the information released by the adjustor planning information with the clear intention of making a parallel between the function of the planner and the one of the adjustor. Both the planner and the adjustor are fed with controlling information and both use it for instructing the system to perform modifications in the output whenever it necessary.

In our model of the feed back loop we have called to the assembly of the comparator and the adjustor the controller. The controller is using monitoring information directly from the output of the transformation and it is producing planning information. To the controller, the control information is internal information and it is necessary to relate these two parts of the controller.

It is particularly important to realise that the behaviour of the system and that of the controller donot depend exclusively on each other's behaviour. Looking at the FIGURE 4.5 below, we can see that the behaviour of the controller depends on the inputs (production system's behaviour and external disturbances) as well as on the way in which the comparator is set and on the alternatives that the adjuster has to its disposal. The comparator will produce controlling information depending on its setting. What we call the setting of the comparator is the range of values defined as the desired range of values.

The definition of the desirable range of values is generally derived from the purposes. Those purposes come, in general, from outside the controller and from outside the production system as well. This means that the parameters of the controller, which constitute its setting, do not depend on the relationship between the system and its controller. Rather, they depend on the relationship between the system plus its regulator and its metalevel.

It follows that the desirable state is not defined within the same level of the controller but, at least, at the level above. The comparator depends on a higher level to find the references to set its limit of normality so that it could judge the output of the system to which it is coupled.

What is not clear is the role of the adjuster in the relationship with its metalevel. In order to make this relationship evident, let us show the adjuster from the point of view of the metalevel. Let the metalevel be, in this example, a line of production.

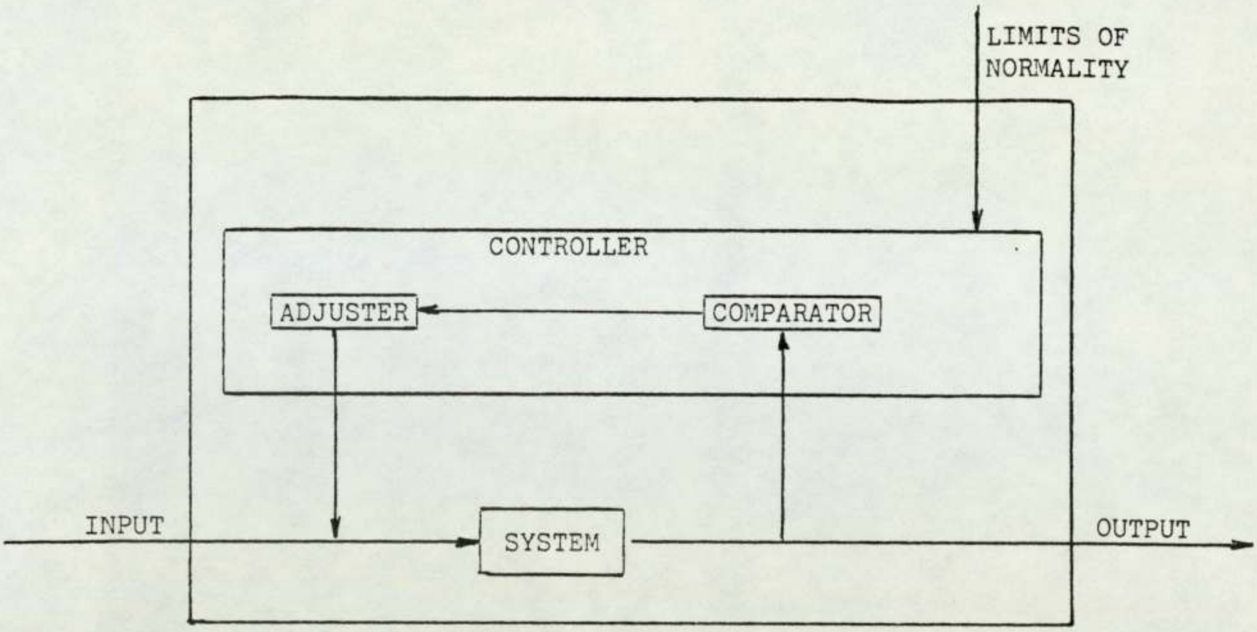


FIGURE 4.5 THE LIMITS OF NORMALITY IN THE FEEDBACK LOOP MECHANISM

The production line foreman asks the operator of a production centre to perform an operation according to certain specification. Suppose that the operator of the operation centre tries to do it but fails because the machine has to be adjusted first to produce the specifications given. Therefore the operator, after making all the adjustments that the machine allows, finds that there are still some specifications not fulfilled. At this point, the operator goes to the foreman to say that the operation cannot be performed because it is outside the possibilities of the equipment. In this case, the communication is established between the adjuster of the operation centre and the comparator of the production line to say that it has failed in carrying out the operation. The message could have been a different one but it would have been equally sent by the adjuster of one level to the comparator of the level above, because the comparator is monitoring in fact what the adjuster of the level below is doing.

Continuing with our example, the adjuster of the production line, once informed by its comparator, could consider several courses of action to overcome the situation. It could modify

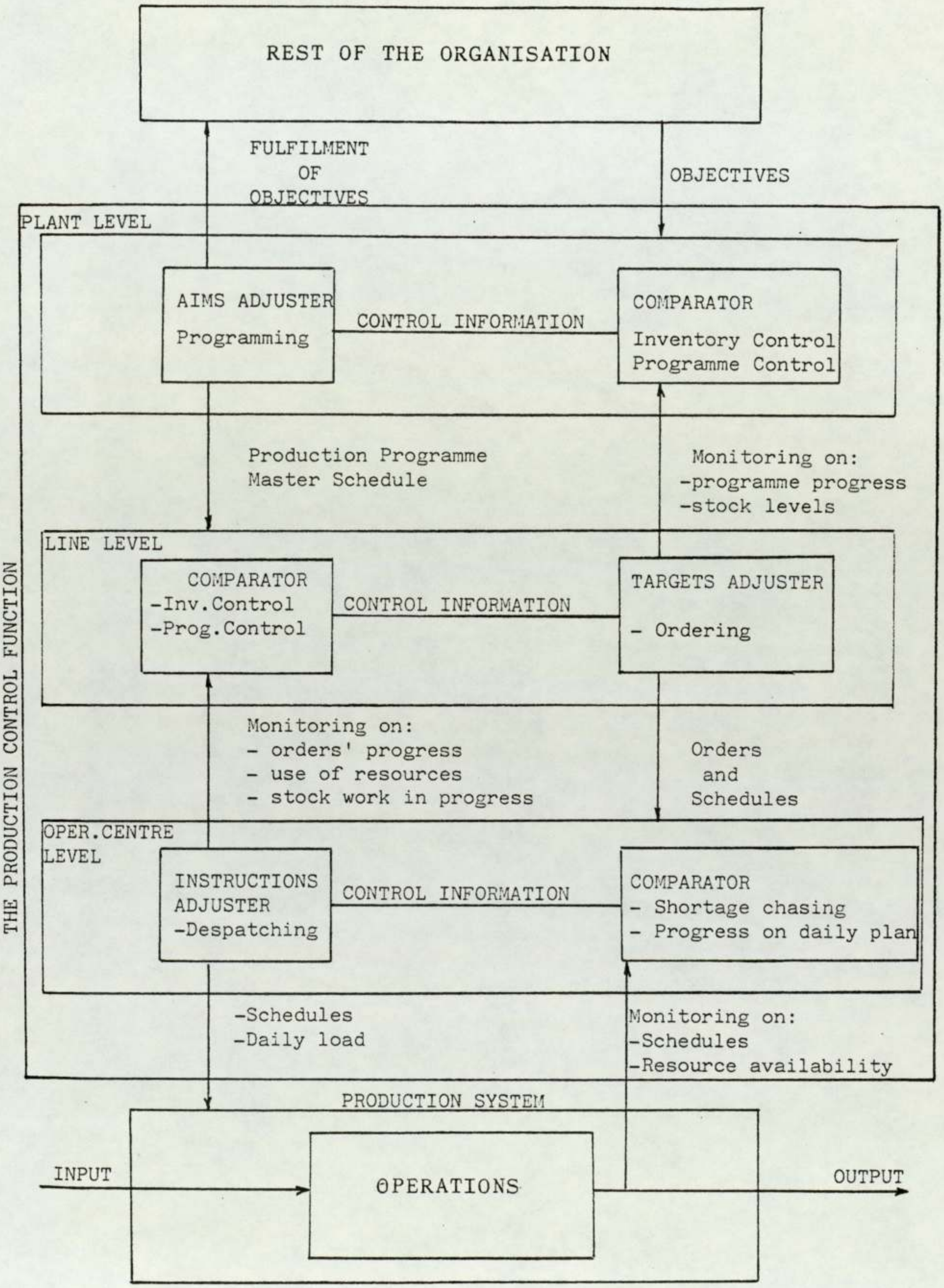


FIGURE 4.6 A HIERARCHICAL FEEDBACK MODEL FOR THE FLOWS OF INFORMATION IN THE PRODUCTION CONTROL FUNCTION

the specifications of the product, subcontract part of it, modify the route of the product, etc. Whatever is decided by the adjuster of the production line, it has to inform the comparator and the adjuster of the operation centre. To inform the comparator to set its references for normality and inform the adjuster in order to have done all arrangements which result to be necessary at the operation centre level.

In the presented FIGURE 4.6, we intend to show how the Production Control function maps into the Production System using the concept of the feedback loop mechanism. According to the FIGURE 4.6 each level acts as the controller of all that is below, accordingly the whole structure can be regarded as a triple feedback loop. It is important to note, from the FIGURE 4.6, that it is necessary to distinguish two parts in the controller, the comparator and the adjustor, in order to explain how the various levels can interact. Once the three levels are integrated with the activity of production we can say that thear behaviour is depending on each other's behaviour as well as on the outcome from the production system. Therefore the main feature of the feedback loop is still present but developed in a more complex structure.

4.4 THE LAW OF REQUISITE VARIETY

One important aspect of the problem of control is that of the amount of regulation that the regulator can exercise. This is the same as to ask from how many states the regulator is able to restore the reguland to the desired state after being left there as a consequence of the effect of the disturbances. This is to what extent the variety in the reguland can be matched by the variety in the regulator.

A regulator able to restore the reguland to the desired state for any disturbance the environment could produce, is said to have requisite variety with respect to the situation under its control. The success of regulation assumes a regulator endowed with requisite variety. Requisite variety implies a repertoire of answers in the regulator as complete as the repertoire of situations it may have to face when trying to restore the reguland to the desired state. This repertoire of answers in the regulator need not match the absolute variety but the variety defined by the variables which are relevant to the identification of the desired state.

In the case of the user of the room that we mentioned before, the desired state could be defined as the room sufficiently lit to read and warm enough to be comfortable. In such a case, the user of the room will have requisite variety over the room if he has a repertoire of actions to put it in that condition if found otherwise. For instance, by simply switching on the light and the fire. In the definition of the desired state here, nothing has been said about the colour of the walls or position of the furniture. Therefore we can assume that whatever the value of any of these other variables, this does not make a difference and the variety is not increased by changes in them. Here, the variety is four - state one: room cold and dark; state two: room cold and lit; state three: room warm and dark; and state four: room warm and lit. Clearly in each of these states, all possible tones of colour, positions of the furniture, etc. are counting as one state because they do not matter to the user. Four is the variety our user has to match and no more.

The law of requisite variety says, as put by Beer (1981):

"Only Variety can absorb Variety"

meaning that only by having a way to reach state four starting from any of the four states is it possible to reach the desirable state in any case. If that is not possible for some of the states, our user will not have his room as he likes it. If for instance there was not a fire in that room, the user would not be able to reach state four if initial state was one or two.

4.5 Intrinsic and Extrinsic Variety and Regulation

The reguland changes its state as a consequence of disturbances coming from the environment. These changes very often lead the reguland to an undesirable state. The effect of disturbances over the outcome of the reguland can be cancelled in two ways. One is the intervention of the regulator, which we have been discussing, and the other results from the properties of the reguland itself.

Let us analyse how the properties of the reguland can prevent the disturbances from affecting its outcome. The variety to be matched by the regulator is what the reguland would display when disturbed. If the reguland would display less variety, then the regulator will have to match less variety. In that case, the reguland would be matching a proportion of the variety of the environment. The reguland will display less variety if it is resistant towards disturbances. That assumes some properties in the reguland which allow it to block the effect of disturbances. This property in fact makes irrelevant to the reguland some of the variety of the environment. That is of course achieved to the cost of developing variety absorbing properties.

In the process of natural evolution, we seem to have a great number of successful examples of these variety absorbing properties. The shell of the tortoise is an interesting example of a variety absorbing property for the system called tortoise. Thanks to its shell, the tortoise is made invulnerable to most predators which is something that very few species without a shell can say.

We have to establish a difference between the two ways in which regulation is tackled. On the one hand, we have those mechanisms that the regulator uses to keep the reguland in the desired state and on the other hand, those that the reguland itself develops to make itself non-sensitive to the disturbances of the environment. These are two distinctive ways in which the variety created by the disturbances of the environment is matched. These ways correspond to what Beer (1959) defines as intrinsic and extrinsic control.

Intrinsic control is defined as a situation whereby the subsystems of a system absorb each other's variety, keeping regulation within the boundaries of the system. On the other hand, extrinsic control is that where the variety of a system is absorbed by the variety of a controller which is external to the system.

4.6 The regulatory model applied to the performance of the Production System

In our case, the regulator is the Production Control function, the reguland is the Production System and the environment is the market. With this mapping, we can proceed to make use of the regulatory model in order to express the problem of performance in the production system. In the diagram below (FIGURE 4.7), we have presented our problem as one of regulation.

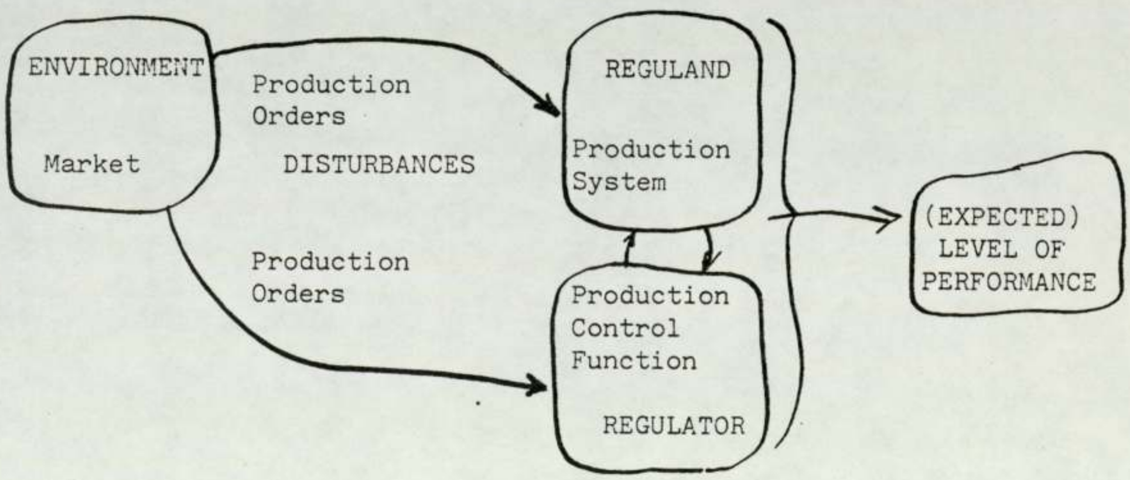


FIGURE 4.7 REGULATION IN PRODUCTION

From this model, we can derive that the achievement of the expected performance requires that the Production Control function regulates successfully the Production System under the disturbances introduced by the market. This statement implies also that the Production Control function needs requisite variety with respect to the interaction of the Production System and the market. Similarly, if as a result of the adaptation of plant and labour to the disturbances of the market, the variety of that interaction is reduced to a minimum, the Production Control function will require less variety to successfully solve the regulation of the Production System.

In reality, it is a critical problem to provide the Production Control function with enough variety as to cope with the complexity of the Production Situation. It is our intention to find ways of resolving the regulatory problem avoiding exclusive reliance on the Production Control function.

According to the law of requisite variety, whatever is the variety generated by the interaction between the Production System and the demand it has to be matched by the variety in the Production Control function.

To avoid the Production Control function having to cope with high levels of variety, the only alternative is to reduce the variety generated by the interaction between the Production System and the demand. Such variety can be reduced by the adaptation of the production system to the disturbances in its market.

This solution implies the development of characteristics in the production system which allow the system to maintain its state after the interaction. If the Production System is able to cope with most of the disturbances of the environment without needing better mechanisms for regulation anytime a new disturbance comes, we could say that this Production System has variety reducing properties. In such a case, the variety of the Production Situation has been reduced and regulation has been improved by means of developing intrinsic control.

From the point of view of the design of control systems, it is desirable that the intrinsic control caters for most of the variety of the environment leaving to the extrinsic control the matching of only the remaining variety. This is desirable because intrinsic regulation needs inbuilt regulation in the very system to be controlled. As in the well known example of the governor of a steam engine, which gets back to the desirable state as a result of going out from it, this type of regulator is the more efficient, yet also the more elegant solution to the problem of control.

Nonetheless, desirability cannot be separated from feasibility. We do not have to go very far to realise that not all disturbances in the field of production can be dealt with by intrinsic regulation. There are disturbances, for instance, that last for a period of time which is shorter than the time required to even implement the intrinsic solution. Eventually, in this case, by the time the solution is about to operate, it would have had to be dismantled. That is the case of normal variations in the demand of a product. It would be unthinkable, for instance, to adjust the production capacity of the plant everytime there is a new order. In that case, quite clearly, what is done is to adjust the use of the present production capacity through a production plan that although always results in the under-utilisation of the plant, is still the only feasible solution. That is why the advantages of the intrinsic type of regulation have necessarily to be comfronted with the feasibility and indeed convenience of different alternatives on the side of extrinsic regulation in each particular case.

As a more general conclusion, we could say the solution to the overall problem of regulation will have to be found by combining intrinsic and extrinsic mechanisms taking into consideration the advantages of intrinsic control in terms of efficiency together with the flexibility of extrinsic solutions.

4.7 CONNECTIVE SUMMARY

We can see very clearly that our problem is one of regulation. It is also clear that in order to fully understand the process by which adequate performance is ensured, we have to make a distinction between intrinsic and extrinsic regulation.

So far, we can say that the problem of ensuring the appropriate level of performance in the Production System does not rely exclusively on the action of the Production Control function.

Intrinsic regulation is different from that exercised by the Production Control function and therefore some other functions within Production Management become involved in the problem of performance.

The way in which the functions connected to the performance of the Production System should interact is the theme of the next chapter.

CHAPTER FIVE

ULTRASTABILITY AND ADAPTATION

5.1 Introduction

For the problem of performance of the production system, we have introduced the concept of regulation as a process of attempting to match the variety of the environment with the regulator. We have made a distinction between the regulation exercised by the production control function and the regulation which is obtained as a result of adjusting the characteristics of the production system to the requirements of the market. We have also demonstrated that these two forms of regulation correspond to intrinsic and extrinsic regulation. Finally, we have expressed our problem as that of finding an appropriate combination of intrinsic and extrinsic mechanisms of regulation to match the variety of the disturbances of the environment.

In this chapter, we shall analyse the relationship between important factors which are the basis of the relationship between intrinsic and extrinsic regulation with the purpose of approaching a clearer understanding of the way to combine them adequately.

5.2 The demand as a source of imbalances for the control system

In our problem, we have to distinguish between those disturbances which are the object of regulation by the control system and those that being outside its range, require the readjustment of the control system.

There are disturbances in demand, such as day-to-day variations of demand within the actual range of products of the company which can be produced by the present procedures.

The entire activity of the Production Control function lies in the category of those disturbances which are susceptible to reduction by the present procedures for controlling production. Also helping to reduce such disturbances are some other characteristics of the production system. According to the discussion in chapter three, the more relevant are the type of layout and the organisation of the direct labour.

There is, however, another range of disturbances which are beyond the capabilities of the present procedures of control. In this category should also be considered those requirements that can only be satisfied at costs beyond the acceptable limits.

Although the production system and their controlling systems are usually designed to satisfy a particular market, the possibility of having to respond to unexpected requirements happens to be very high. The reason is that the demand changes because of the dynamic nature of the market. The market changes over time because it is the resultant of a large number of dynamic factors determined by the social activity as a whole.

Factors such as the increase of population and the changes in individual preferences, the policy on taxation and commerce, the technological development and the availability of new products and processes, the availability of raw materials and the availability of money in the economy, the unemployment and the level of growth of the economy are some of the factors which are continuously affecting the market.

To a great extent, these factors change outside the control of the company. These market changes may reach a point very different from that for which the production system was designed. If such kind of changes takes place, it is very likely that the production system will not be able to respond. Because of this, the company moves in a highly uncertain situation. Nonetheless, it is fair to say that some of the factors which affect the demand do change gradually and eventually its trend may possibly be predicted. A great deal of work can be done to reduce the uncertainty by means of better forecasting procedures. These have been developed in almost every direction in the area of concern of management and in particular with respect to the demand for final products.

The method of robustness analysis (Rosenhead, 1980) has also been presented as an alternative to use in highly uncertain situations. This basically advocates making decisions such that they do not close the possibility of changing the course of actions if circumstances so advise, maintaining flexibility of future decisions.

A fundamental characteristic of these methods is that they assume the adjustment of decisions in view of either the happening of changes or its forecasting. That is, they point to the adaptation of the system to the changes in the environment.

In the case of production, it is evident that the production system has not control over these disturbances in the environment. So the production system cannot rely on the non-occurence of disturbances which threaten its viability or the viability of the whole company. Given the fact that those disturbances do take place and that they happen to affect the conditions for the viability, the only way in which the production system can protect its viability is by adapting to the environment. This can also be expressed by saying that adaptation is a necessary condition to maintain the level of performance that ensures the viability of the company.

5.3 Adaptation and Ultrastability

The concept of adaptation has been widely discussed in relation to the survival of individuals and species. Species, over a long time, have been threatened by countless factors that they cannot control. It is an invariant in their histories that those which adapted survived. More recently, a parallel has been established (Beer, 1972) between the survival in the field of biology and the survival of the organisations created by mankind as part of its life in community. In fact, the creation itself of those organisations seems to respond to the necessity of the species to survive.

A concept from cybernetics which has a great deal of relation with adaptation is that of Ultrastability. Before going into ultrastability, it would help explaining first what stability means according to cybernetics.

According to Ashby (1976), if for a system S there is transformation such that being the system in state X, it remains in state after the transformation T, then the system S is said to be stable with respect to the transformation T. Algebraically, this means: $T(X)=X$.

If state X was the desired state and T is somehow the effect of a disturbance on the system, then the system will be stable to that disturbance. In fact the purpose of regulation is that of reproducing stability upon the desired state. In this sense, what the regulator should do is to combine the effect of disturbances with its own repertoire of actions in order to produce transformation T as a resultant, so that the state of the system remains unchanged.

If disturbances are $\{D_i\}$ $i=1, \ldots, n$ and actions of the regulator are $\{R_j\}$ $j=1, \ldots, m$ then to succeed in regulation, there should be at least one R_j in $\{R_j\}$ such that when combined with D_i gives T for every D_i

$$\exists R_j \ni D_i \times R_j = T \; \forall D_i$$

An ultrastable mechanism is that which is able to adapt its regulatory system in order to respond to a new set of disturbances, different from that for which it was initially designed.

Roughly the ultrastable mechanism has two regulators - one which is to be used under normal conditions and the other which is for adapting the regulatory system itself when the first one is faced with situations it cannot cope with. In the diagram FIGURE 5.1 presented below, we have included the second level of regulation in regulatory model discussed in the last chapter.

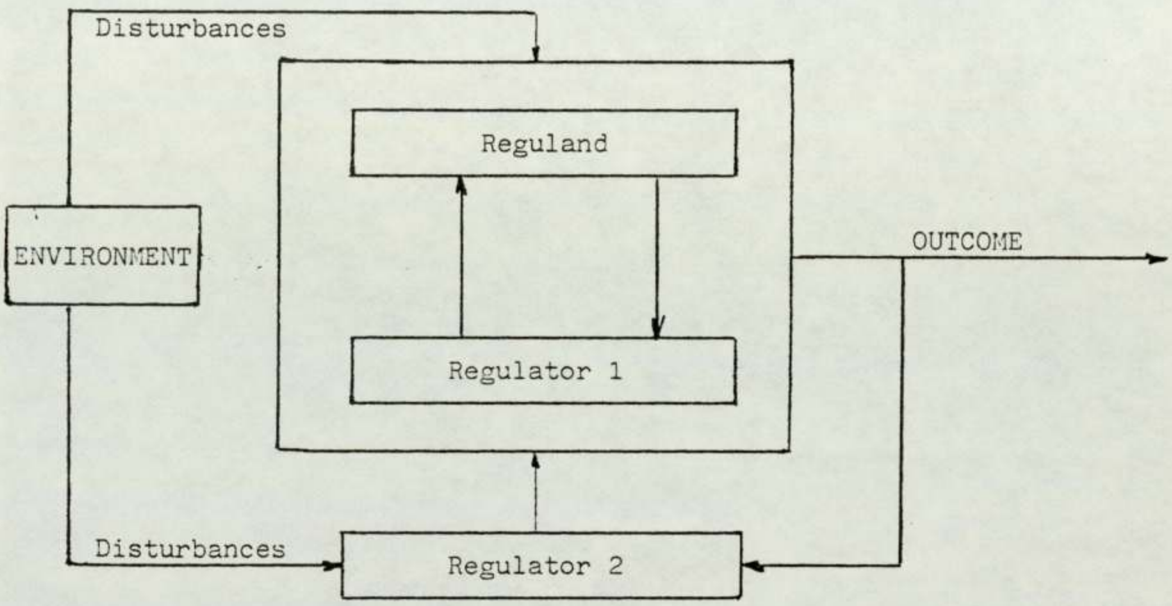


FIGURE 5.1 THE ULTRASTABLE MECHANISM

5.4 THE SECOND LEVEL OF REGULATION

What is new in the concept of ultrastability is the second regulator. The second regulator allows to survive under conditions for which it was not designed. Consequently, the system will extend the capacity to survive if the environment changes in ways it is not supposed to. The second regulator has two tasks of a different nature. First it has to recognise the inability of the first regulator to cope with such disturbance, and secondly, it has to modify the regulatory system to restore control.

5.4.1 DETECTION OF FAILURE IN THE FIRST LEVEL OF REGULATION

In relation with this aspect there are two ways in which the second regulator can operate. One alternative for the second regulator is to assess the behaviour of the set Reguland/Regulator and determine the inability of the first level of regulation if that behaviour consistently differs from the desired behaviour. It has to be pointed out, nonetheless, that the mere occurence of undesirable behaviour shall not be considered as a definitive sign of regulatory failure of the first level. It should be realised that the first regulator has the option to control by error. That is by a feedback mechanism which assumes the occurence of errors and therefore the presence of abnormal results is normal to certain degree.

Definitively, the inability of the first level of regulation is determined by comparing the degree of existing undesired behaviour with that which is supposed to be acceptable. In this case, the set Reguland/Regulator is considered a black box for which the behaviour is not forecast. Being so, it is necessary to measure its result, compare it with some standard and only then establishing the appropriateness of its functioning. In terms of stability, it can be said that neither $\{R_j\}$ nor $\{D_i\}$ are known, but it is possible to recognise T.

The second alternative to recognise the inability of the first level of regulation is such that the set Reguland/Regulator is not a black box and therefore it is possible to anticipate the result of its action if the initial conditions are known.

This method is based on the knowledge the second regulator has about the limitations of the first regulator. Here the second regulator monitors the disturbances acting upon the reguland and determines beforehand whether or not the first regulator will be able to respond.

If, consistently, the perturbations are of the type that the first regulator cannot cope with it should be understood that this is not in a position to exercise regulation and will have to be modified. This alternative is what is known as a feed-forward mechanism.

In terms of stability, what is known is the set $\{D_i\}$ for which there are some R_j to combine with so as to produce the transformation T. Therefore any perturbation not belonging to that set will be regarded as non-reducible to the transformation T by the present set Regulator/Reguland. This way has a clear advantage over the first one which is that of anticipating the effect and avoid the damage that it might cause to the viability of the system if it can provide an appropriate answer.

The time that elapses between the occurence of the regulatory failure and the restoring of regulation is critical. During this period the system is working with a performance under the level expected and if this prolongs excessively, it will seriously damage the viability of the system. It is also evident that in a control system as complex as that used in production the limitations can only be known approximately and the margin of error could lead the system to oscillations that may be as dangerous as the instability itself. In general, it could be said that in real cases, there is neither a complete knowledge nor a total ignorance of the way in which the regulator and the reguland combine with the disturbances to produce the result. That is why it seems to be advisable to use both ways to complement each other.

5.4.2 THE ADJUSTMENT OF THE REGULATORY SYSTEM

When regulation of the first level is lost, what happens in terms of stability is that at least one D_i appears for which there is not a R_j such that $\{D_i\} \times \{R_j\} = T$
Anytime that disturbance takes place, the regulator of the first level will not be able to generate the complement R_j which combined with D_i produces T.

There is a solution - let us call it the extrinsic solution - which consists of providing the regulator with the missing R_j. This means to enrich the regulator of the first level.

The other solution, which we call the intrinsic solution, is one in which a new perturbation is not different in effect from of any for which there is already a response in the regulator. In order to understand better this statement, it should be necessary to point out that $\{D_i\}$ is not the change in the environment but the effect it introduces in the reguland. In this way, the new disturbance can be made 'harmless' if the reguland itself is able to not be affected in a different way from that it is used to. This obviously requires a different reguland from the initial one; this is a reguland already adapted to this particular disturbance. The intrinsic solution implies that the reguland has to be made able to absorb the new variety in the environment.

As it is clear from the discussion in chapter four, the conditions under which regulation is carried out can be modified either by modifying the first regulator or by modifying the reguland itself so that a new set of disturbances can be matched. It is also apparent that regulation can eventually be restored by either of these two ways. In a nutshell, we can say that the second regulator has in its hands the task of deciding the type of balance to be given to intrinsic and extrinsic solutions in restoring regulation.

According to the criteria for selecting either type of solution which we discussed earlier, here we will add that for the second regulator to operate, a high degree of coordination is necessary between the intrinsic and the extrinsic parts of the regulatory system.

5.5 ULTRASTABILITY AND THE PROBLEM OF PERFORMANCE IN THE PRODUCTION SYSTEM

According to what was discussed in section 5.2, we concluded that in order to keep performance at a level compatible with the viability of the system, the production system has to adapt to the disturbances of the environment.

We have shown that the ultrastable mechanism is a good approach to the problem of adaptation. Our next step should be to relate the ultrastable mechanism to the performance of the production system. But first we have to establish some correspondences between the ultrastable model and our problem.

In this first place the level of regulation corresponds to the Production Control function. Its constant and direct relation with the problem of performance when taking in its hands the task of organising the resources in order to satisfy the demand does not leave doubts about its role.

Secondly, the source of disturbances is, as we have already said, the market and those parts of the company in charge of buying and selling. In some cases, like production by orders, it is the clients themselves who directly express the requirement to the production system. In others, like production to stock, it is the knowledge the company has on those preferences which generates the requirements and hence the disturbances.

The reguland corresponds, more precisely, to the plant, labour and the industrial process of production. It is this set of elements that in the end carries out the transformation of resources into finished products. It is the performance of this process of transformation which we are interested to improve.

The second level of regulation is more difficult to identify. Fisrt, because its components are scattered in several activities of production management, and secondly, because rarely are they all present. The activities of production management which are connected to the task of the second regulator are those which are in charge of:

i) the introduction, adaptation or substitution of industrial processes and methods
ii) the organisation of machinery, equipment and space within the plant
iii) the organisation, improvement and training of the work-force.
iv) the revision of methods and systems for controlling and coordination between departments related to the three areas mentioned above.

Within the company the following areas could be identified as involved with those aspects:

i) Production planning since it takes care of the adequacy of plant and technology to be used in production.
ii) Industrial Engineering also seeks the adjustment between technology, plant and methods of work.
iii) Personnel as it caters for training, availability and organisation of the labour force.

With these elements and the ultrastable regulatory model, we can present our problem as follows:

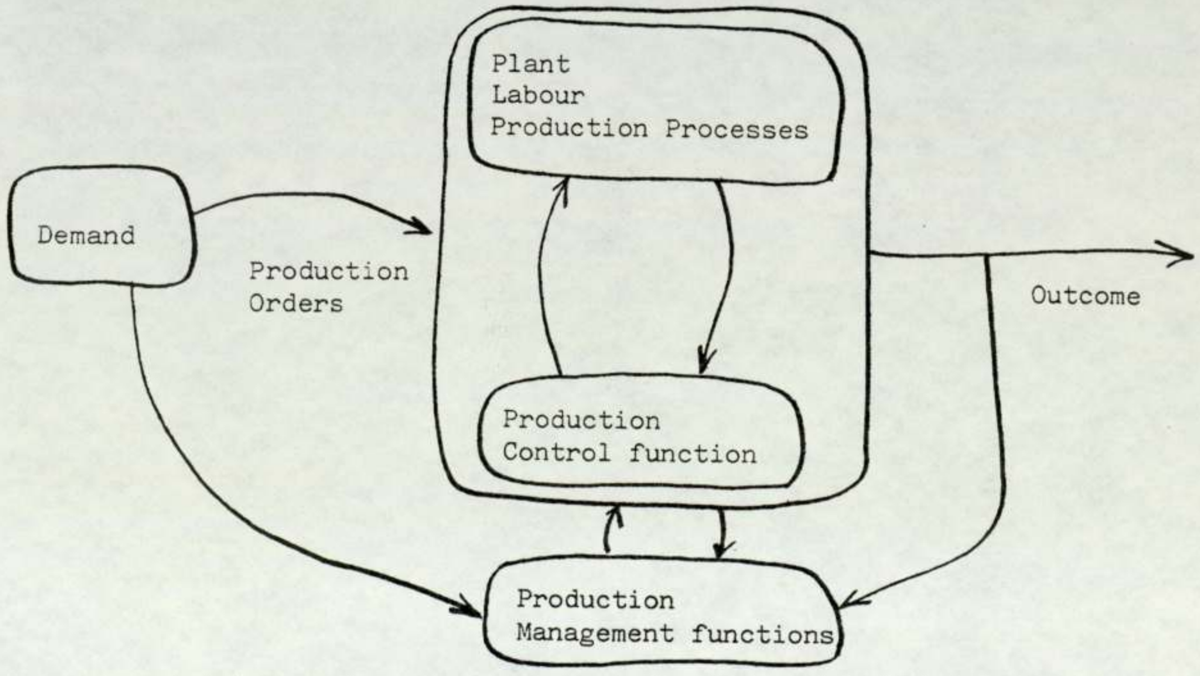


FIGURE 5.2 THE ULTRASTABLE MODEL APPLIED TO THE PROBLEM OF CONTROLLING THE PRODUCTION SYSTEM

As we said we see the solution to the problem of performance of the production system is in the hands of the first and second levels of regulation.

We have already referred to the first level of regulation, its activities, its internal connectivity and the way in which it intervenes the doing of the production system. Now we would like to refer to the second level of regulation.

In the first place we should say that manufacturing organisations tend to adapt with different levels of success to the changes in the environment. This suggests that somehow the second level of regulation operates within these organisations. In general the adaptation time happens to be long and this being a critical variable to survival, we will concentrate on its causes.

It is possible to divide the adaptation time into detection and identification of the problem followed by formulation and implementation of solutions. In the task of formulating and implementing solutions, the Production Management function is better prepared than in the identification of problems. For the manufacturing company, it is common to develop new methods of production, finding the way to improve the assignment of machinery and labour to production processes, designing new products and also to modify the procedures in the Production Control function.

In relation to such problems, there is a vast experience and also an organisational structure is available to respond. In addition there are usually deficiencies in the communication and hence the coordination between the units engaged in such activities so the organisation cannot fully use its mechanisms to formulate and implement solutions. In this sense, there is little to improve apart from providing better coordination between the functions of production management.

The mechanisms by which the organisation learns about the existence of problems which require the modification of parts of the production system though are rather informal and inefficient. They may take too much time.

In relation to the time necessary for the detection and identification of problems, we have to point out that the mechanisms of communication which serve the functions called to adjust the regulatory system usually are rather informal. In general, the problem has to recur several times before the operators take notice of them. Some time later its effect is noticed at higher levels and a memo is usually sent asking for an explanation. Eventually the need for an investigation is established but it lies forgotten several weeks somewhere in the plant. From time to time, the case is reactivated by the repetition of the problem and everybody blames everybody. Finally, a study is asked to the appropriate department. After the department establishes the technical aspects of the problem a different process begins. Responsibility is assigned for deciding who will be responsible for necessary actions in the solving stage. Only then the problem is on course to solution.

In Appendix one, we are referring a case where we tell the common process by which a company arrives at a solution. In manufacturing companies, most of the elements necessary for the modification of the regulatory system are present. Nonetheless, in most of the cases, these are not able to produce adaptation in an efficient manner because the relationship between the problems which affect the performance and the modifications to be carried out is not well established.

Comparing the functions of the second regulator and the mechanisms available in the organisation, we will determine the missing parts so that they can operate as a regulator able to adapt. In general what seems to be missing are:

i) A monitoring channel for the outcome of the production system and/or the disturbances of the environment informing those parts of the production management function which are in a position to modify the system of regulation.

ii) References for normality for the results of the production system or the disturbances of the environment which are considered with the way in which the outcome or the disturbances are measured and also are meaningful for the functions of production management.

iii) Coordination between the parts of the production management function which belong to the second regulator so that its intervention could be smooth and sustained.

In chapter six, we present a solution to the three points mentioned so as to enable Production Management to work as a second regulator.

CHAPTER SIX

DETECTION OF FAILURE IN REGULATION THROUGH THE DISCONTINUITIES OF THE MATERIAL FLOW

6.1 Introduction

We can always be sure that it is possible to improve the performance of the production system. Nonetheless, as it has been made apparent, it is only in reference to viability that we can be sure that performance needs improvement in absolute terms. We could state our problem as that of improving the viability prospects of manufacturing companies by looking after the performance of the production systems. In this sense, performance is not an end in itself but a measure of viability.

Being the central issue that of viability, it came to be relevant the capacity for adaptation of the production system. Changes in the environment, and in general, changes in the conditions of regulation, threaten the viability of the organisation. Since these changes are not controllable by the organisation, its only alternative to survive is to adapt to those changes.

Ultrastability mechanism is the cybernetic abstraction of a mechanism able to adapt. By comparing that mechanism with what is currently found within manufacturing organisations, we have listed what is supposed to be missing to make them adaptive. In terms of the ultrastable model, what seems to be more poorly developed is the second level of regulation.

In this chapter, we want to develop some practical steps in order to improve the second level of regulation making use of the Production Management functions. The starting point for this analysis will be the deficiencies found in the process of producing the second level of regulation.

These are:

i) lack of a mechanism for monitoring the outcome of the production system and/or the disturbances coming from the environment which can then inform those functions of Production Management which are in a position to adjust the Production System and/or its first regulator.

ii) lack of references for the normal functioning of the regulatory system and for disturbances from normality which can be understood by the functions of Production Management which are responsible for introducing modifications to the production system and/or its first regulator.

iii) lack of coordination between the parts of Production Management required to produce the second level of regulation between themselves and also with the parts in the reguland which would be affected by the action of the second level of regulation.

Finding ways to overcome these deficiencies will point towards improvement of the second level of regulation and therefore adaptation.

6.2 Detection of regulatory failure of the first level

In this section, we will concentrate on the first two points listed above which together constitute the lack of a capacity to detect regulatory failure of the first level. The solutions which we will discuss can be classified as feedback solutions according to our discussion on those mechanisms in section 5.4.1 This means that we are more inclined to monitor the outcome of the production system than the disturbances in the environment. Although there are good reason to move towards the integration of both feedback and feedforward solutions, here we are only prepared to discuss the feedback type.

What has to be assessed is the performance of the set Regulator/ Reguland, that is the performance of plant, labour and processes of production under the control of the Production Control function. What we have to find out are the mismatches between the variety generated by the interaction of the reguland and the environment and the variety of the Production Control function.

6.2.1 THE RELEVANCE OF THE MATERIAL FLOW

As it is discussed in Appendix 2, the joint product of the production system and the production control function is the flow of material through the production facilities.

As a general statement, we could say that jobbing production is characterised by an intermittent material flow whereas continuous production is characterised by a more continuous material flow. In both cases as in the intermediate range, the action of the production control function tries to improve the continuity of the material flow.

A higher level of continuity in the flow of material complies with the purpose of the Production Control function as this implies a better use of resources, since slacks are reduced, and also a shorter throughput time which is desirable if promised dates are to be met. In general, we could say that the more continuous the material flow, the better the performance of the production system.

In an ideal situation, what comes out of one operation centre should be allowed to enter into the next operation centre almost instantly. That period of time between operations could be longer if it is shown to be convenient to wait until a lot of certain size is gathered at the end of the preceeding operation for purposes of optimising the use of storage space and material handling equipment. Discontinuities of the material flow beyond that point, will reflect the presence of queues, delays or failure to gather the necessary elements to start production in the next operation centre. These discontinuities are not desirable and constitute problems that the planning activities of Production Control should take care of. Clearly the presence of queues and delays is one of the main sources of wastage of resources. For every minute the material is in the plant, financial resources have to be spent in the form of stock holding costs and wages.

6.2.2 DISCONTINUITY OF THE MATERIAL FLOW AS A SIGN OF REGULATORY FAILURE

A second aspect to look at is whether or not this variable can tell us something about the mismatches which we want to detect. What is clear is that important discontinuities in the material flow will show the failure of the Production Control function to carry out production in a more efficient way.

Nonetheless, if we were to apply the criterion that discontinuities and mismatches map perfectly, we would be making two types of mistakes. Firstly, not all discontinuities are caused by mismatches and secondly, that not all mismatches produce a discontinuity.

In a situation where there are no queues but there is a high level of idle time, a discontinuous material flow will not show. Nonetheless such a situation is not desirable from the point of view of the use of resources though it may be regarded as acceptable from the point of view of meeting the demand. A situation like that may not concern production control but it does affect the intrinsic mechanisms of regulation like production planning and layout.

On the other hand, it should be clear that the problems we are trying to detect are regulatory problems. This means problems which appear despite regulation being exercised. In this sense, manifestations of discontinuities before regulation is exercised are not representing problems in the regulatory system, at least not of the regulator. A case of this kind is the stoppage of a machine as a result of a breakdown. Here the material flow has been interrupted but it does not mean that the first level of regulation has failed. It only represents machine failure. It would be regulatory failure if the Production Control function making use of all precautions made and after taking all possible corrective actions delivery dates are still not met. In fact, the occurence of a breakdown cannot be regarded as a failure of the first regulator since it is not its concern though the consequences this may have are. It is in this second aspect where Production Control function has to be tested.

Therefore in order to use the continuity of material flow as a representation of mismatches in the first level of regulation, we ahve to take two complementary actions in addition. First, to filter those discontinuities which do not represent mismatches and secondly, to measure separately those mismatches not detectable as discontinuities of the material flow.

The elements which will have to be separated from the monitoring of discontinuities in the material flow are machine breakdowns, industrial actions and absenteeism, accidents and fires. That is, stoppages affecting the continuity of the material flow which cannot be avoided by the Production Control function. On the other hand, mismatches which donot affect the continuity of the material flow are in general problems of inadequacy of the Production System to the task it has to perform rather than inadequacies of the Production Control function itself.

For instance, the problem of excessive idle time (not having discontinuities) is clearly a case where the demand is below the production capacity or also a badly balanced production line. Improvements in any of those cases is more the concern of areas of Production Management such as Production Planning (as defined by Burbridge, 1978) and layout rather than Production Control. In general, improvements to these aspects will point to a better use of resources rather than getting orders finished in a shorter time since not having delays there cannot be delays in production orders. Without discontinuities in the material flow, it is very unlikely to have delays in production orders. Unless, of course, delivery dates and schedules are totally divorced or both divorced from reality.

It is useful at this point to introduce another variable to monitor. That is the time spent in preparing the machine for a different operation, the set-up time. The usefulness of having a record of this variable will become clear later, when discussing the problem of analysing the causes of the discontinuities.

Therefore, to monitor the joint outcome of the production system and the production control function, we propose the monitoring of discontinuities in the material flow, stoppages, idle time and set-up time.

6.2.3 REFERENCES FOR NORMALITY

The discontinuities detected through the monitoring exercise needs to be compared with some values representing normality before we can say that they constitute a mismatch.

As we pointed out in section 5.4.1, the fact that the production control function could be controlling by error implies the presence of discontinuities in the material flow which does not necessarily mean poor regulation. In order to tell the difference between a normal discontinuity and a mismatch, we have to compare all discontinuities against the reference for normality.

The basis of a criterion for normality in the exercise of regulation should include the question of the viability of the organisation. In this sense, discontinuities that the organisation cannot afford must be avoided and therefore are not to be considered normal.

But this question of viability is difficult to handle; first, because it varies from company to company, and secondly, because of the difficulties in finding a metric to do the measuring and comparing. Besides, what the organisation can tolerate today may not be tolerable tomorrow. The first conclusion is that references for normality cannot be universal values but only applicable to the individual company. Secondly, that references for normality have to be related to the present state of the company rather than absolute figures. Finally, that we can only have an approximation of those values, because, in general, metrics will not fit perfectly and therefore allowances will have to be granted to cover errors that we can only know exist.

Bearing these conditions in mind, we are suggesting a method to set those references rather than giving specific values. In the first place, they are to be set so that they can be improved by subsequent approximations and that means an iterative method which is not only iterative for the setting of references but iterative for the whole exercise of monitoring the adequacy of the first level of regulation. Fortunately, this feature can be provided to the second regulator without great loss.

The second regulator, to which this monitoring mechanism belongs, needs to monitor permanently the outcome of the first level of regulation. As a consequence it has the possibility to iterate and approach closer and closer to the values meaning normality. If we examine briefly the method of operation of the second regulator, we have that after the records of discontinuities are confronted with the references for normality, a group of discontinuities, related to particular production facilities, is selected to be tackled.

After these discontinuities are tackled, the records of discontinuities will show the effect of the intervention of the second level of regulation. Here is where the second iteration, to improve the result already obtained, can take place. Here it is the choice to change the references for normality depending on whether or not the viability of the company can be foreseen to be in danger if references are not changed. When setting references for normality, we are somehow manifesting the need to give closure to our problem. Not having an external entity to provide closure this has to be provided by the interaction between the perception of the internal situation and the environmental response. Although we may need several trials before setting the value of references for normality, the method suggested is not trial and error. It is not because we reach those values through a successive approximation, each one improving on the previous value. The general structure of our monitoring procedure can be accomodated to the requirements of these methods both in terms of timing and making decisions. In order to be convergent, this method requires the assessment of the past trial before formulating the new values. Clearly the more truthful the assessment and the more knowledge available about the transformation under trial, the better the next approximation.

The way in which viability prospects relate to the value to be used as references for normality seems to be so complex as to reject the idea of an analytical formula to set the references for normality. Rather, we think that the intelligent application of the experience and common sense of those who own the problem could be more valuable. Their personal personal perceptions of the effect of eliminating a certain range of discontinuities will have on the viability should be used to generate a new trial.

The owners of the problem of production, that is those engaged in carrying out the functions of Production Management related to the second level of regulation, should participate in the setting and revision of references for normality.

6.2.4 A METHOD FOR MONITORING THE COMBINED OUTCOME OF THE PRODUCTION SYSTEM AND THE PRODUCTION CONTROL FUNCTION

A method based on the above concepts can be outlined to monitor the combined behaviour of the production system and the production control function as well as to establish the points where action should be taken. It would also be possible to advance in general terms the course of the action to be taken.

We measure certain variables at the production facilities over a period of time, we filter the condensed information in order to produce some indices and finally we will relate the values of those indices to general courses of action. The first stage consists of measuring:

a) the continuity of the material flow by measuring the waiting time of the production orders before the production facilities

b) the degree of heterogeneity of the material flow by measuring the set-up time in the production facilities

c) the relationship of load to capacity by measuring the idle time at the production facilities.

These measures should be taken for a period of time at least equal to the production period so that the effect of the average production load on the production facilities could be assessed. Measurements should be taken at all production facilities, or at least at those likely to show discontinuities.

A parallel activity is necessary at this point which is the identification of groups of production facilities which are relevant from the point of view of the Ordering activity.

The second stage will transform the data collected in the first stage into information about mismatches.

It will produce:

1) the values of the variables 'idle time' and 'set-up time' for each day on each production facility, and the variable 'waiting time' for each order in front of each production facility each day

2) the following indices with the data of each day for each production facility:-

a) $\alpha_{ij} = \frac{\text{Total waiting time in machine i, day j}}{\text{Total machine time in machine i, day j}}$

OR $\alpha_{ij} = \sum_k WT_{kij}$/Total machine time in machine i, day j

where WT_{kij} is the waiting time of order k before machine i during day j

and 'Total machine time' is the time the production facility and the operators are available for production

b) $\beta_{ij} = \frac{\text{Total idle machine time in machine i, day j}}{\text{Total machine time in machine i, day j}}$

where 'Total idle time' is the time when the production facility and the operators are available for production but there is no production.

c) $\gamma_{ij} = \frac{\text{Total set-up time in machine i, day j}}{\text{Total machine time in machine i, day j}}$

where total set-up time is the sum of the times spent in preparing the machine to produce a different product.

Let $\overline{\alpha}_i$, $\overline{\beta}_i$ and $\overline{\gamma}_i$ be the average value of α_{ij}, β_{ij} and γ_{ij}, therefore, if N represents the number of days of the period where measurements have been taken, then

$$\overline{\alpha}_i = \frac{1}{N} \sum_j ij$$

$$\overline{\beta}_i = \frac{1}{N} \sum_j ij$$

$$\overline{\gamma}_i = \frac{1}{N} \sum_j ij$$

The ideal value of $\bar{\alpha}_i$ $\bar{\beta}_i$ and $\bar{\gamma}_i$ would be zero. Nonetheless, as ideals do not have room in reality, we will consider that the values α_{oi}, β_{oi} and γ_{oi} are to be considered upper limits of acceptability for $\bar{\alpha}_i$, $\bar{\beta}_i$ and $\bar{\gamma}_i$ which comply with the references for normality.

It is very probable that the values $\bar{\alpha}_i$, $\bar{\beta}_i$ and $\bar{\gamma}_i$ will vary considerably from one industry to another, also from one company to another and even between production facilities belonging to the same group within the factory. Because of that, general rules for setting those values are difficult to find, and we are suggesting to rely upon the experience of those more closely related to the problem of production.

Using this approach for setting α_{oi}, β_{oi} and γ_{oi} we will transform into a zero any value of $\alpha_{ij} < \alpha_{oi}$, $\beta_{ij} < \beta_{oi}$ and $\gamma_{ij} < \gamma_{oi}$ and into a '1' any value of $\alpha_{ij} \geq \alpha_{oi}$, $\beta_{ij} \geq \beta_{oi}$ and $\gamma_{ij} \geq \gamma_{oi}$ and fill in the following table. The transformed values are going to be $0 < \alpha_{ij} > 1$, $0 < \beta_{ij} > 1$, $0 < \gamma_{ij} > 1$

MACHINES / DAYS	MACHINE 1				MACHINE M		
	$\langle\alpha\rangle$	$\langle\beta\rangle$	$\langle\gamma\rangle$		$\langle\alpha\rangle$	$\langle\beta\rangle$	$\langle\gamma\rangle$
DAY 1							
2							
3							
4							
DAY N							

TABLE 6.1 RECORDING TABLE WITH TRANSFORMED VALUES FOR α, β AND γ

3) There are eight possibilities of configurations made out of zeroes and ones in a set of three: 000,001,010,011,100,101,110 and 111. For every production facility included, it is necessary to analyse the frequency of appearance of each of those eight configurations through the N days of the monitoring period.

The relative frequencies are going to be F_{il} where i denotes the machine and l denotes the configuration. Using the information in TABLE 6.1 we can construct TABLE 6.2

CONFIGURATION / MACHINES	1	2	3	4	5	6	7	8
	000	001	010	011	100	101	110	111
1								
2								
i		$F_{i,2}$						
M			$F_{M,3}$					

TABLE 6.2 RELATIVE FREQUENCY TABLE OF CONFIGURATIONS FOR ALL MACHINES

4) In the extreme case where one of the relative frequencies for a machine happens to be 1, we will identify that machine with that configuration. In the general case, several configurations will have relative frequencies greater than zero for the same machine.

For the general case, we are going to identify the machine with those configurations having the greater relative frequencies and that added give more than 2/3. That information can be organised in the following table.

CONFIGURATION / MACHINES	000	001	010	011	100	101	110	111
1			✓	✓		✓		
2	✓			✓				
3								
M							✓	✓

TABLE 6.3 TABLE OF RELEVANT RELATIVE FREQUENCIES OF CONFIGURATIONS FOR EACH MACHINE

5) From TABLE 6.3 another table can be constructed where machines belonging to the same group are analysed. In this table (TABLE 6.4) we will add the relative frequencies of each configuration for all machines in the group. If the number of machines in the group is L, then we will characterise the group by those configurations whose added relative frequencies give a result greater than (2/3)*L.

6) The same is to be extended to the whole set of machines in the plant by extending the number L to M, which is the total number of production facilities in the plant.

CONFIGURATIONS / MACHINES	1 000	2 001	3 010	4 011	5 100	6 101	7 110	8 111
1			F_{13}					
2		F_{22}						
3								
L								
FREQUENCIES		$\sum_{i=1}^{L} F_{i2}$						

TABLE 6.4 RELATIVE FREQUENCY TABLE OF CONFIGURATIONS FOR THE L MACHINES IN ONE GROUP

6.3 DIAGNOSIS ON THE CAUSES OF DISCONTINUITIES

The first part of the role of the second regulator was the detection of failure to achieve regulation at the first level.

A second stage is that of identifying the cause of the discontinuity considered abnormal so that the search for solutions could be focused more precisely. At this second stage, one tries to associate the values of the three variables or the representative configurations with possible defects and to find some courses of action to improve the situation.

The main causes of discontinuities for the material flow have been shown (Burbridge, 1978) to be:

a) lack ofproduction capacity
b) inadequate scheduling
c) inadequate loading
d) high level of heterogeneity

By monitoring the waiting time, we are in a position to identify the presence of discontinuities in the material flow. By monitoring idle time and set-up time, we can detect the presence of situations where either a), b), c) or d) or even a combination of them is probably the cause for a discontinuity.

It should be said that increasing the production capacity by adding more machinery will always be a solution to the problem of a discontinuous flow, nonetheless, it may be the more expensive solution. For that reason, we are interested in finding which other factors are also present so that courses of action different from adding more machinery could be examined in the first place.

We are going to analyse the cases which can be found assuming that one configuration of the three variables is predominant.

a) (000): There is no significant waiting, idle and set-up time. In this case, we will say that there is no problem. There is nothing to improve and there is no discontinuity.

b) (001): The only significant time is set-up time. Again there is no problem. In the first place, as there is no waiting time, there is no discontinuity in the material flow. Nonetheless, we can assume that by reducing the set-up time, some extra production capacity would be available and knowing that could be useful. Whether or not that extra capacity is necessary is another problem, but here we could say that the set-up times can be reduced, either by engineering methods, by producing in larger batches or by reducing the variety of products.

c) (010): The only significant time is idle time. There is no discontinuity in this case, but the machine is clearly under-utilised. Knowing that there is spare capacity could be an advantage, of course. Eventually, by concentrating all idle time in one period, it could be possible to concentrate their some activities such as periodical maintenance or training.

d) (011): The only significant times are idle time and set-up time. Again there is no discontinuity, but clearly the machine is under-utilised. In this case obviously, there are two ways in which more capacity could be made available if necessary which are:- by using the idle time or by reducing the set-up time, if at all possible. The very fact that there is no waiting time indicates that there is no need for that extra capacity at the moment; nonetheless, that information could be of a great value for purposes of starting new products, assessing the need for expansion or the replacement of technology.

e) (100): The only significant time is the waiting time. In this case, there is a problem. Orders are delayed because of this machine. We cannot know whether or not this delay is as critical as to make the company lose part of the market or a customer; nonetheless, in either case, we know that this is not desirable because of not the holding stock costs which are involved. Unfortunately, there is no idle time to make use of or set-up time to try reducing in order to reduce the waiting time. This is a problem of lack of production capacity. There are some alternatives though. One is to explore the possibility of reducing the load in the production facility either by re-routing products through different machines (which may have shown potential extra capacity), or by producing less altogether. That is the concern of other functions of the organisation as well as taking of decisions in these matters will be more a matter for negotiation. There is also the alternative of buying more production capacity either by subcontracting or by introducing more machinery and also by devising modifications to the present equipment in order to improve productivity.

f) (101): There is a significant waiting time and a significant set-up time. In this situation, alternative courses could be followed as well. There is a problem as there is waiting time. Concentrating on ways to provide more production capacity, we should think of the possibility of reducing the set-up time by the means that were discussed earlier. In this case, there is also the possibility that improvements in scheduling could help by distributing the heterogeneity more evenly through the production period. On the other hand, courses of action oriented to the acquisition of more production capacity like the ones discussed in case e) would also apply.

g) (110): There is significant waiting time and idle time. In this case, there is a problem where loading and also scheduling are in a position to help. How to make use of the idle time to avoid queuing is most important in this case.

Therefore, a modification to the present procedures to carry out the scheduling and loading has to be examined very carefully. If by doing so, there is also the need for more production capacity, then courses of action like the ones discussed in point e) could help.

h) (111): The waiting time, the idle time and the set-up time are significant. In this case, the more difficult of all, we should be prepared to combine all the courses of action outlined so far. Nonetheless, it could be said that the analysis of these courses of action would be simpler if starting by reducing the idle time, secondly the set-up time and finally dealing with the problem of buying production capacity.

In TABLE 6.5, these cases are summarised.

The results in TABLE 6.3 are not going to be as simple as the ones shown in the TABLE 6.5 and therefore the analysis will be more complex than the one we have presented.

If we assume that two configurations are going to have, in general, a joint frequency of more than 2/3, we can see in TABLE 6.6 the associations which can be established between variables and courses of action. If no one single configuration is to reach a frequency of 2/3 but two different configurations are required, for example (010) and (100), then according to TABLE 6.6, it means that sometimes the machine is underloaded and sometimes it is overloaded during the same monitoring period. In such a case, we suggest to revise the scheduling method in use.

WAITING TIME	IDLE TIME	SET-UP TIME	COMMENTS
0	0	0	No problem
0	0	1	No problem
0	1	0	No discontinuity but machine under-utilised
0	1	1	No discontinuity but machine under-utilised
1	0	0	Machine overloaded; either reduce load or buy more capacity
1	0	1	Machine overloaded; cutting down heterogeneity may help; if not, see Case 100
1	1	0	Machine badly programmed; improve loading and scheduling; if not enough, see Case 100
1	1	1	Try first to make use of idle time by improving loading and scheduling; try cutting down heterogeneity and the effect of it; if not enough, see Case 100

TABLE 6.5 DIAGNOSIS AND COURSES OF ACTION DEPENDING ON THE CONFIGURATION

CONFIGURATIONS WITH THE HIGHEST FREQUENCIES		OVER-LOADED	UNDER-LOADED	SCHEDULING PROCEDURES	LOADING PROCEDURES	HETEROGENEITY	MORE CAPACITY
000	001						
000	010		✓				
000	100	✓					✓
000	011		✓			✓	
000	101	✓				✓	✓
000	110	✓			✓		✓
000	111	✓			✓	✓	✓
001	011		✓			✓	
001	010		✓			✓	
001	100	✓				✓	✓
001	110	✓		✓	✓	✓	✓
001	101	✓		✓		✓	✓
001	111	✓		✓	✓	✓	
011	010		✓			✓	
011	100	✓		✓			
011	110	✓	✓	✓	✓	✓	
011	101	✓	✓	✓			
011	111	✓	✓	✓	✓	✓	
010	100	✓	✓	✓			
010	110	✓	✓		✓		
010	101	✓	✓	✓		✓	
010	111	✓	✓	✓	✓	✓	
100	110	✓			✓		✓
100	101	✓				✓	✓
100	111	✓			✓	✓	✓
110	101	✓		✓		✓	
110	111	✓	✓		✓	✓	
101	111	✓			✓	✓	✓

TABLE 6.6 DIAGNOSIS AND COURSES OF ACTION
WITH TWO CONFIGURATIONS

6.4 The coordination among the functions of Production Management

The third aspect which we identify as necessary to make the Production Management functions play the role of the second regulator is the coordination of all parties involved in producing adaptation.

The need for coordination between the functions of production management comes from the fact that their assistance is necessary both in structuring and solving the problem as well as implementing those solutions. After receiving diagnostic information, the functions of production management are called to assess more closely the situation, formulate solutions and implement them. Without these steps, the process of adaptation for which the second regulator is responsible, would not be possible.

Coordination is necessary during the stages mentioned above because the diagnosis will contain, in most cases, alternative courses of action which individually or as a set require the expertise of different functions in some or even all these three stages. For example, the diagnosis could be that as a result of having excessive waiting and setting-up times in one machine, something must be done to reduce the setting-up time either by devising a faster way to set up the machine or by loading and scheduling the machine so as to produce bigger batches, as in the case described in Appendix One. In a situation like that, it will be necessary to have the expertise of at least Production Engineering, Production Control, and Production Process Design. If the problem cannot be solved at that stage, it could even be necessary to think of the participation of Production Planning in order to either replace the machine or enlarge the production capacity for that operation. Clearly in this case, coordination will be necessary between those functions while assessing in more detail the extent of the problem and also while looking for solutions and putting them into practice.

The more specific characteristics of the coordination are defined by the relationships which are necessary between these functions through the three stages where their participation is required.

One major feature of the coordination which derives from the permanent operation of the second regulator is that coordination should be continuous. Let us comment here about the differences between the coordination required by the second level of regulation and the coordinating experience commonly found in industry.

The joint implementation of solutions by several functions of production management is a well known experience in most companies and it is basically the same as coordination of projects. On the other hand, the participation of several functions in the problem solving stage is a more rare experience but it is still undertaken, usually at a rather high level within the Production Management and the Production Control function, by means of adhoc committees and working parties. The main disadvantage of these experiences is that they are usually set up for a one-off purpose disolving rapidly after the solution is found not even lasting till the implementation.

For the purposes of the functioning of production Management as a second regulator, we see the necessity for a more permanent liaison between these functions in the problem solving stage. Finally, in this respect, the structuring of problems by several functions of production management is an even more rare experience in companies. The closest manifestation we have found are the preliminary steps of the problem solving experience mentioned above. Similarly, in this case, these experiences lack continuity. One other thing also relevant to mention in relation to coordination is that apparently the functions of production management are not the only parties that should be involved. Especially in structuring and solving the problem situation, we see the benefit of the participation of those that will be affected by these modifications.

In particular, the operators and the supervisors of the plant should be brought into the coordinating exercise. Their participation at these two stages is beneficial because of the value of the detailed and practical knowledge they have on the running of production. I have to confess, for instance, that the solution given to the problem described in Appendix One was suggested to me, in a crude form, by one of the operators of that machine. In this sense, the need for coordination becomes also a need for a richer interaction between the management of production and the work force.

We do not suggest a single specific solution to the problem of coordination here since every company has its own set of unwritten rules on the way they interact internally. Therefore, this is a point left as an open question for the organisation itself to answer. Nonetheless, a glance at one of the more recent experiences concerning the attitude of management and the workforce towards a richer interaction and the participation of the people from the shop floor in matters of Production Management may help to envisage the benefits that coordination and participation can bring.

An idea originally conceived in the United States and implemented later with great success in Japan is now starting to be looked at with great interest in the U.S.A. and Europe. This is the experience with the Quality Control Circles.

Tse Ka Kui (1981) defines Quality Control Circles as " .... *a small group of people doing a similar work who meet voluntarily on a regular scheduled basis, usually under the leadership of a section head or a senior worker, to identify, analyse and seek solution to work related problems*".

The results from implementing the Quality Control Circles scheme in several countries are indeed remarkable from the point of view of achieving a higher productivity, better product quality and more harmonious labour relations.

The key to success of the idea of Quality Control Circles is that they enable richer interaction between groups involved in the production process allowing in that way the contribution of a wider part of the company to help in the decision-making process. Quality Control Circles make use of *".... the knowledge, experience and creative intelligence of the workers which have been generally ignored"* (Tse Ka Kui, 1981).

The philosophy underlying Quality Control Circles points in a similar direction to the type of coordination and participation which we see necessary for the second level of regulation to operate. The experience that can be gained from the use of Quality Control Circles is indeed a good course for the development of ideas and procedures for coordination. Similarly the technique which we are proposing could play an important role in companies which have already adopted Quality Control Circles scheme since in a sense, Quality Control Circles also help in the success of the second level of regulation.

CHAPTER SEVEN

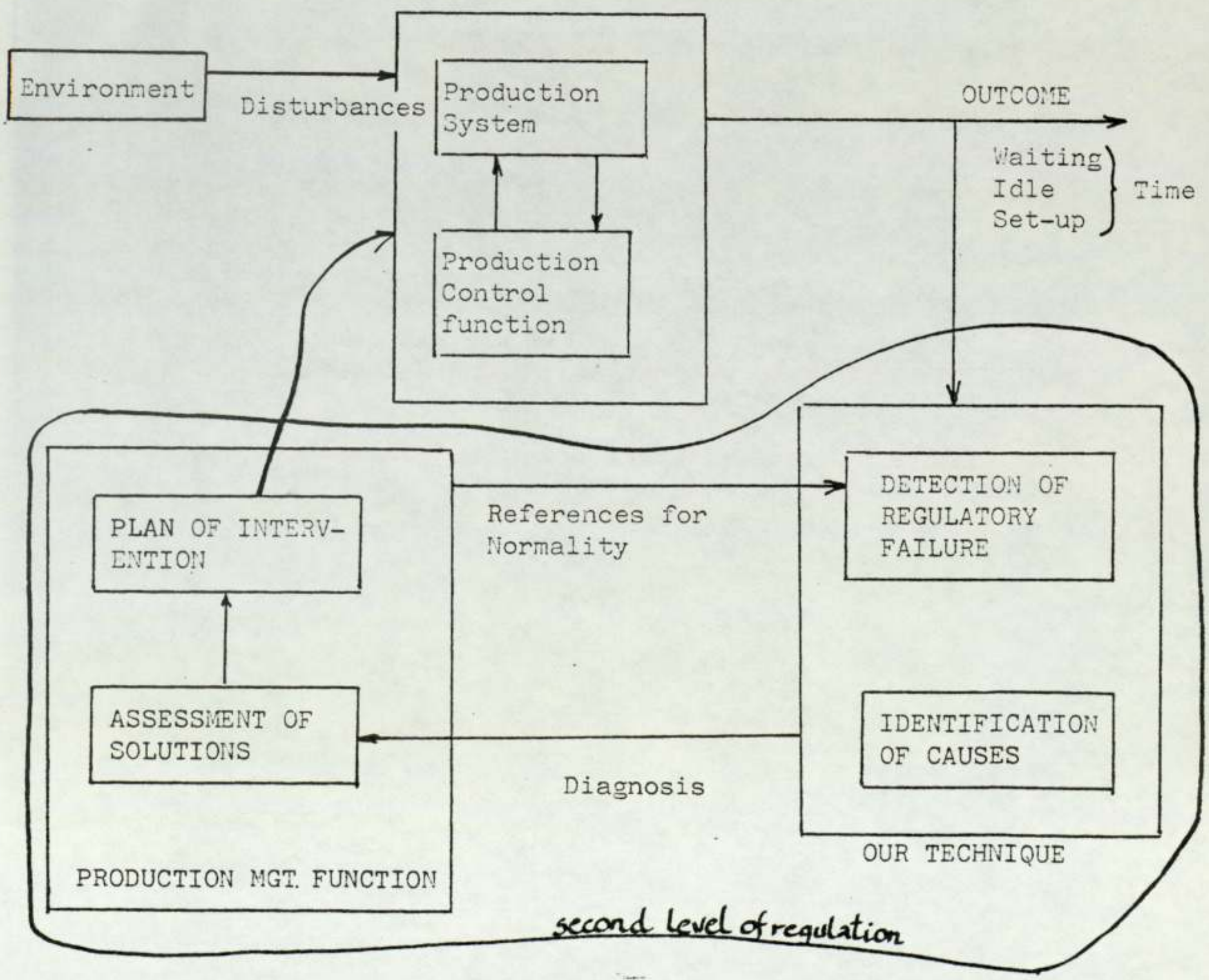
DISCUSSION AND CONCLUSIONS

7.1 THE SOLUTION TO THE PROBLEM OF CONTROL

The solutions presented in the last chapter are the requirements considered necessary to develop the functions of production management into a second level of regulation.

It is appropriate here to examine the role of these solutions in the general context of the problem of regulation. In the diagram (FIGURE 7.1) below, we show these techniques and procedures within the second level of regulation which is part of the ultrastable model.

FIGURE 7.1 THE TECHNIQUE AND THE SECOND LEVEL OF REGULATION



We can summarise our technique as:

i) monitoring the outcome of the production system and the production control function

ii) detecting the failure of the first level of regulation

iii) identifying the type of problem in broad terms.

The result of our technique is therefore a diagnosis of the regulatory proficiency of the production system.

This diagnosis is to be examined and analysed further by the functions of production management and other parties involved in or affected by either the present problem or the consequences of its solution. The purpose of such process is the design of a solution. This is a problem-solving process. The action of the production management functions is essential to that process.

The advantage of the method proposed is that an early diagnosis of the causes of the uneasiness, will be available for the Production Management functions to prepare a solution. By doing so, we are helping to restore regulation sooner and therefore avoiding to a greater extent the damage derived from exposing the system to disturbances which reduce its performance and increase the risk to the viability of the company.

Adaptation cannot be ensured by an early detection of deviations from normality alone for it also requires the adaptative change to take place. Nonetheless, an early detection of threats to viability can help the production of the adaptive changes in two indirect ways. On the one hand, the problems are detected at an early stage, where they are in general less critical than if left to escalate unattended, therefore the solutions required may be easier to find. On the other hand, the solving of the problem could also benefit from the fact that our diagnosis is able to identify some causes of the problem and also some possible courses of action. The utility of this solution depends on whether or not the Production Management functions tackle successfully the problem already detected. That depends to a great extent on the ability of the organisation to coordinate its efforts effectively.

7.2 THE USE OF THE METHODOLOGY

From a methodological point of view, we can summarise our work as the observation and description of a situation, the use of some concepts and principles to express that situation in a way that it shows its more important features from the point of view of control over that situation.

Here we discuss some points we found relevant in our work with respect to the methodology we followed as well as an overall view on the methodology itself.

First of all, we should say that there are two reasons which forced us to model the situation under study rather than looking for solutions from the description as a production problem.

On the one hand, it was difficult to find a framework from specialised literature on the planning and control of production. One part of the problem was the great deal of difference in the meaning that each author ascribes to widely used terms like 'control', 'planning','production system', 'production management' and the great variety of terms used to refer to concepts like 'production control' as well as to the indistinct references they make to scheduling and loading, planning and programming, and continuous and flow type of production. As a consequence we could say that in the field of production control, there is not a universal technical language which we could use to express and analyse the problem of control. That is the main reason why even when more than one hundred books specialised in the subject were surveyed, only a handful of those were used in this research. This was not because of the divergency or irrelevance of the views expressed but because of the incompatibility of the terminology used to express those views.

The second reason to look for concepts and principles outside the sphere of production control was that the concepts we required were not available in specialised literature. We needed concepts and principles of general application but in the referenced literature we found mainly recommendations and prescriptions applicable to more or less specific situations. Although these were valid, their concern was at a lower level of abstraction than the one where the more general problem of control was to be expressed.

The need for a set of concepts and principles of a greater generality than those used to describe either production control or its context became apparent when we came to introduce the context of the production control function into the problem of performance.

Somehow, the great diversity of situations had to be synthesised following a coherent theory of control and also a framework serving as an interface between the more practical area of production and that theory of control.

Although we are aware that there is a great deal more in the theory of systems and cybernetics than what we chose to use, we felt that there was no point in referring to those disciplines further here since our intention was to apply them in the modelling of a particular situation.

We have found that cybernetics and systems theory are powerful tools for the modelling of complex situations both because of the universality of its principles and because of the precision of their concepts and laws.

We found difficulty in applying cybernetics on its own for it is highly theoretical in its framework, but when referring its principles to a model of systems, it becomes a more practical and useful theory. That is what we intended to do.

The value of modelling the production problem in that way was that it made possible to identify areas for improvement much easier than if using the specialised language. We transformed the problem situation into a model, then working with that model, we deduce the conditions for success and later we compared these theoretical conditions with what in our experience is the common practice in the manufacturing industry which we commented on, both in Appendix One and chapter three. From that comparison, it was possible to identify the changes necessary in the real case in order to satisfy the conditions for successful control.

We have to change our tools when having to produce practical answers to the particular aspect which we identify as poorly developed in the previous stage. These are the more familiar tools of production control. For instance, the way to monitor the continuity of the flow of material has some connection with some techniques used for the balancing of the production capacity in the highly continuous type of production, in particular that suggested by Burbridge (1971).

In relation to the different tools, we used in this research, we should say that the Systems Approach and Cybernetics proved to be very useful in structuring our problem whereas in the more practical stages of problem solving, a more analytical approach like that of Operational Research was found useful. The Systems Approach and Operational Research are two relevant disciplines in the field of Production Management. Nonetheless, from what we have done, we could say that they have to combine to be useful in tackling real problems. The way to bridge the gap between these two disciplines, we think, is by combining them, making use of their particular qualities at specific stages rather than converting one into the other.

7.3 THE CONTRIBUTION OF THE ORGANISATION TO THE SECOND REGULATOR

In order to meet the three main deficiencies in the ability of the controlling system of production to match the requirements of the second regulator, there needs to be a process of assimilation by the company and also contributions in specific aspects. Here we discuss the particular aspects of our solution which need the adjustment of the organisation and in particular the type of contribution required from the organisation for the successful operation of the second regulator.

7.3.1 THE ORGANISATIONAL LOCATION OF THE SECOND REGULATOR

The technique proposed is embedded in the second level of regulation because it detects the inability of the first level of regulation to exercise control.

Nonetheless, the technique is only a part of the second regulator which also requires the contribution of the existing functions of production management to find and implement a solution to that inability. Although we can see a clear relationship between our technique and the functions of production management, we foresee a problem for the technique and the functions of production management to work as a unit from the organisational point of view.

Basically, the functions of production management are carried out by specific departments under the supervision of production management. The role to be played by our technique does not belong to the area of concern of any of those departments in particular. Moreover, the role to be played by our technique in conjunction with the techniques of production management as a second level of regulation is of a higher level than that of these functions in the sense that the second level of regulation is in fact a resultant of all of these functions and not that of any in particular. In addition, once the second regulator is in operation, what these functions do will be what the second regulator determines has to be done. This poses the problem of accountability and location of the second regulator, within the organisational structure of Production Management. The organisational responsibility for the second regulator should lie at the level of the production manager.

We would generally expect that the Production Control function gathers the information needed for the monitoring exercise. Afterall, this function is in an excellent position to do so. Also analysts from management services could process the information and generate the diagnosis. Then a coordinating committee should be formed by different functions of Production Management to analyse the diagnosis and direct the finding of solutions.

A solution like that for the organisational location of the second regulator could apply to many cases. This is one of the important adjustments required in the company for the solution to operate.

7.3.2 THE COORDINATION BETWEEN THE PARTIES INVOLVED TO GENERATE AND IMPLEMENT SOLUTIONS

A second aspect where a contribution from the organisation is required is that of developing adequate mechanisms of coordination between the parties involved in structuring and solving the problem as well as in the implementation of those solutions. It is not common practice in most manufacturing companies that to have permanent coordination at these three stages between the parties we propose to get involved. Therefore, it will be necessary for the organisation to learn how to coordinate these parties.

The gathering of information and the generation of feasible solutions are essential parts of the task of the second regulator, especially at the structuring and solving stages. We have suggested that an open participation could be more helpful in that direction than a more rigid scheme of interactions.

A higher level of participation and involvement of those affected by the problem and eventually by the solutions has two major advantages which are that this enables the gathering of relevant information and views which are not easily obtainable by more formal ways and also the development of a sense of commitment with the courses of action finally taken.

In fact, in view of what is the current practice in the manufacturing industry in relation to these matters, the generation of effective mechanism of interaction may constitute an effort of considerable proportion and therefore it has to be borne in mind in relation to the operation of the second regulator. The final solution to the problem of coordination may possibly be a compromise between formal and informal mechanisms of interaction but what is certain is that it will rely on the effort of the organisation for its formulation.

7.3.3 THE ADJUSTMENT OF THE REFERENCES FOR NORMALITY

A third aspect of our solution which also depends on the contribution of the company is that of the definition and adjustment of the references for normality. The references for normality are still the biggest problem in our solution.

Let us examine again the FIGURE 7.1. The outcome of the production system and the production control function is monitored. Depending on the references for normality, we define a particular situation as either a regulatory problem or not. If it is, we analyse further information and produce diagnosis which is received by the production management functions. These functions generate interventions which will eventually change the outcome. If the solution is not good, the problem situation will persist, again, according to the references for normality. If that happens, a second diagnosis is produced and a different solution is put into practice and the cycle goes on bridging the gap between the actual and the desired outcomes closer and closer.

This cycle is able to improve the solutions it produces. Nonetheless, the references for normality, which are so important to the success of the whole operation of this method, cannot be adjusted within the cycle. It is clear that the only reason why the functions of Production Management are able to set sensible references for normality lies on the interaction they have with the rest of the organisation, since they have gathered some idea of what survival means in terms of the variables of the production system. That perception comes mainly from accumulated experience about bad and good times of the company together with not very precisely structured connections in the production side.

While the mechanism to assess the appropriateness of the values of the references for normality will remain more or less the same after this cycle starts operating, it should be realised that we will at least have, in addition, a difference between what is actually happening and normality to be associated to each point in the history of survival of the company. That is vitally important to start a learning process. If, for instance, those differences tell us that the company is doing well while everything else in the company tell us otherwise, we can be sure that the references for normality will have to be changed.

We are helping a great deal to adjust the references for normality by providing a measure of normality for the situation in the area of production which can be compared with views in the wider context of the entire company. Even so, what has to be stressed here is that the human experienced perception cannot be replaced in the assessment of the general conditions of survival. This is the contribution of the organisation in relation to the references for normality. It is the role of those operating and specially managing production to judge the validity of the references for normality which are in use so that they can be better adjusted.

From what has been said, our solution needs the contribution of the organisation in several ways.

7.4 THE APPLICABILITY OF THE SOLUTION

The technique proposed in chapter six can be applied to any manufacturing company. Nonetheless, the degree of success it may have in producing the second level of regulation might differ from one company to another.

Since the success of the solution depends on the effectiveness and collaboration of the production management functions, it is apparent that those characteristics in the organisation will make its application more fruitful. Well established production management functions would help, for instance, to provide more adequately the information required by the technique. Although the technique requires little information in comparison with that required by the Production Control functions, for instance, for some companies with a very low level of organisation in matters of production management, the provision of the necessary information could be an obstacle for the application of the technique.

Similarly and as it is clear from the previous chapter, effective production management would be in a better position to provide the necessary infrastructure for the operation of the second level of regulation. Our solution being an hybrid solution, in the sense that it makes use of the existing organisation, its application will have to consider the experience and skills available in the organisation.

7.5 NEXT STEPS TO IMPLEMENT THE SOLUTION

In order to implement the solution discussed in the last chapter, for the second level of regulation, we consider necessary to discuss here three steps.

The first step is oriented towards the implementation of the technique of diagnosis itself whereas the second and third are more concerned with producing the contribution of the organisation which we discussed in the previous section.

First, it is necessary to develop a system of information able to bring all the necessary information for the monitoring technique to work as well as to analyse that information in order to produce the indices which are used for the diagnosis. In the development of such systems, appropriate forms for the recording of the waiting, set-up and idle times as well as stoppages should be designed and measures should be taken in order to ensure that these forms are filled in the course of production.

At the end of the production cycle, this information should be processed in order to calculate the indices necessary to the diagnosis. Although this processing can be carried out manually, we are more inclined to advise the use of a computer program so that access to past data could be more easily and rapidly available in the event of having to compare past and present situations, that is, before and after courses of action have been implemented to cure certain deficiencies.

Such a system of information and the procedures to generate the indices should be tested for internal consistency but also with respect to the part played by the organisation through an experimental exercise caring not to interfere with the normal running of the activities of production or those of its management.

Secondly, for a particular company, it should be necessary to adjust the references for normality in order to produce the indices of the diagnosis. From the monitoring subsystem, our technique obtains aggregated values of the waiting, idle and set-up times are produced for every production centre, line of production or group of machines considered important. These values have to be compared with references for normality so as to define which of those production centres and lines of production are showing abnormal behaviour. In that direction from comparing the diagnosis produced by the experimental running of the monitoring subsystem in the previous step with the present knowledge of the production system, it should be possible to set tentative values for the references for normality.

Finally, and after the mechanism to produce the diagnosis are designed and tested, it is necessary to give attention to the mechanisms which can find and implement solutions. There are practical aspects to be dealt with first for the functions of production management to be able to work as a team in finding solutions. Some of them are the setting of a coordinating committee and making available some infrastructure to provide and keep information (such as opening common files related to the new role they have to play). Then a complete loop of the second regulator should be carried out in experimental basis so as to generate the situations where the need and characteristics of the coordinating mechanisms will become apparent so as to produce and implement solutions.

This exercise on the running of a complete loop of the second regulator certainly involves introducing changes to regulation but it should, nonetheless, be experimental in the sense that it should undertake only some minor changes since its main purpose is to assess the functioning of the second regulator rather than involving the company in a large scale programme of modifications at this stage. One has to bear in mind that the use of this technique is something to be learnt by the organisation through practice and continuous assessment of weaknesses, therefore a progressive approach leading to the full operation of the second level of regulation is what we see appropriate to follow after this experimental exercise.

This means that a great deal of attention should be given by the organisation to the process of implementation because of its learning nature.

7.6 Ideas for further Research

A final point we wish to refer to here, is that only the feedback type of mechanisms for the second regulator were explored whereas the feedforward type of mechanisms were not developed at all. In this review of the contribution of our solution to the problem of performance, we should say that it would be a more powerful solution if able to combine both feedback and feedforward mechanisms in the second regulator.

Therefore, we strongly advise that further research should be carried out on the feedforward mechanisms of control for the second regulator. The relevance of such a research is that it would permit the second regulator to anticipate adjustments so avoiding disturbances that can damage the performance of the production system.

APPENDIX ONE

CASE STUDY ON THE PROCESS TRIGGERED BY THE INCREASE ON THE DEMAND OF A PRODUCT IN A MANUFACTURING COMPANY

A1.1 PREFACE

In 1976, I had the opportunity to participate in a small project that illustrates the way in which medium-size companies adapt to changes in their environment and also some of the concepts we use in modelling as well as to identify some weakness in the process of adaptation.

A1.2 BACKGROUND

Madeco S.A. is a Chilean company manufacturing copper, aluminium and non-ferrous alloy products. The basic products are tubes, pipes, bars, metal sheets and strips and electric wires and cables.

At that time, there was an increase in the demand for copper strips due to the setting-up of a company to produce car-radiators to satisfy the Latin-American market. One day, the Industrial Engineering department received a request to study a sheet cutting machine that was causing a great deal of problems in satisfying these new orders. It is necessary to point out that more than six months had elapsed between the increase in the orders and the receipt of the request for the study in the Industrial Engineering department. First, I shall reconstruct what happened during those six months.

A1.3 THE DEVELOPMENT OF THE PROBLEM SITUATION

Initially, the machine in question was working one shift and without any pressure. When the orders for metal strips came, the Production Programming department imposed two shifts for the last two weeks of each month.

On reviewing the results at the end of the third week of the first month, this plan was changed. It was decided that three shifts were necessary to catch up during the fourth week and two shifts throughout the following month with permission for overtime still falling behind schedule. At the beginning, there were difficulties to cover those new shifts. Because this was the only machine working outside normal hours in that section, there was no foreman or supervisor readily available. There was also problems to get operators since this machine had never been important and so not many were familiar with its operation.

During the second week of the second month, the machine was put to work on three shifts because as a matter of fact, it had been working that way by means of overtime. Approval was not easy to obtain from the personnel department since this meant recruiting extra workers. In spite of these efforts, the backlog equated to about ten days work at three shifts.

During the third month, the Production Programming department received instruction from the production manager to solve the arrears situation caused by that machine. To that end, a special inspector was assigned and following-up controls everyday were enforced. Parallel to that, the foreman was asked to watch the machine and the operators more closely to avoid wasting time and also special priority was given to the machine from the point of view of maintenance.

At the end of the third month, the backlog was even bigger than before, but the rate at which it was growing was smaller. At that time, it was thought that if the approved measures were carried out more carefully, the growth of the backlog could be stopped though not reduced. These measures were further reinforced and at the level of the production management, a search was launched for a producer to subcontract the backlog. During the third week of the third month, it was apparent that backlog was still growing and there was no other producer able to fulfill a subcontract for the backlog.

Until then, the customer had manifested his concern several times and his claims had been given polite apologies with definitive promises. But about that time, the customer gave a clear warning that if the situation was not normalised, he was going to be forced to import copper strips from Peru or Argentina. The Sales Manager and an Assistant from the Production Programming department went to a meeting with the client to explain to him the situation and the effort the company was making. They also promised to put an end to the situation during the following month.

During the weekly meeting of the managers, the production manager was put in a difficult position when asked to explain what was happening. The problem was defined as serious and in a later meeting of the Production Management section, it was decided that all possible avenues should be investigated under the direct command of the Production Manager.

As a consequence, the operators were blamed for inefficiency and lack of skills, also the quality of the material and the sharpening of the disc-blades used for poor quality cutting. The handling system was also blamed for damaging the final product. Eventually, the Production Engineering department was ordered by the Production Manager to do its best in reducing the percentage of rejection as soon as possible, which by that time was about 10%.

By the end of the fifth month, the backlog was bigger than a month's production. Even when most ideas had been tried, all the departments involved kept blaming each other for not releasing necessary information or not being too keen on the other's propositions. The situation was in such a mess that everyone disappeared anytime the problem was mentioned.

In the meeting of managers, the production manager in his despair said that the only way out was to buy or construct another machine because definitively the load was bigger than the production capacity.

Within the production area, the only department that was familiar with economic appraisal was the Industrial Engineering Department. As a consequence, this department was asked, not to prepare a study for the acquisition of a new machine, but rather to justify the purchase of it. In parallel, they asked the Industrial Engineering Department to study the allocation of such equipment.

In this way, our department became officially involved in this problem. We sent letters to different machine producers in Europe and the U.S.A., asking for quotations. In the meanwhile, we started a study of the location for the new machine. From the operating point of view, the best place was beside the existing machine. Besides, it only required the removal of an old electric panel which was out of use. In the course of that investigation, we found that the same site was being considered for an expansion of the export warehouse which was just at the other side of the wall.

By then the national market had shrunk to one fifth of the previous five-year period as a result of a very serious recession in the building industry. As a result, most of the efforts of the company were directed to the international market and therefore the expansion of the export warehouse had a higher priority. Having taken that aspect into account and there being no other suitable place, not even near the actual machine, we informed the Production Manager that unless the expansion of the export warehouse was reconsidered, there was no point in continuing with the study on the purchase of a new machine.

Almost six months had elapsed since the orders were first placed. The relations with the client were in a very bad state and the only reason why we were still receiving his orders was that he had not been able to complete the necessary formalities to import raw materials from Argentina. We were however asked by the Production Manager to keep looking for other places to install the machine and to go ahead with the study for the purchase.

Facing such requirements, we pointed out the existence of a location not very far from the first machine but we expressed our concern because the space was too small and this could be a serious obstacle to the efficient operation of the machine. We substantiated our opinion with a quick study of time and movement of the operation where, perhaps unnecessarily, we talked about the percentages of time for operation and for preparation of the machine. In the final paragraph of that study, we suggested that the use of that location required a more detailed study of the actual work methods because these could be improved and were impractical in the new location.

Strange as it may sound, someone in the management read the report of that study and thought that the study we were proposing was worth carrying out, and we were given a free hand to go about the entire problem.

A1.4 THE SOLUTION

We decided to start afresh with the problem and very soon we defined our objective as that of reducing the set-up time. From a more detailed time study, we found that the cutting operation was taking 25 minutes and that the preparation, when necessary, took 67 minutes. Over a week, we found out that the machine was taking about 60% of the time cutting the material while the remaining 40% was used in preparing the machine for a different cutting.

The preparation of the machine consisted in aligning several discs with cutting edges at very precise intervals on an axle. The distance between the discs was obtained by inserting smaller discs between the disc-blades until producing the correct separation. There was a great deal of trial and error in the operation because of the high precision that was required between the cutting discs. During the preparation, the machine could not cut.

Very soon we agreed with the production manager that the machine did not have enough production capacity under the present procedure. Although short of time, we thought that it was worth trying an alternative procedure.

This study followed two lines. One to programme the machine so that bigger batches were produced in order to reduce the number of times the preparation of the machine was necessary. The other was to look for ways to prepare the machine so that the cutting was interrupted for a shorter time.

According to the results of the first approach, we concluded that it was possible to reduce the total preparation time but that was depending on the load, the product-mix, the capacity and availability of other machines in the line and even when these aspects could be handled, the reduction was not enough.

The second approach was more successful. We found a way to make the axle removable so that blades could be mounted outside the machine while another axle was in operation. The mounting of blades took a bit longer than before and also the remounting of the axle. Nonetheless, the cutting process was interrupted for only about 15 minutes instead of the 67 minutes that prevailed before as total preparation time.

This proposition was accepted and implemented straightaway. The backlog disappeared by the middle of the eighth month.

A1.5 Analysis of the case

The case we have been referring to can be analysed in a broader context to show that there is another problem hidden which is still to be solved.

After an important change in the market, the Production System was found to be unable to satisfy the demand for a particular product. Gradually several departments, related to Production Management, became involved in searching for solutions. Initially the emphasis was on making the machine and labour available for production for as long as possible. When that avenue was exhausted without results, it was followed by using the time the machine and the labour were available in the best possible way. After six months, it was realised that there was still not enough production capacity. The Industrial Engineering department rephrased that conclusion by saying that there was not enough production capacity under the present method of work. Once that method was changed the problem was solved.

This is a case where the Production System has adapted to a change taking place in its environment.

Clearly a change in the market of the product is a change in the environment of the Production System and it can be considered a disturbance since it lead to the upsetting of the production system as we mentioned earlier. It is also apparent that a change in the mechanical characteristics of the machine made possible a different method of work under which the production system was able to respond satisfactorily. That change can be regarded as the specific way in which adaptation is manifested. We proceed by discussing the process leading to adaptation.

The steps that can be recognised in our example are:
- the perception of inability to respond,
- the trial of the more familiar alternatives within the present production situation,
- the recognition of the overall failure and therefore the need to change the present situation, and finally,
- the design ofalternative ways to change the present situation itself.

Although subtle, there is a difference between changes within the situation and changing the situation itself. Changes within the situation were, for instance, the extension of the working hours, the reduction of scrap and the changes in maintenance priority. Changes in the situation, on the other hand, would have been the addition of more machinery to the plant and this, as we certainly showed, was a change in the production method.

A crucial step towards adaptation is that of realising that the desired outcome is not attainable within the present situation. This is crucial because it marks the point at which adjustments to the variables of the operation of the Production System cannot make the system produce what it is expected to. This means that the Production System, at least in the particular respect of that product, is out of control. Increasing the number of hours, or reducing the scrap and caring about the material handling by stretching the actual procedures to the limits, or even reducing the non-productive time by servicing and repairing the machine at once, are measures which although improving, do not solve the problem.

Indeed, the Production Programme department is the more important in the aim of organising the short term adjustments and therefore is part of what is called the first level of regulation. At that stage, it is clear that whatever the Production Planning department did was not going to solve the problem. Therefore that is the point at which it is realised that the first level of regulation cannot cope with the disturbance.

If we recall the description given above, the consensus on that issue caused a great deal of strain on the company. For several months, the management thought that there was no such impossibility but it was unwillingness in the departments involved. Only after a painful trial and error process did the management come to realise that impossibility thus risking, during that process, the loss of the customer.

If the only way for the management of production to realise the failure of the first level of regulation is trial and error then they are not to be blamed for taking so long. Nonetheless, from a methodological point of view, it is desirable to have a better way to answer that question. The lack of a better way to establish the inability of the first level of regulation is the other problem without a solution the existence of which we mentioned at the beginning of this section.

It is most important to note that before the inability of the first regulator is recognised, the possibility of adaptation is completely closed. Five out of seven months it took to solve the problem were spent by the company in establishing that inability in its own way.

Once that was clear, two types of solutions were explored. One, changing the scheduling and loading procedures so that producing bigger batches was imposed. That was a solution based on changing the way in which the Production Planning department carried out the regulation. That was a change to the first regulator and therefore an extrinsic type of solution. It pointed to equate the complexity generated by the new demand over the Production System by complexity in the regulator. This alternative failed because under the conditions at that time, it was not possible to match that complexity.

The second was the change of the method of work allowed by a technical modification. That is a change to the production system and therefore it is an intrinsic solution. In that sense, the effect of the disturbance is reduced by the Production System itself. Although the change to the production system, in this case making the axle for the disc-blades removable, was carried out completely by outsider to the production system, this alternative is called intrinsic because the effect it produces over the outcome of production is from within the production system.

Quite clearly and to round up this analysis, the departments in charge of designing and implementing the modification in the Production System belong to the second level of regulation. In this particular case and given the way in which duties were associated to departments in that company, the Industrial Engineering department was definitely part of this second level of regulation. Certainly other departments were also considered to be playing a part in that role like the mechanical engineering department that designed and built the removable axle.

A1.6 Discussion

In the case we described, although there was a great deal of interaction between different departments in the field of production management, it could be said that there was a lack of sustained coordination. Even in the unstructured way in which different alternatives were tried, these same trials would have taken less time if a better coordination had existed between the different departments involved.

Therefore, one thing we can learn from this case is the need for coordination between the departments involved in the first and second levels of regulation in order to facilitate adaptation.

The second aspect which we see important to stress is the lack of a more formal procedure to detect the failure of the first level of regulation. It is apparent that the number of stages to cover before establishing the failure of the first level of regulation can be very large. Therefore, the trial and error method is bound to be considerably time-consuming, especially in the case of absolute failure of the first regulator where all alternatives would have to be tested.

In particular cases like the one we described, where only one machine was involved, a more structured procedure could be based on well known Industrial Engineering techniques and be sorted out fairly quickly. Nonetheless, in more complex situations where more than one machine are involved, that approach may not be useful.

Therefore, this is still an open question in the general case.

APPENDIX 2

THE RELATIONSHIP BETWEEN THE MATERIAL FLOW AND THE PRODUCTION CONTROL FUNCTION

A2.1 THE MATERIAL FLOW

We identify three elements in connection with the material flow:

a) The material flow system

b) The parameters of the material flow

c) The state variables of the material flow.

A2.1.1 THE MATERIAL FLOW SYSTEM

The material flow system is defined as the set of production facilities storage places and handling equipment, their production capacities. physical location and relation of precedence according to the route of the products. To the description of the elements of the material flow system it is relevant to mention here the usefulness of representations such as The Process Chart, The Flow Chart, and techniques for analysis such as the Flow Analysis as described by Burbrige (1971).

The study of the material flow is the concern of the Production Planning Function which has been defined as:

> *"The management function concerned with planning, directing and controlling the method to be used to produce the products and/or services of an enterprise. This function is also concerned with the choice of production facilities and with planning the layout, or spatial relationship between the places where work is done."*

A2.1.2 THE PARAMETERS OF THE MATERIAL FLOW

The parameters of the material flow are those values which determine what materials are going to flow, in which quantities and when. According to Burbridge

(1978), these parameters are:

1) The order quantity
2) The run quantity
3) The transfer quantity
4) The set-up quantity
5) The order cycle
6) The order phase
7) Schedules and
8) Loading programmes.

These parameters can be classified and defined in the following way:

a) <u>Quantity parameters</u>

1) The order quantity: *"is the quantity of items to be produced, which is specified in an order or instruction"*

2) The run quantity: *"is the total quantity of a component which is processed consecutively, at a given work centre, during one or more successive working periods"*

3) The transfer quantity: *"is the quantity moved together as a batch between work centres"*

4) The set-up quantity: *"is the quantity of components - not necessarily all the same - which are processed at a work centre between changes of tooling set-up"*

b) <u>Timing parameters</u>

5) Order cycle: *"The period of time elapsed between orderings of the same product"*

6) Ordering phase: *"A measure of the relationship between the production cycles for batches of different parts used in the same product or assembly. In multi-phase ordering all the cycles start and finish at different times. In single-phase, all cycles start and finish at the same time"*

7) Load: *"The total of the standard times of all work assigned to a given work centre plus allowances for machine idle time, ancillary time, and down time, and for substandard performance"*

8) Schedule: *"A record of the starting and finishing times at which to begin and complete each event or operation comprising a procedure"*

A2.1.3 THE STATE VARIABLES OF THE MATERIAL FLOW

The state variables of the material flow are variables which show how the material is flowing and therefore can be regarded as a measure of the material flow itself. Those variables are:

1) the throughput time
2) levels of stock
3) relationship output/capacity
4) delays and queues.

Ways to measure those variables can be easily recognised. In addition, it is apparent that the attainment of the objectives of the Production Control function implies that some values for those variables are more desirable than others. It would be desirable, for instance, to have a throughput time as close as possible to the processing time for every product, levels of stock as slow as possible, the output as close as possible to the capacity and the delays and time spent in waiting system as close to zero as possible.

A2.2 MATERIAL FLOW AND REGULATION

The relationship between the material flow and the problem of regulation can be treated by analysing the elements of the material flow in connection with the problem of Production Control. The characteristics of the material flow system are highly dependent on the type of layout and the route structure of the products. The major types of layout have been already identified as functional, group and line. A second aspect of the allocation and use of production facilities, in relation to the material flow, is the route structure. That is treated by Burbridge (1978) and he identifies the types of production systems according to a relation between the variety of final products and the variety of components: raw materials and parts with which production starts.

"1. Explosive systems start with a very small variety of different materials and produces a large variety of different components. Typical examples can be found in foundries which make many different castings from a small variety of different types of pig iron, scrap metal and other miscellaneous items...."

"2. Simple process systems are those which start with a small variety of different materials and produce an equally small variety of different final products. Typical examples can be found in a cement factory, in many chemical plants and in most plantation industries...."

"3. Implosive systems start with a large variety of different components and convert them into a small variety of different products. A typical example of an implosive system is found in assembly".

Depending on the relation between the variety of final products and the variety of the initial components and materials needed for production, the routes are going to be different in terms of controlling production. The route structure is more related to the functional relationship between production facilities than to the physical location and that is why it is seen as complementary to the information from the layout.

There is a close relationship between the material flow parameters and the planning activities of the Production Control function. It could be said that the purpose of the planning activities (programming, ordering and despatching) is the production of the parameters of the material flow for each production order.

The activity of despatching, for instance, is involved with scheduling and loading as well as with the problem of determining the transfer quantity and the set-up quantity. On the other hand, the ordering activity is directly involved with the stabilising of the run quantity as well as with the order cycle and the order phase. Finally, the programming activity should be associated with the production of the order quantity and also with what is called the master schedule.

The way in which those parameters are determined depends very strongly on characteristics such as the type of production, the demand for final products, the type of manufacturing and also the type of layout.

The state variables of the material flow are related to the controlling activities of the production control function (Progress Control and Inventory Control).

It is quite clear that the level of stocks are the concern of the Inventory Control activity whereas the throughput time, the relationship output/capacity and delays are the concern of the Progress Control activity.

The way in which these variables are to be measured and interpreted will vary with aspects such as the type of make, which directly relates to the problem of stocks, the type of layout, which strongly affects the throughput time and also the degree of intermittence which affects in general the way progress control is done.

In the following diagram (TABLE A2.1), the correspondence between the material flow, the production control function and the characteristics of the production situation is summarised.

Activities	PRODUCTION FUNCTIONS	MATERIAL FLOW	PRODUCTION SITUATION
	PRODUCTION PLANNING FUNCTION	FLOW SYSTEM PROCESS CHART ROUTE CHART FLOW CHART	TYPE OF INDUSTRY TYPE OF LAYOUT & DEGREE OF AUTOMATION
	PRODUCTION CONTROL FUNCTION	FLOW PARAMETERS	
PLANNING ACTIVITIES	PROGRAMMING AND ORDERING	QUANTITY ORDER RUN	TYPE OF PRODUCTION AND DEMAND
PLANNING ACTIVITIES	DESPATCHING	TRANSFER	TYPE OF LAYOUT
PLANNING ACTIVITIES		SET-UP	TYPE OF PRODUCTION
PLANNING ACTIVITIES	PROGRAMMING & ORDERING	TIME ORDER CYCLE ORDER PHASE	TYPE OF PRODUCTION TYPE OF MANUFACTURE
PLANNING ACTIVITIES	PROGRAMMING, ORDERING AND DESPATCHING	SCHEDULE LOAD	TYPE OF PRODUCTION STRUCTURE OF FAMILY PRODUCT
		DEPEND ON →	
CONTROLLING ACTIVITIES	PROGRESS CONTROL	STATE VARIABLES THROUGHPUT TIME	LAYOUT, TRANSFER QTY., RUN QTY.& SET-UP QTY
CONTROLLING ACTIVITIES	INVENTORY CONTROL	STOCK	RUN QTY., TRANSFER QTY. & THROUGHPUT TIME
CONTROLLING ACTIVITIES	PROGRESS CONTROL	OUTPUT/CAPACITY DELAYS, QUEUES	SCHEDULE & LOAD
	←	ARE THE CONCERN OF	

TABLE A2.1 RELATIONS BETWEEN THE PRODUCTION FUNCTIONS, THE MATERIAL FLOW AND THE PRODUCTION SITUATION

We suggested that the material flow is an isomorphism of the Production Control function and that in being so, there should be some relationships between the elements of the material flow able to generate the dynamic of that function.

a fundamental relationship is that the values of the state variables depend exclusively on the characteristics of the material flow system and the values of the material flow parameters.

It could be said, for instance, that throughput time, depends on the type of layout, the transfer quantity, the set-up quantity and the run quantity. The levels of stocks depend on the run quantity, the transfer quantity and also the throughput time. The delays will depend on the efficiency of schedules and load programmes.

Besides, the state variables of the material flow are measurable and there are references for their values in terms of the attainment of the objectives of the production control function. The state variables to which we are referring only in general terms, are, in the end, a good measure of continuity.

Stocks and delays are examples of discontinuities of the material flow. The throughput time is the total time the material takes to go through the material flow system and the relation output/capacity gives an idea of the degree of utilisation of production on resources.

Those characteristics of the state variables make them suitable to be used in controlling the material flow system and therefore the performance of the production system.

The relationships between the elements of the material flow in connection to the activities of the production control function can be seen in the following diagram (FIGURE A2.1).

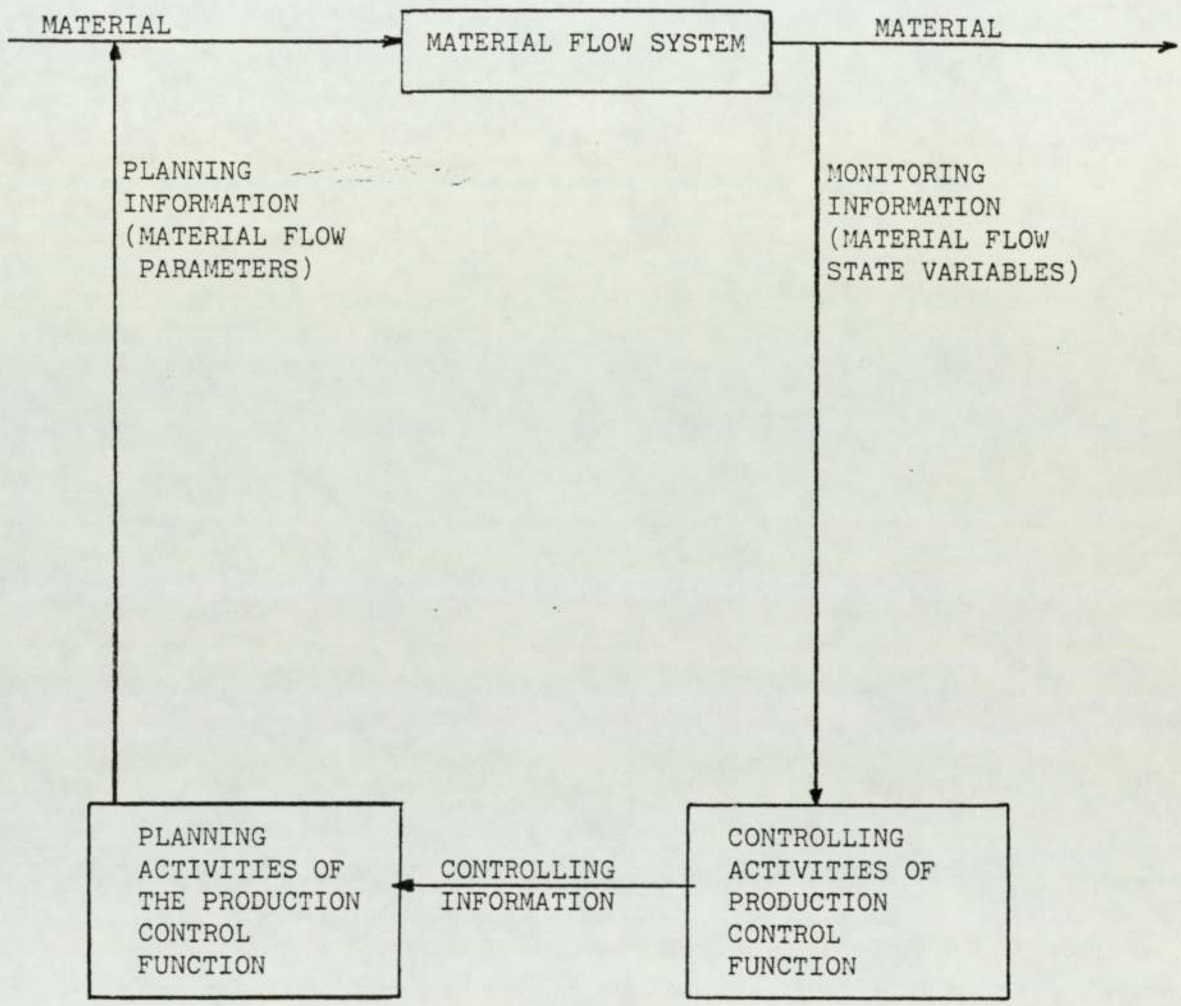


FIGURE A2.1 THE MATERIAL FLOW IN RELATION TO THE PLANNING AND CONTROL OF PRODUCTION

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