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**MEASUREMENT OF
THE EFFECTIVENESS
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**MEASUREMENT OF THE
EFFECTIVENESS
OF THE
PRODUCTIVE UNIT**

**Sir EWART SMITH, M.A., M.I. Mech. E.,
and
Dr. R. BEECHING, B.Sc., Ph.D.**

**BRITISH INSTITUTE OF MANAGEMENT
17 HILL STREET, LONDON, W.1**

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EDITORIAL NOTE

This proceeding was held at the Conway Hall, London, under the chairmanship of
Sir Charles Renold, J.P.

MEASUREMENT OF THE EFFECTIVENESS OF THE PRODUCTIVE UNIT

SIR EWART SMITH and DR. R. BEECHING

This paper was circulated before the meeting

1. Introduction

The title which the Institute has selected for this discussion is in very general terms, and it deals with problems for which there is no generally agreed and acceptable method of treatment. Our task is, therefore, one of peculiar difficulty and no attempt has been made to put forward firm proposals which could be applied under all circumstances. Instead, we have tried to draw attention to some of the more important factors governing the effectiveness of industry, and to indicate possible methods of working out comparative results.

In the case of the physical sciences, it is a truism to say that progress depends very largely on effective measurement, and subsequent analysis of the results. A similar view is now becoming more common with regard to the social and economic sciences, although precise measurement, as in the present instance, is often difficult and the variables extremely numerous.

Although no simple solution to the problem of measuring effectiveness appears to exist, we are nevertheless convinced that a most useful purpose can be served by making such approximate and comparative measurements as are appropriate to individual sections of industry, or to the national economy as a whole.* The results must be examined critically, however, and with due regard to the limitations imposed by the methods employed. Measurements of this kind are particularly important in enabling trends to be determined more exactly and at an earlier date than would otherwise be the case; in addition, such procedure will automatically induce a critical and analytical approach to all phases of industrial production.

It is with this objective of raising issues for critical examination that we have approached our task. We are well aware that the specialists in economics, statistics, and industrial management, may disagree in whole or in part with the views which are expressed, but it is hoped that a useful discussion will result from such constructive criticisms.

The broad implication of the term 'The Effectiveness of the Productive Unit' is clear, but it has no precise meaning. Before discussing how the required measurement of effectiveness may best be made, it is well to decide what is to be measured and for what purpose the results are to be used.

Effectiveness implies the achievement of purpose, and it is important, therefore, that we should agree on the purpose of the productive unit, i.e., of industry. On this there may be some divergence of view. At one extreme, there are those who believe that the main purpose of industry is to give employment; at the other end of the scale, there are those who regard it

*S. R. Dennison has pointed out (Lloyds Bank Review, January, 1949) that the economic plans put forward in the Government's Economic Surveys for 1947 and 1948 depended on assumptions with regard to productivity. At the same time, the former Survey admitted 'that the absence of precise facts on this vital question seriously hinders remedial action.'

primarily as a source of profit. It is proposed here to accept the view that its purpose is to provide the goods which the community requires at the lowest possible cost measured in terms of expenditure of real resources. Of these resources, manpower is by far the most important, whether it is manpower directly employed in the production unit under consideration, manpower which has to be used for the production of the necessary capital equipment, that which is needed to produce and transport the raw materials required, or to provide power and other services. It could be argued that, on a long-term basis, 'the man-year of brains and brawn' is the only and ultimate resource of mankind. On its efficient use everything else depends.

Our immediate objective is, therefore, to determine output relative to the total effort expended or, as it is commonly expressed, to measure productivity. The ultimate objective is to increase this ratio, and the measurements made should provide data for dealing with the problems involved, and for recording the progress which is made.

2. The Meaning of Productivity

The term Productivity is taken to mean 'the volume of output which is achieved in a given period in relation to the sum of the direct and indirect effort expended in its production.' The result is usually expressed in terms of output per man-hour or per man-year. The former ratio is appropriate to the problems of local management and the study of the efficient use of facilities during working hours; the latter to the broader consideration of the results achieved relative to the wider economic picture.

It is common, when considering the overall effectiveness of national production, to measure productivity as the ratio of total output to numbers of men actually employed. Insofar as the nation can be regarded as approximating to an isolated system, which does not draw its capital resources or services from outside without equivalent payment, such a measure includes all the manpower used.* In the case of an industrial unit within the national economy, however, manpower employed in the unit cannot be regarded as the *total* effort expended in achieving the output attained; account must also be taken of the external manpower serving the unit, in the supply of raw materials, services, and capital facilities. The coal industry may be quoted as a pertinent example. Figures are published for output per man-shift and per man-year for those men directly engaged in the industry. In addition, there are large numbers of other branches of the economy, such as engineering, whose only purpose is to improve the equipment of the mines. Any true measure of effectiveness must take this service into account.

Productivity is used, in this paper, as synonymous with overall effectiveness, and not in the narrow sense of covering only the efforts of the operative: we believe that the latter meaning can be unfair and misleading. This is not intended to belittle the importance of individual effort, at all levels, in the industrial field.

3. The Factors Affecting Productivity

The accompanying chart, Figure 1, is intended to show the factors upon which production depends, and hence their relationship to productivity.

*In this respect Marshall Aid distorts the picture. The present rate of this aid is equivalent to the wages of approximately 750,000 industrial workers at current British wage rates. The total number engaged in industrial production in Great Britain is some 10,500,000, so that Marshall Aid is equivalent to an increase in our industrial production of 7%, as a first approximation.

Management is not listed as a separate main factor, because it is of a different order from the others, and operates by influencing all of them. The analysis in Figure 1 indicates the many ways in which management can exercise control over industrial effectiveness.

The main methods of approach to increased productivity can be deduced from this chart. These are listed below, with a note on certain important distinguishing features.

Means of Increasing Effectiveness of Production

(1) Improve Basic Processes.	} Long Term. Requiring Capital Expenditure	} Without Limit.
(2) Improve Plant and Equipment.		
(3) Standardize Products and Reduce Variety.	} Intermediate Term. Possibly Requiring Capital Expenditure.	} Total Effect Subject to Limitation.
(4) Improve Methods of Plant Operation.		
(5) Improve Planning of Work and Labour Control.	} Relatively Short Term No Appreciable Capital Expenditure Required	
(6) Increase the Effective Rate of Working of All Employees.		

Since the main subject of this paper is the measurement of industrial effectiveness, rather than consideration of methods of increasing it, these means of improvement will not be discussed in detail, but we should take cognizance of them in considering methods of measurement. To be fully useful, measurements of effectiveness must not serve only as a means of recording what has happened; they must also aid improvement by giving data for diagnosis, and show effects in relation to causes. Moreover, in order to make the measurement a sensitive, reliable, and rapid indicator of the effect of any known change, it should be applicable to the appropriate section of the operations. Thus, an overall index of effectiveness for a large company might give a good indication of the result of a general change in the company's policy, but would be a poor guide to the effect of installing new plant in one small section. Therefore, we must consider means of measuring effectiveness for organizations varying in scale from the simplest unit to the total industry of the nation.

4. The Problems of Measurement

As we have already suggested, the true measure of industrial effectiveness is the ratio of output achieved to effort used, but the measurement of each part of this ratio can present many difficulties.

4.1. *The Measurement of Output**

The problem of measuring output depends very much upon the type of production considered and the exactitude of the comparisons which it

* The problems associated with the measurement of mixed forms of output are discussed at considerable length, and very clearly, in the University of Cambridge Department of Applied Economics Monograph 'The Measurement of Production Movements.'

is desirable to make. Since there is no satisfactory common unit for measuring all forms of output, comparisons of effectiveness between units producing quite different products are of doubtful value. Even comparative measurement of the output of any one organization at different times presents severe problems, if the output is made up of a multiplicity of products which change in kind or in relative proportions.

An additional problem arises from the fact that the effective output of a unit is not the ultimate product, but the difference between this and the incoming materials, i.e. the added value. Therefore, a measure of the output of finished product alone is not satisfactory for our purpose, if raw materials are changing.

4.2. *The Measurement of Effort*

Where it is considered satisfactory to measure productivity by relating output to the manpower *directly* employed, no problem arises under this head. Difficulties only occur when we try to improve the measurement, by applying corrections for the effort involved in the provision of capital equipment and other services. There is, however, a common unit in terms of which all such resources may be considered for our purpose, namely, a unit of manpower (either the man-hour or man-year).

5. **Methods of Measurement Already Applied**

A number of different methods of measurement are already in use, which are of considerable value in the study of industrial effectiveness, provided they are used with due appreciation of their limitations.

5.1. *Measurements Based Upon Direct Measurement of the Physical Volume of Output*

A very useful form of measurement, possible where the nature of the product concerned remains sensibly the same, is a measurement of the physical quantity of output per man-hour or per man-year. This provides comparative results which give a broad indication of changes in effectiveness of industries such as coal mining, steel production, shoe-making, etc. The Bureau of Statistics of the U.S. Labour Department collect such data for many industries, on a yearly basis, and generally express the results in terms of man-hours per unit of output, e.g. man-hours per pair of shoes (by types). Some data of this kind is also collected in this country, although not so extensively. Use of such a measure involves the assumption that the average quality of the product does not change, and it takes no account of the invisible manpower employed, i.e. the men providing services or capital equipment from outside the industry. This type of index is akin to that for the 'elementary production unit' considered in Section 6.1. In that section, possible methods of including allowances for capital equipment, services, and changes in raw materials are suggested, for application if required.

5.2. *Measurement in Terms of the Monetary Value of Output*

Where the output to be measured is composed of a multiplicity of products, liable to change in kind or in proportion, a crude measure of gross output may be obtained by using monetary value as a common basis of measurement. The corresponding net output may be determined by deducting from the gross output the value of raw materials and services used. This is the form of measurement used for the National Census of Production. From it may be derived a measure of output in terms of pounds sterling per man-hour or per man-year. Insofar as added financial value may be regarded as a true measure of output, this form of measurement gives 'absolute' values, and permits comparisons between different industries at any one time. Since it takes no account of changes in the value of money, however, it cannot be used for the very important purpose of studying trends in effectiveness for any one industry, or for industry as a whole. This form of measurement can be greatly improved by the use of a price index, to correct for general changes in money values, as described in the following section.

5.3. *Measurements Using the Corrected Monetary Value of Output*

Where the purpose of measurement is to study change, and rates of change, in effectiveness of organizations or industries with complex and varying forms of output, monetary value can be used as a means of assessing the relative importance of products, provided the effect of price changes is eliminated. One convenient method of doing this, which has been used, is to reduce the total financial value of the output to a base year value, by using a price index for the group of products concerned. This gives a measure of the relative volume of gross output, even though the result is expressed in pounds sterling. The contributions of various products to the total are weighted in proportion to their base year values. The corresponding volume of net output may be derived by subtracting the value of the materials used, also corrected to base year prices by means of an appropriate cost index.*

The total 'volume' of output obtained in this way can be compared with the manpower employed, to give a measurement of productivity. For the purpose of showing trends, the result for any period can conveniently be expressed, relative to the base period, by an index number. This type of index is illustrated by an example in Appendix I.

When an index of productivity is calculated in this way, services externally supplied may conveniently be taken into account by treating them in the same way as raw materials. Moreover, a correction can also be made for the capital equipment employed. This allowance may be an important one, and it can be included, in an approximate way, by deducting the depreciation allowance on the plant and equipment from the corrected value of the net output.†

*Ideally, the value of each product should be reduced to a base year value, by taking account of individual price changes. In practice, however, this might be very difficult, and it is more convenient to correct the total value of the whole output. Price indices for this purpose may be determined in a variety of well-known ways, but an index prepared on a chain-base system has the advantage of simplifying the inclusion of new products.

† This method of allowing for capital equipment is convenient, but not strictly logical, in that an input factor is treated as negative output. A better method is to add an allowance of manpower in the denominator, in the manner described in Appendix II.

Where output is of a varied nature, or changing in its relative proportions, the method described above may be the best practicable means of obtaining an *overall* measure of effectiveness. It has the great advantage of simplicity, but under conditions of unstable prices, fixed rates of profits, protected markets, or shortage of supply, prices cannot be regarded as a reliable measure of relative value, and the contributions of various products to the total output may be seriously distorted.

5.4. *Production Costs*

It may well be asked why production costs cannot provide all the information necessary to study the effectiveness of industry. The broad answer is that the type of data at present collected for costing, and the normal mode of presentation, does not provide a reliable guide to the true effectiveness with which resources are being used in relation to the basic problem of raising the efficiency of the whole economy. Thus, two units producing the same product might show the same costs, although one employed twice as many men as the other, at half the wage rate, their capital costs being the same. From the national point of view, requiring economical use of manpower, and from the point of view of the men employed, there is no doubt which is the more effective unit, but this would not be shown directly by cost data. While a 2 to 1 ratio may be extreme for the conditions inside any one country, international comparisons between highly industrialized countries show that variations of this order do in fact exist.

Production costs are normally prepared with a view to assessing the profitability of any form of production under given conditions. They serve, indeed, a vital purpose, since profitability is a necessary condition for the continued existence of most organizations, and is highly desirable even in nationalized industries. Nevertheless, for the reasons already given, profits cannot be regarded as the sole criterion of effectiveness.

In our effort to improve the economic position of this country we should, therefore, study and, as far as possible, measure productivity directly, and should not depend upon cost data which is primarily collected and presented for a more limited purpose. This does not mean, of course, that when the nature and purpose of measurements of effectiveness are clearly recognized, systems of costing might not be devised to give the required information in the right form. It is merely a warning that most existing systems of costing need supplementing with additional data, and further analysis, before they can be an adequate guide to true effectiveness. A useful measurement would be, for example, the ratio—average hourly wage rate/cost per unit produced.

5.5. *Measurement of the Effectiveness of the Individual*

An important factor in the measurement of productivity, under any given physical conditions of plant and equipment, is the effective rate of working of the human beings employed. In fact, as already pointed out, this is the only factor suggested in some people's minds by the

word productivity. The technique of 'Work Study,'* which includes Method Study, Motion Study and Work Measurement, has been developed over a number of years. Work Measurement makes it possible to measure the work content of any job, the number of work units performed per hour, and the effectiveness with which labour is used. This approach appears to provide the only means of studying the influence of personal effort on overall effectiveness separately from the other factors involved.

6. A Suggested Approach to Comparative Measurement

Certain new methods of treatment are described in the following part of the paper. They are not put forward with the idea that they, or those mentioned in the previous section, are the only methods which might be used. Choice of method must depend upon circumstances, and even a relatively crude form of measurement, used with discretion, is better than none. The methods now to be discussed tend (in their full form) to be idealistic, but it is believed that difficulty in adopting them is more apparent than real, provided they are applied with understanding.

It has already been pointed out that overall measurement of effectiveness for a complex organization can do no more than give a general indication of whether the long term trend is satisfactory or not. Valuable as such information is, it is also desirable to have means of analysing and guiding the efforts of management to achieve improvement. Since such a drive will frequently take the form of many local and minor changes in the various sections of the organization, measurements of effectiveness must also be made in detail if they are to give rapid, sensitive, and reliable indications of the value of these changes.

We are thus led to consider the possibility of synthesizing the overall measurement from measurements for each of the departments or elementary operating units which make up the larger organization. The elementary units referred to will normally be the smallest sections which are definable, as separate components of the whole entity, for managerial purposes. Therefore, the problem is treated in two stages:—

Comparative Measurement of Effectiveness for the Elementary Operating Unit.

The Combination of Unit Indices to Give an Index of the Overall Effectiveness of an Organization.

6.1. *Comparative Measurement of Effectiveness for the Elementary Operating Unit*

Where the elementary unit produces substantially the same product, or carries out the same service function all the time, the measurement of the physical volume of output of the unit presents no difficulty. For the comprehensive measurement of effectiveness, however, we must take account of all input factors, and the obvious way of doing this is to

*It is impossible, within the scope of this paper, to give a detailed description of the well-known and important technique of 'Work Study.'

measure them all in terms of 'manpower equivalent.' The full measurement of effectiveness would then take the form :—

$$\frac{\text{Volume of output per annum}}{\text{divided by} \left\{ \begin{array}{l} \text{Average number of men employed} + \text{manpower equivalent of} \\ \text{capital equipment} + \text{manpower equivalent of services received} \\ + \text{manpower equivalent of changes in raw materials.} \end{array} \right\}}$$

Means of calculating the various correcting allowances, should they be considered necessary, are described in Appendix II.

If the output of any operating unit is of a complex nature, which cannot conveniently be sub-divided, the total volume of output may be determined through the medium of corrected financial value, as described in Section 5.3. In that case, it may be preferable to measure net output by deducting the corrected value of raw materials and services from the corrected gross value of output, since variations in raw materials may also be complex. In any case, there is much to be said for making the important correction for capital equipment by including its manpower equivalent in the denominator.

It may be objected that this means of measuring output is open to the same objections when applied to a unit as when applied to a large organization as a whole. This is largely true, but it will not generally be necessary to treat a very high proportion of units in this way. In most cases, a much more direct measure of physical volume of output will be found possible.

The inclusion of an allowance for the manpower equivalent of plant serves a very important purpose, even though no change in the plant may occur. It is a 'fixed charge,' irrespective of the volume of production, and its inclusion should therefore encourage intensive plant utilization and the development of plant which is highly productive in relation to its cost.

Measurements made in the manner suggested above would give a continuous record of changes in real effectiveness over long periods, even though considerable changes in plant, methods, and raw materials might occur.

For the purpose of controlling the day-to-day effectiveness of operation of the unit, it is sufficient to measure the units of output per man-hour, taking account of only the men actually employed.

6.2. *The Combination of Unit Indices to Give an Index of the Overall Effectiveness of an Organization*

The method of combining unit indices to obtain an index for the whole organization is illustrated by an example in Appendix II.

It is proposed that the indices for the constituent units of the organization should be weighted in proportion to the total manpower equivalent associated with the respective units. As will be seen, this method of combining unit indices is very simple, and requires the collection of no further data. It gives an index which shows changes in the average effectiveness with which total resources are being employed.

The advantages of calculating an index of production efficiency in this way are:—

- 6.2.1. Whereas an index of overall effectiveness for a large organization will show long term trends, *detailed* measurements of effectiveness are necessary for the study and control of efforts to achieve improvement. It is obviously desirable that the detailed measurements should be directly related to the overall measure, and only by synthesizing the latter from the former is this achieved.
- 6.2.2. By making measurements for elementary operating units, it should be possible to collect data relatively easily, since normal costing and labour control stages are likely to correspond with operating units.
- 6.2.3. The measurements of effectiveness for operating units will be of direct value to the management of those units, and will stimulate increased interest in effectiveness.
- 6.2.4. Many sections of the organization, particularly service or 'over-head' groups, whose manpower could only be included in an overall measure in an unidentifiable manner, can be treated as separate units subject to efficiency measurement. Thus, indices of relative effectiveness might well be determined for such sections as transport (in ton miles, or locomotive hours), routine testing (number of tests made), stores (requisitions handled), invoice section (number of documents dealt with), etc.

Only a relatively small proportion of the personnel of the organization, not identifiably associated with any measurable side of production, would not be included in the numerator of an index built up from measurements for the operating units. Such manpower can, however, be brought into the denominator, and will reflect its influence in this way.

7. Conclusions

The problem of measuring effectiveness, or productivity, in industry is complex, and no single method of treatment which can be applied in all cases appears to exist. Nevertheless, appropriate forms of measurement are desirable in order to assist in analysing the factors affecting efficient industrial production, to stimulate thought and action, and to show trends and rate of progress. Effectiveness is taken to mean 'the volume of output which is achieved in a given period in relation to the sum of the direct and indirect effort expended in its production.'

Three main types of measurement are generally desirable:—

- (i) A measure, or index on a time base, of the effectiveness of each identifiable section or department of the organization under consideration.
- (ii) A measure, or index, of the overall effectiveness of the whole undertaking. Preferably, this should be built up from the results obtained under (i).
- (iii) A measure of the effective effort of the personnel involved. This can be obtained by applying Work Measurement technique.

In order to arrive at a true measure of effectiveness as defined, it is necessary to make allowance, not only for the total number of personnel engaged in the unit under examination, but also for the 'invisible men' who serve the unit externally in the supply of the necessary capital equipment, raw materials, and other services. To what extent and in what detail such corrections should be made will depend on the circumstances peculiar to each case.

The main objective has been to indicate lines of approach with a view to clarifying the nature and purpose of the measurements which are required, rather than to explain in detail how such measurements may best be made. A clear perception of purpose, and an appreciation of the major factors involved, will indicate what measurements are appropriate, and how far these can be of an approximate and simplified nature in the first instance.

Cost data, as normally collected and presented, are not considered to provide a sufficient guide to effectiveness. On the other hand, it is possible that costing systems, supplemented by other forms of measurement and, in particular, by the measurement of individual effort, may be devised to provide a satisfactory guide in future. Appropriate methods of direct or comparative measurement should be the concern and interest of all branches of management, and, properly applied, should yield far-reaching results in achieving a more rapid rate of progress than has hitherto been obtained.

INTRODUCTION BY CHAIRMAN

SIR CHARLES RENOLD, J.P.

Ladies and gentlemen, I have first to apologize for the absence of Sir Ronald Weeks who was to have taken the chair. He has unfortunately been taken ill.

I understand that there is an idea abroad that only specially invited persons are given an opportunity to speak at these proceedings. That is not the case, we welcome contributions from the floor of the hall.

The subject of the discussion tonight is the 'Measurement of the Effectiveness of the Productive Unit'. This is a very timely topic. Comparisons of productivity are very much in the air and comparisons of all kinds are being made. Any attempt to give a definite meaning to such comparisons is of great importance. It is difficult to reduce this concept of productivity to any degree of clarity, and still more to measure it. We are grateful to Sir Ewart Smith for tackling this problem for us. He is a brave man, because it is a very controversial topic. I imagine that the techniques suggested will arouse considerable criticism—they are controversial.

Sir Ewart Smith is a Director of Imperial Chemical Industries Ltd. He is also an engineer. Therefore we can be sure that we have in him someone who combines the practical approach with the wide knowledge of business. I will ask Sir Ewart Smith to introduce his paper.

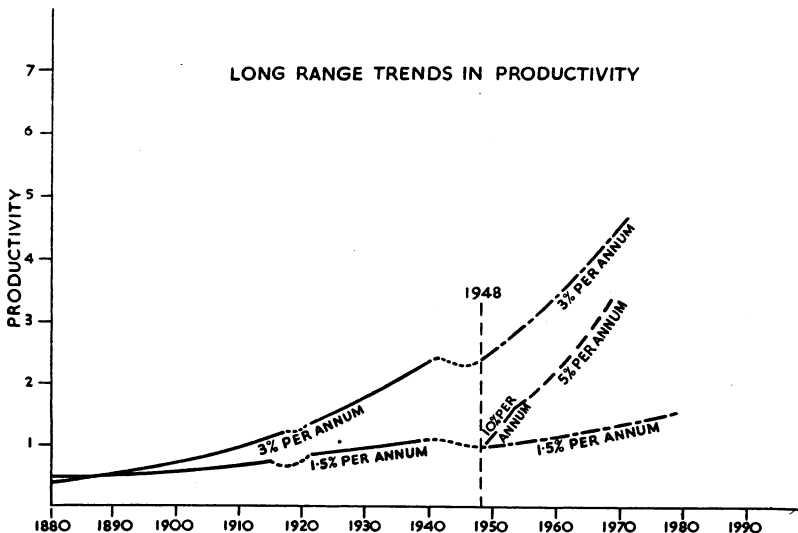
INTRODUCTION TO PAPER

SIR EWART SMITH

Mr. Chairman, ladies and gentlemen, I thank you for your remarks with regard to my courage, but certainly anybody undertaking this task needs, I think, a great deal of it, more, I feel than I in fact possess. However, my collaborator and I have ventured to put down some thoughts on this very difficult and thorny subject quite deliberately with the object of stimulating discussion and criticism.

The difficulties of obtaining any method of measurement which is universally applicable will be quite obvious to anybody who has thought about the problem. In fact I think there is not, nor can there be, any one method which can be selected as applicable in all cases. All we have therefore attempted to do is to survey as far as we could the background of the factors which come into this matter and to raise speculations and make suggestions which might at least in part be applicable in some cases. I am not going to attempt in the few minutes at my disposal now to go through the paper in detail, or even to take each of the heads of it. What I would like to do is to touch upon one or two points and underline some of the factors which I believe to be of importance.

We can all be agreed that it is important that we should have knowledge of what we are doing and where we are going. We have made the point that costing systems while they are indeed very necessary and extremely valuable as giving some lead on the efficiency and progress and movement of industrial businesses, do not in our opinion in their present form give all the data that is necessary, or at least desirable for full control of this very important matter of productivity, which we will use as a short term for effectiveness. We can agree, therefore, that data is necessary.



It is necessary to analyse where we stand, to work out the trends as shown by past results and from that analysis, if possible, to work out possible lines of action for improvement in the future. Having taken the action, it is equally necessary that we should be able to measure the results.

The particular point which I wish to stress is that there is no need, in this matter, to obtain absolute values. What is desirable is that we should be aware of change and rates of change. We have ventured to put on the screen a somewhat elementary looking diagram of two organizations, shall I call them, showing the productivity per man-year in the past and up to the present time for each of them. One, broadly speaking, shows an average annual rate of increase of 3 per cent per annum compound, while the other has a rate of increase of 1.5 per cent per annum. As a starting point, we take somewhere before the turn of the century when both are at about the same level of productivity. Continuing at those rates, with some upset due to the first war, and a rather bigger upset due to the second war, we arrive at the present time, 1949, where the top organization shows rather more than double the productivity of the other.

I wish to stress that a small difference of 1.5 per cent can, in 60 years or so, lead to this very big actual and absolute difference at the present time. We have then carried on those two curves and projected them into the future, assuming the same respective rates of increase. This shows that, whereas at present there is about a two to two and a quarter ratio between them, in 25 years or so, the disparity will have increased tremendously.

Also shown is a curve which indicates the result which would be obtained by the lower organization if for five years it went ahead at 10 per cent per annum, and thereafter at 5 per cent. It would still not catch up to the top organization in 25 years but it would then be a very different picture.

Those figures, based upon the best data available do represent approximately the United States and Great Britain. They can be criticized in detail with regard to the exact comparison, but there is the broad picture as we see it. That, of course, is a challenge. It illustrates very forcibly the desirability of knowing all the time, in what direction one is heading. We have all known for many years that industrial productivity in the United States is very much higher than in this country, but I do not think that it has penetrated our national consciousness that here is something which is fundamentally unaffected by wars, and is not of a temporary nature. In the paper, although perhaps not particularly within its terms of reference, we have listed what we believe are some of the more important factors that affect productivity or effectiveness. I will just briefly run over them. They are: the supply of raw materials; the type and nature of the basic processes; the quantity of plant and equipment; the technical efficiency of plant and equipment; the types and varieties of products, and the way in which labour is utilized.

Each of these factors is broken down successively to show upon what they in turn depend, how they can be split up, and in particular the influence of management.

The point I want to make in connection with this diagram is that, although we frequently say we are under many disadvantages compared with America, in fact it is really only in relation to raw materials, and to a less extent internal market, that the United States has an advantage. It is quite

true that she has three times the population, that is to say, three times the natural market. Her actual market is six times, but it is as a result of her own actions that has made it six times, instead of it really being proportional to the population ratio. On raw material she certainly has some advantages but not perhaps as much as would appear at first sight. For example, it is just as easy to bring iron ore here from South America as it is to take it to the appropriate North American port. In the case of factors other than raw material and population it is hard to show that we suffer from any natural disadvantage. I do not want to stress that any more. I certainly do not want to be defeatist about it, but far otherwise, I wish to be encouraging because, if in fact, the difference between us is largely under our own control, we can indeed do something about it. It is when your difficulties are caused by something which is not under your control that you have a right to feel despondent. Methods of improvement, of course, logically flow from such an analysis. I believe that a careful attack on productivity, from every angle, and its measurement, would lead if we so willed it, to results, not perhaps so continuous or striking as the middle curve, but certainly something far better than the lower curve on the diagram. I have no doubt whatever that they could, and I believe will, lead to something better than the $2\frac{1}{2}$ per cent or so rate of increase which has been suggested to us for the next four years.

We have tried to set out four different lines of attack on this problem. We have in the appendices given certain suggestions which in the ordinary course of business in the ordinary undertaking I am quite sure many of you will say are highly theoretical and under working conditions extremely difficult if not impossible to carry out. Of course they are, but nevertheless I believe it is fundamentally important that we should analyse all these factors. We should have regard, for instance, to what we have called the invisible men who stand behind the personnel in any manufacturing unit.

I will quote a simple illustration of what I mean. In many industries now it is not abnormal for the capitalization required per individual of the organization to be something between £4,000 and £6,000 per worker. I am talking about new factories built at present-day prices. There are cases, of course, where it is very much less. Equally there are cases where it is very much more. Let us take a figure of £5,000 per employee. Let us further assume that the life of that equipment would be twelve years. In a rapidly changing and progressive technical world, in many cases that is not an unreasonable short time to take. On those figures of twelve years and £5,000, if you are going to write off that plant, as you must in time, and assume you do it by equal instalments, that is a charge of roughly £400 per annum. That means that the worker in the industry with that £5,000 piece of equipment and services standing at his elbow, if he is just working on days, has an invisible man who is getting just about the same average wage or salary that he himself is getting. That invisible man has to be housed, clothed and fed and his children have to be educated, as is the case with the direct worker. I do not want to over-stress this point, but to me certainly that sort of illustration does bring home the importance of watching the overall picture.

It is pertinent also to notice that if that plant and equipment could be used continuously on three shifts, each of the direct workers who would then only have to support one-third of an invisible man getting the same wage salary

level. I mention that by way of drawing attention to the supreme need to make full use of the capital equipment we have, particularly the best and newest.

For the measurement of productivity to be of the greatest possible use, it is not sufficient just to have overall national pictures or overall industry pictures or overall company pictures. In my opinion it is very necessary to carry the measurement down to the actual working units, or as we call them in the paper, the elementary units of the industry. What we recommend in the summary is that there should be careful attention to the measurement of productivity in the elementary units; that there should be a method of combining those results for the bigger aggregation of the works or the company, if the company consists of many works. From that, of course, it would be desirable to go to the industry and then, as we are beginning to do, to go from the industry to the country.

In dealing with the elementary units of the organization, I have referred so far to the overall productivity results which you obtain from the efforts of the management, the men, the external supply of services, and so on, but equally it is desirable that we should have a measure of the individual efforts of the employees. I use 'employees' and not just 'workmen' because I include staff just as much as anyone else. As far as I can see the only possible real approach to the measurement of the individual's efforts, which has any basis, is through the technique of Work Study and Work Measurement, or something on those lines. We have not enlarged upon that in the paper simply because paper and time would not permit, but I would not like it to be thought that we wish to put forward what may appear to be rather elaborate theoretical methods of approach and neglect the rather simpler, more direct, and very important approach which we have under our hand, and which, of course, is already being used to an increasing extent.

The Chairman said we should meet criticism. I am quite sure we will. We are quite prepared to receive hard buffets, but hope that some of the suggestions thrown out may be of interest, that we shall attack this problem in such a way that we get to know the facts, that we analyse the possible means of improvement and measure the results of our actions.

If we do this, I am sure that in a very few years that curve will present a very different picture.

DISCUSSION

MR. A. W. WILLSMORE, *Consultant* : Our speaker today is to be congratulated on the improvements that he has made in the familiar per man-hour measure of output. If adjustments of this type are made, the international comparisons which are drawn, and so disconcertingly drawn, between this country and America might be found to be not so disconcerting after all. But I do not think that the curve of productivity that the speaker has shown us will be lifted merely by international comparison. I feel that if that curve is to be lifted, it will be lifted only by the individual efforts of the business man. I have a very strong feeling that measures of effectiveness of the type covered in the paper are not the measures which the business man can use towards achieving this object.

I know there are many business men who are quite obsessed with this idea of an omnibus index of efficiency—an index which will wrap up all the facts in one nice neat figure. Frankly, I do not see what they are going to do with this package if they get it. The effectiveness of a unit is far too complex an idea to button up in one neat figure—it is a complex which has to be studied in detail. I agree with the speaker that we are not after an absolute measure of efficiency. Neither are we after a measure of present efficiency compared with past efficiency: there is all the difference in the world between a 10 per cent improvement on what was previously a fairly good result, and a 10 per cent improvement on something which frankly was deplorably bad. What we do need in business is a measure of the efficiency of every individual factor in the business compared with how good it could be, not with how good it happened to be in the past. There is, in fact, a business technique which was developed particularly for this purpose and I am very surprised that our speaker has not mentioned it—I refer, of course, to standard costing. I know that standard costing is abused, but when standard costing is used properly, and when we set our standards properly, we have just the sort of thing for which we are asking, particularly so far as labour utilization and material utilization is concerned. If in our individual businesses we coupled standard costings with flexible budgets to cover the expense element, then we have got a tool we can really use to take our relative efficiencies to pieces and see where we ought to achieve improvement.

The speaker rightly emphasizes that profits cannot be regarded as the sole criterion of efficiency. He is undoubtedly right, but I cannot help feeling that they somehow do come into the picture. Industrial effectiveness is something more than just increased productivity—it means producing values in excess of costs. If this is done it will be difficult to avoid making profits. But, we have to face up to the fact that an individual firm may be inefficient on this type of measurement of productivity, but nevertheless very efficient if it is able to produce the right combination of service, material and labour which will command (because they are the right combination), a high premium on the market. That is the lesson we should have in mind. In fact, we shall not lift our efficiency until we realize that, as well as increasing output per man, we have got to be able to sell the output before we can get anything out of it.

MR. KENNETH MARSHALL, *Joint Iron Council*: I am very tempted to join issue with the last speaker, but prefer to leave that until I have spoken to by brief. I would like to say that I consider this paper is quite the best contribution we have had on this subject. My own organization has been studying this question for very nearly a year, and have been using for our own guidance a formula very much on the lines outlined in this paper. We have been very shy about saying anything about this, because it is obvious that the first reaction of anyone to a formula of this kind is: 'How is it going to apply to me? What use is going to be made of it? Is it going to be a sort of University tripos examination, and will those who do not get at least third passes be sent down?' We are rather using it as a basis for a test to see how an individual is getting on and see how he is compared with his competitors. Very interesting results occur in a practical way. It has stimulated people to visit one another's foundries and see what is the difference in productivity level between this and that process. It is on that basis that we are using it, not as an arbitrary measure of suitability or a right to go on producing, but rather as an encouragement to improvement of efficiency.

I will deal in detail with some of the points which arise out of this calculation, first of all with the question of the measurement of the capital employed. A great deal there seems to me to depend on when you value your plant and at what date. Are you to take present-day replacement values? To give a concrete example, what sort of valuation of plant are you to give to a foundry which is about 80 years old? Are you to say: 'We are going to charge for capital and manpower as if the foundry had been built at present-day costs?'

Then there is the question of life. If you take a scale of five years, writing your plant off on that basis, you will obviously expect more from your plant than if you put it on a scale of twelve or twenty years. The point arising out of Sir Ewart Smith's introductory remarks is that it is quite obvious from his indication of the silent and invisible man who has got to be fed and supported, that it is also true to say that the earnings of the visible man and the invisible man should be approximately the same. If the invisible man is earning more than the visible man, then the ratio of workers to capital requires increasing or *vice versa*. Therefore an interesting point is whether the manpower equivalent of your plant is equivalent to your existing manpower. We have used that method to encourage some lofty schemes of mechanization which might otherwise be impossible.

Then there is the question of the estimation of capital. Are we to include as part of the capital equipment things which are really non-productive. A great problem at the present time is working conditions in foundries, but a great deal has been spent in improvement of amenities and the provision of washing facilities, and so on. If that extra capital equipment has also to earn its dividend, then we are going to make it more difficult to improve conditions. Therefore, are we to set aside for those amenities and not bring them into a calculation, or are we to include them on the assumption that they will result in an immediate improvement in working. If additional capital equipment is to be introduced, it has to be pointed out to the worker that because more invisible men are there it does not mean he can take life more easily.

In the paper it is suggested that we should measure the efficiency of the unit assuming it operates under equally favourable conditions to any other unit; in other words, we are going to ignore the external economies and assume, when comparing unit A with unit B, that unit A and unit B were equally favourably placed for access to raw material and transportation and the various other considerations. We have to make up our minds whether we are considering relative efficiency of units in their own environment or in a comparable environment. It is impossible to compare the output of one foundry with another by tonnage unless the foundries are almost exactly similarly situated.

A difficulty does arise which is brought out by a simple illustration. Let us compare the efficiency of two units, one of which is producing iron castings and the other producing fountain pens. In the case of the iron castings, if you include all the working personnel, you will not be very far out. But in the case of the fountain pen, the working personnel is only a very small part of the cost. Unless you include the cost of selling you leave out a lot of costs which should be taken into consideration. If you include the cost of selling you have to include manpower and your market organization. Some firms' products fetch a high price because in their product is embodied a good deal of sales service or quality or inspection. Therefore you should include all your inspectors and that sort of service. You cannot entirely divorce quality from service.

Then there is the difficulty of comparison when you have one part to compare with another, where one part is more efficient than another, because perhaps it is actually paying higher wages, or because it is using more expensive equipment or a particular raw material. Therefore it is very important to have the net profit and to deduct the cost of the raw material, otherwise you may get an unfavourable comparison. But it still does leave for solution the problem that one unit may be more efficient than another because it is paying higher wages. Therefore you must bring in the cost factor as a corrective there.

I come back to where I started, by saying that I think this paper is extremely valuable in indicating a method of attack, but I think methods in this field should be improved.

MR. D. J. LISTON, *The Metal Box Company Ltd.*: I speak with a certain amount of embarrassment. My Company has already joined issue in the general and economic Press with various statistics on productivity which sought to compare the figures of this country with those of other countries. We have disputed the validity of those figures, at least as applied to our own products. Now I propose to raise some queries on this paper, and my embarrassment is brought about by the fact that we in our own Company have not yet found a final answer to measuring our own productivity. I wish primarily to raise the difficulties as we see them from the point of view of a group seeking to measure the productivity of a largish number of widely separated production units; aiming to calculate a global figure for our company as a whole; to measure that figure against the productivity of the industry of which we form a part and finally, to compare our own industry with industries in other countries.

I disagree with the authors in the application of their particular form of measuring productivity to a *productive* unit. I feel that as a measure of efficiency of perhaps a commercial enterprise, or of industrial activities as a

whole, when you are dealing with really large figures it is worthy of consideration, but as a measurement of efficiency of production, particularly of efficiency of the management in your operating unit, it fails to take into account quite a large number of factors which one must take into account if one is to do the subject justice. It tends to lay too much stress on certain factors which, however important, are by no means of such over-riding importance as to justify exclusive attention to them.

I do not agree that everything should be related to the efficiency with which you use your manpower. The object of industry may not be to employ as much labour as possible, but it is not necessarily its object to employ as little as possible. What one has to measure in any form of concern which necessarily has to adjust itself to varying conditions of markets, varying types of product, and varying degrees of mechanization is this: how far have the individual units used their manpower in relation to all their other resources to the best possible advantage. You will not get this by expressing your conclusions exclusively in terms of manpower or manhour efficiency. You must, for instance, take into account the relation between your manual and your mechanized processes, which in turn is tied up with your general overhead structure, insofar as part of the efficiency of your company depends on how far you are flexible in the long-term to change from short to long production runs, and various other factors of this sort.

Secondly, I do not think the paper pays sufficient attention to distinguishing controllable from non-controllable factors so far as they affect the management or a manager of a productive unit. By non-controllable factors I mean all those corrections which are introduced into the figure to cover your services, the purchase price of your materials, machinery, and so on. In other words, all those 'invisible' men. The point I wish to emphasize is that your invisible men from the point of view of the manager of your productive unit, are also uncontrollable men. It is really not good enough, particularly in an organization which indulges in central buying or anything like that, to measure your productive efficiency in relation to a large number of factors which are beyond the manager's immediate control.

That again brings me to judging your output on selling values. It is not easy to compare everything in terms of unit volume of output. On the other hand, if by taking any other criterion you are going to mask what is a very real failing, I feel that you may have to limit the expression of the productivity figures to such less ambitious fields as your statistics may permit. In other words, just because you have only a limited range where you can compare the efficiency of your output in terms of volume of production as opposed to selling values, I think you may have to limit yourself in that way and not to change your criterion to selling values, particularly in conditions where your selling price policy and your commercial policy generally may not be determined by the management of your individual productive unit.

I think the paper was a little cavalier in its treatment of the statistics available from a normal costing system, whether that system is standard costing or whatever system operates. Statistics of efficiency seldom arise automatically out of the costing material presented by the accountants; but I submit there are few of the necessary statistics which cannot be devolved from your basic material if you allow your production executives and your other

executives concerned with the policy of the unit to have full access to those figures and to collate and readjust them in a way which will focus on productive efficiency.

My final point is on international comparability. It is rather unfortunate that because we have to purchase our machinery, say, from the United States or from somewhere which makes our machinery more expensive, because, say, we have to buy the machine in Birmingham rather than in London, or because the scarcity value of our machine is such that it sends up the price to a very large extent, that our production is to be considered less efficient. That is the effect of introducing the various adjusting factors of the cost of your material, machines, etc. It does, in fact, mean that the more expensive your machinery, the less efficient your figures will show your particular industry could be. That is perhaps not so important from a national point of view, but when we are told that arising out of that sort of comparison British industry is three, six, eight or ten times less efficient than its opposite number, in other countries in the world, I think this is just a little bit dangerous and a practice which ought not to be encouraged.

THE CHAIRMAN: This seems to be a convenient moment at which to answer the questions raised by the three speakers. When introducing the paper, I omitted to mention Dr. Beeching, who collaborated with Sir Ewart Smith in the production of the paper. I hope he will forgive the omission and accept our thanks for the part he has played. I will now ask Dr. Beeching to deal with the points which have been raised.

DR. BEECHING: Mr. Chairman, I will try to deal with the major points which have been raised, although there are so many that I shall not be able to cover them all. I should like to emphasize first of all that these measurements are intended to be comparative and, generally, comparative for one organization. Therefore, in many cases the references to the peculiarities of any particular organization are not nearly so important as they would seem, because they are peculiarities which persist in time. What you want to know is how you are performing now, under the general conditions that affect you as an organization; as compared with your performance in the past. Are you moving in the right direction under the conditions which do inevitably affect you? The fact that the measurements generally speaking are intended to be comparative for one organization does eliminate some of the difficulties. That is not to say that some difficulties do not remain.

The last speaker criticized the use of selling price. I would point out that sales value is only used as an intermediate stage in arriving at a measurement of *volume* of output. The total financial value of the output is corrected for the change in selling price as a means of getting a measure of relative volume of production. It is not a perfect method. It does, in fact, have the effect of weighting the contribution of various component parts of the total production in proportion to their value in the base year. It is not perfect for that reason, but it is a method of getting a relative measure of volume which eliminates as far as possible changes in selling price.

Mr. Willsmore suggested that these international comparisons might be improved if we took into account some of the allowances which have been suggested in the paper. Then the last speaker contended that the failure

to take them into account was, in fact, distorting the picture unfavourably to us. In effect, when you consider the overall performance of the nation you do tend to take account of the fact that it consumes its own capital equipment, so that you can treat a nation to a very large extent as a self-contained unit. It produces the capital equipment which it uses, so that if you measure its overall output and relate it to the number of men employed within the nation, you do get a measure of productivity for this very mixed bag of products, which you can compare with the very mixed bag of products that another nation produces, provided you assume that the variety of products produced by the nations—I agree it is an assumption—are roughly speaking the same. Therefore, this problem of allowing for production of capital equipment and provision of services is not involved to anything like the same degree in international comparisons.

Mr. Willmore also suggested that it would be far better if the effectiveness with which you operate in all respects could be compared with the limit of possibility. I agree, but we do not know the limit, and that is a difficulty in making any such comparison. Therefore, it is useful to see if you are improving on what you did before, and to a lesser degree to see how you compare with other people operating under similar but not identical circumstances.

He then went on to suggest that the method of standard costing does in fact do this. I just cannot agree. Any method of standard costing must be based on the methods which you use or the methods which you visualize using; but there is no guarantee, and in fact no probability, that the methods you use or the methods which you visualize using approach the ultimate ideal. Therefore, standard costing does not make any comparison between your performance and the limit of performance possible now or in the future.

The point was made—it is a very real and important point—that a factor affecting the efficiency with which a business is run is the wisdom used in deciding what to produce. This method does not pretend to take that into account; but, once you have decided what to produce, you are still concerned to produce it as efficiently and effectively as possible. That is what we aim to measure. We do not take account of the overall wisdom of management in deciding what to produce this year and next, and how to vary their product to catch the market. But once you have decided what to produce, you do want to produce it as efficiently as possible. Another point which was mentioned, and again an interesting one, was that there is a suggestion in the paper that you want to use as few people as possible. There is no such suggestion in the paper. The suggestion is, that you want to use the overall resources as effectively as possible; but that does not mean to say that you want to use the least possible number of employees within your own unit. If you have got very heavy capital commitments and a good deal of capital tied up in your plant, then you may want to increase the number of men you actually employ to get the highest overall effectiveness. The result of including an allowance for plant and equipment in your measure of productivity is to bring that out very, very clearly. In contradiction of the speaker's remark, the paper does not say that you want to use as few men as possible under all circumstances. It says very clearly that under many circumstances it will pay you to use more men. Reference has been made to the fact that measurement takes

into account a lot of factors beyond local management control. It may be that some of the factors which are mentioned are outside the control of the particular local management of some unit. In that case, in judging its efficiency, I would agree that you should not blame them for anything which results from those factors and not taking them into account in your measurements at all. You can only see what their performance has achieved and free them from blame for things beyond their control, by taking cognizance of all those factors to see how they do affect matters.

Mr. Liston said that he felt that costing, although it did not automatically tell you all you wanted to know about effectiveness, could give you all the information required if the cost figures were adequately analysed. I think that is so, but the contention is made in the paper that the cost data, as normally presented does not give the information that management wants. I venture to suggest that a good many people do not analyse their cost data to derive the information which they need in this particular connection. I think that systems of presenting cost data could be devised which would give very much clearer indications. I would further suggest that, if they are to do that, they must take account of the factors which have been mentioned in the paper.

I perhaps have not covered all the points, but I hope I have dealt sufficiently with some of them.

MR. KENNETH FORECAST, *de Zoete & Gorton*: I should like to begin by apologizing for taking up your valuable time. I actually handed in my card before realizing that it should have been marked 'Question', but now I am committed to saying a few words.

The method of measuring productivity by using manpower in the denominator rests on the supposition that there is such a thing as a standard unit of manpower, which is a scientific measurement and capable of comparison, whereas, as we all know, an hour of one man's labour, for instance, specialist labour, is worth far more than that of a labourer. An hour of labour of a man paid £15 a week is worth more than that of a man who is paid £10 or £5 a week. I thought perhaps this could be overcome by a quite simple technique of dividing output, whether it is in terms of units produced or value of units produced, not by the number of men employed, but by the wage bill incurred in employing them, so that the firm employing five men at £10 a week would divide by the same figure as a firm employing one specialist at £50 a week. This is a suggestion for overcoming that little difficulty, which has been mentioned by other speakers.

I was extremely interested in the measures of productivity which take value into account, and not physical units. You may be producing efficiently something which is not wanted, and that seems to me a bigger waste of manpower than producing less efficiently something which is wanted. I rather favour a method which uses money values in the numerator and based on selling prices. Now if you take net selling values, after deducting cost of material and charging capital depreciation, for your numerator and divide by the wages bill (instead of the manpower) the units in the denominator and numerator are both monetary units which cancel each other out, so that the quotient is to some extent independent of changes in the value of money. Also, whatever the unit of national currency in

which you are measuring, be it dollars, francs or pounds, this is also cancelled out. This may be of use in carrying out historical and international comparisons.

A number of you must be completing a voluminous census of production form for the Board of Trade. It would seem that by making a note of the figures before sending in the return you would be doing yourself a very good turn and getting a measure of productivity quite cheaply. This form has been designed to give you the net selling value of your output. There are elaborate instructions given by capable statisticians of the Board of Trade as to how to deduct various items from your selling values and how to take into account changes in stock and work in progress. When you have got this figure of net value, you then divide by your total wages bill. You will then be in a position to compare the figures for the industry as a whole when eventually the Board of Trade publish those figures. Unfortunately, I do not think that the Board of Trade are at present employing this idea of using the wages bill in the denominator instead of numbers employed, but presumably that could be effected quite quickly, and I think it would give a rather useful measure to manufacturers and would in some respects compensate them for the trouble they are taking in filling in this extremely detailed report. It might, in fact, increase the productivity of statisticians engaged on the census of production if this were adopted.

MR. G. VIVIAN DAVIES, *Consulting Engineer*: I have found this an ingenious and most interesting paper. The chart included is a fascinating one. During the war I was at the Ministry of Fuel in charge of the Industrial Fuel Economy Campaign. There we tried to assess efficiency on the basis of the utilization of fuel as compared with output. In view of that experience this paper is particularly interesting to me. I remember one industry told me it was absolutely impossible for them to save fuel because they were so efficient. When the figures came out, the worst firm, producing a well-known liquid, consumed 150 lbs. of fuel per barrel, whilst the most efficient firm consumed 30 lbs. of fuel per barrel. We applied a lot of factors, because there were obviously many differences in methods of production, but even after a generous allowance for various factors we found that the difference was between about 35 and 120, which took a good deal of explaining.

I should like to join issue with Sir Ewart Smith right at the very start of the paper on page 3. I had the temerity to challenge Professor Harold Laski at a Labour Party meeting to give me one example of a successful nationalized industry in any part of the world. (I apologize for bringing politics into this.) He answered very cleverly by saying: it depends on what you mean by success. On the second occasion when I thrust my neck out, this time by asking a Minister of His Majesty's Government the same thing, I tried to define success by saying that I thought a successful industry was one which provided the best possible working conditions for the persons employed in it, manufactured the product concerned at the lowest possible price, and paid the highest possible return on the capital invested I would suggest that this question of providing the best possible working conditions is a vital one. I know that in Sir Ewart Smith's firm a great deal of attention is paid to this aspect, and I am not implying any criticism there. The only answer I think to State control is to make the workers in an industry feel part of the team, whether you do it by co-partnership or any other method, and then they won't want State control.

I would like to ask Sir Ewart whether he does not think that the price factor should also be introduced into the figure for depreciation shown in Appendix I. The figure for depreciation in each case is £340,000. After all, conditions are changing year by year, so should not depreciation also vary? If you had a fire and had to replace the whole of your plant, it might cost you more or less to replace depending on whether the price had gone up or down.

On the question of output over the numbers employed in the industry, and a previous speaker has also raised this point, I am not sure that it can be universally applied. The tendency now is towards large continuous units, particularly in such industries as Sir Ewart is connected with, where the capital involved may be over half a million, but the operating personnel may be very small indeed. How can you increase the productivity of such a plant? If you speed up the process, you may upset the quality of your product or run up against safety regulations; you may increase the accident rate. What I think is more important is to prevent a breakdown or stoppage, because any breakdown or stoppage in such a plant would completely outweigh anything you might do by way of reducing personnel or cutting costs in other directions.

What I would suggest—I put it forward with all deference—is that a plant of this sort should be looked at very carefully to find the weak links; it should be split up into component parts. Then you could duplicate the parts which may be liable to breakdown. If you did this you would be reasonably safe from failures, and if a failure of one part did occur it would not then entail a complete stoppage of the whole plant. You might by so doing involve yourself in quite an appreciable capital expenditure. How do you compare two plants, one where you had done this so that you were reasonably sure in the event of a breakdown that you would not be holding up production, and another plant where this had not been done? How does Sir Ewart's calculations take into consideration this particular aspect?

My last point has reference to this chart again on the question of efficiency of management. I am told on very good authority that the efficiency of the staff sections of large companies is by no means what it should be and that sometimes it takes over six months from the time an applicant has put in for a position to the time when he is told whether he is wanted or not. I suggest that there must be something wrong there, apart from the bad effect on the man concerned. If a firm really does want somebody surely it does not take them six months or longer to decide this.

DR. ROSTAS, *Statistics Division, Board of Trade*: Mr. Chairman, I wish first of all to congratulate the authors of this brilliant paper, which is an important step towards productivity measurement in this country. It is perhaps the first time that such an important principle—that progress in productivity depends very largely on effective measurement and subsequent analysis of the results—has been pronounced from the managerial side and so effectively elaborated.

I wish also to call attention to the discussion of the problem in the paper why production costs cannot provide all the information necessary to study the effectiveness of industry, a point which is often put to those engaged in productivity research. As the authors rightly point out the type of data

at present collected for costing, and the normal mode of presentation, does not provide a reliable guide to the true effectiveness with which resources are being used in relation to the basic problem of raising the efficiency of a whole economy. I think that the emphasis is on the utilization of real resources. My comments on the actual methods of measurement proposed in this paper are connected with this basic principle.

The paper rightly suggests that the two fundamental technical issues are how to measure output for this purpose, and how also to measure input. History and experience indicate that increases in productivity over time are relatively very small, 2 to 3 per cent per annum for manufacturing industry as a whole, though with variations from industry to industry. We must look consequently for some very sensitive way of measuring output. For this reason as well as because we are concerned with the utilization of real resources I am in favour, as far as possible, of measuring output in physical units. This involves a great many difficulties. One has to take into account changes in the quality of the product, and in the scope of the processes used by the firms, i.e., whether they buy more goods and services outside or not, and so on.

In a sense measuring changes in output by the value of net output corrected for price changes overcomes a great many difficulties. It allows for quality changes in so far as they are reflected in prices; it allows for differences in the process covered, as the cost of bought materials and services is deducted from the total sales value. It allows even for differences in the quality of workers. Moreover, when applied by an individual firm, there is perhaps little difficulty in obtaining reliable price data. There are, however, shortcomings in this method. Changes in net output will, apart from variations in labour content, also reflect changes in its other constituent elements such as overheads, depreciation, selling and advertising costs and net profit margins, none of which is closely related to managerial effectiveness as defined by the authors. In cases where the same sort of articles are produced and it is reasonable to presume that buyers are sufficiently well informed to ensure that prices are kept fairly well in line, i.e., in a competitive market net output per head is a fairly good rough measure of productivity between plants or firms or—after adjusting for price charges—for charges over time. When it comes to industries or multi-product firms with widely differing products, the variations in net output per worker for each product are so substantial that aggregating the output of these products by net output weights might be a misleading guide for measuring charges. The reports of the Censuses of Production indicate the wide variations in net output per worker from industry to industry, and there is plenty of warning against using such figures in comparing the efficiency of various industries in absolute terms. I do not wish to suggest, of course, that the authors are in favour of such a comparison, I only wish to bring home the limitations of the net output method. I would like to suggest that whenever the method as suggested in Appendix I of the paper is used, an attempt might be made to use instead of net output weights labour content weights. The relative labour content of the various products A to D may not be available continuously, but for a short period, taking a sample of firms or of plants it may be possible to ascertain them, and in many ways this would be a more reliable way of weighting output for productivity purposes than by the relative net output.

The other problem which is raised in this paper is the way of measuring input. I entirely agree that other elements of input than labour directly employed should be taken into account, but I am not certain whether I actually agree with the method which is suggested. In many ways it might be more advisable to take account of the other elements of input, especially of capital as an explanation of differences rather than by incorporating the manhour equivalents into the index. But should the latter course be followed, in measuring the manpower equivalent of capital equipment it will be necessary to differentiate between the viewpoint of the individual firm and that of the nation. In the latter case, changes in the efficiency in the machine-making industries will also have to be considered.

From the point of view of the individual firm the formula suggested for the comparative measurement of effectiveness for the elementary operating unit (p. 10) can be perhaps somewhat simplified. In so far as changes over time and not performances of plants producing the same sort of product are compared I would suggest that it is not necessary to take the manpower equivalent of services received. It would be sufficient to take, just as in the case of raw materials, manpower equivalent of *changes* in services rendered, e.g., if in one period the firm is generating its own electricity, while in the second period buys it from the grid, an allowance will have to be made for this change. In so far as the manpower equivalent of capital equipment is concerned, the authors suggest dividing the equivalent annual cost of equipment by the national average annual income for industrial employees of all kinds. Instead, I suggest it would be better for the firm to take the firm's own average annual income per all employees. This is easier to compute, because for lack of reliable data on salaries, the national average is not readily available. It is also more logical. From the point of view of the firm the choice is really whether to spend say, an additional £300,000 on capital costs in any one year or employ x number of additional employees, x being equal to the £300,000 divided by the average emolument of employees in their own firm.

But even from the point of view of the individual firm, this allowance for capital equipment may not be entirely satisfactory. I can imagine the case of a firm which for ten years does not add anything to its capital equipment while the average wage per employee will have changed. Then, although there is no change in the actual capital equipment employed, there would be a change in the actual manpower figures on account of capital employed and there would be an unwarranted adjustment in the productivity figures. These are problems which no doubt require much more thought.

From the national point of view, when allowing for labour incorporated in capital equipment, as I mentioned, changes in the efficiency in making capital equipment will have to be taken into account. This can be well illustrated by the way in which this factor works out in international comparisons. I do not wish to go into details of international comparisons on this occasion. But insofar as differences in capital equipment are concerned, I would like to say that I entirely agree with the suggestion of Dr. Beeching. What matters from the national point of view is what proportion of the national resources are utilized to produce the capital equipment which the nation's industry is using. So that if one compares the capital equipment used say in British and American industry, what matters is the relative

proportion of the American industrial population producing capital goods and finished goods for the consumer respectively as compared with the relative proportions in the industrial population of this country.

SIR EWART SMITH: Mr. Forecast, I think, suggested that we should take the ratio of sales value to manpower cost, and that thereby you would cut out the variation in the value of money. You would do that, but you would tend to entirely miss the point of the ratios we are trying to get at. For instance, you could have the case where costs were the same and wages double, as you have between this country and America, and you would then entirely miss the point. There is, of course, a standard unit of manpower in the work unit, which comes from the Work Study technique to which I referred before. For dealing with the employment and results of individual effort, that is quite invaluable.

Mr. Davies referred to working conditions. Of course, they are important. All I can say is that such factors are surely summed up by the sort of things which we put on our chart (See Figure 1). They condition the attitude of labour and the efficiency with which it works. It includes such things as light, ventilation, and so on, which unquestionably are important.

Mr. Davies suggested that in the allowance for capital we should bring in a price factor. I am not going to attempt to deal with that in detail today. I refer you to today's issue of the *Times* for some aspects of that subject. I do want to stress in this connection—it applies to many other things in this paper—that we are not attempting to lay down rigid rules for every case. It is up to each particular industry or particular firm to say how it can best measure its relative volume of output and how it shall make allowance for capital equipment employed.

I do particularly want to stress my own personal view that when you are dealing with these small units—that is where you start with your basic efficiency or inefficiency—if you can go for physical volume, something which people can see and understand, that is highly beneficial, and very often you can do that. I have suggested, for instance, in the paper, that you can take out an effectiveness index for the transport system of your works by taking your locomotive hours or your ton miles of goods handled relative to labour. You can take out an index for the stores department by taking the number of requisitions handled. By all means, when you can do it, go to the physical thing. But when you come to large things, you may not be able to do it. Hence we have suggested in the paper a method of taking the output from the component parts of the unit and combining them in a very direct way in order to give an index for the whole organization.

I will not attempt to deal with the very interesting points which Dr. Rostas made, but I should think that what I have just said about physical volume and the corrected cost volume is pertinent in connection with his remarks. I would like to study his remarks carefully before answering them in detail. Anything he says is well worthy of our most careful attention.

MR. R. DOLMAN BIBBY, *Harris Lebus Limited*: I have done a lot of reading on this subject. It is still fairly much of a mystery to me whether there is an absolute answer. I have enjoyed some of the points made in the discussion. I wish perhaps the discussion had been a little broader, but I am left with the feeling that one of the big problems

which we have and seems to be nearly always missed in dealing with a subject of this kind that, the significance of these indices is not properly appreciated. There is an awful danger in providing boards of directors or general managers with any kind of convenient index which they can talk about glibly, generally without really understanding themselves what it means. There is the danger that, instead of adding to the effectiveness of the unit, they get a lot of people chasing round on some abstruse generalization not really followed and which they cannot break down and explain its import to the people who have, in the ultimate, to do something about this efficiency. My own belief is that, if you have a very highly trained and objective board of higher management, this kind of index is very useful; but, if you have not (few boards and general managers believe that they are the ones open to criticism on these grounds) frankly I think you are better off without it. If you talk in terms which are going to indicate whether you can pay the wages next Friday as easily as you paid them last Friday or whether you are going to sell your product for ninepence when Joe Doings down the road sells it for sevenpence, then you are going to break down your ideas so that they are understandable. If you break down your figures so that all can understand them from the point of view of your combine or so that you can use them in departments, then you will get somewhere.

The other point is that it is better to criticize people in a stimulating way for their low efficiency, providing you measure their efficiency in things which are within their control. I think that top management men do not realize sufficiently the impact on lower executives of changes in policy, vacillations, failure to make policy and that sort of thing, things which can be felt all down the line all down the index: such things as when you get rid of one buyer and hire another with a new lot of contacts and you try out different lubricating oils or glues.

There is one other point I would like to make which is perhaps right off the subject of the paper and not really relevant to this discussion, but which I feel should be made. I feel that these meetings—I have been to all of them and have enjoyed them—are all at one level. In general I have the impression that the papers are written at a level and the discussion in the past has been directed to a level which concerns the big battalions, and are not sufficiently dealing with the very important and marginal section of our productivity, the small factories. The presentation of the papers is often in such a form that a man who is running his own business and perhaps has not had time to read it or to get somebody else to read it for him, does not get sufficient introductory background to the subject. One takes a little too much as read. I think we should try and make sure that some aspects of the subject are directed towards giving some guidance to the small manufacturer. We should reserve part of the available time for some comment from representatives of small concerns. We will never be able to help them with just papers and learned dissertations. I do put that up for the consideration of the Institute when arranging these matters in the future.

DR. BEECHING: I would like to comment on the remarks of the last speaker. I think the point he made about overall measurement, unsupported by detailed measurement is a very important one. A board of directors presented with an index of the overall effectiveness of their organization

might see that it was going up and all was well, but if it were going down they would then want to take some action. Merely sending a message down the line, 'Do something about it,' would not be very much good. Someone, somewhere, has to decide what to do. For that purpose you obviously want detailed study of the units which are going to be affected by managerial action, all the way down the line. It is for that very reason that we think it is important to build up your overall index from detailed measurements for operating units.

Written Questions

There are two written questions. The first one is by Mr. A. Hudson Davies of Fibreglass Ltd., as follows: 'One can see the point of this index as a means of following change in the same business or the same product. Can we have an example of the sort of situation where by studying the productivity indices in two branches of the same business (or two products) the directors can decide to abandon one and reinforce the other. Would not this decision follow from the quite normal examination of costs, profits and markets?'

DR. BEECHING: On the question of trying to compare the productivity of two different products, it is the old problem of trying to compare apples and pears. Merely measuring in terms of financial value would give you some guide, but it might be very misleading. I think you could not decide that question simply from productivity measurement. If you want to compare two units within an organization, which are producing substantially the same thing under reasonably similar circumstances, then the case is very different. You could tell whether one unit was inefficient by comparison with another and measurements of the sort which we suggest would very materially assist the board of directors in deciding whether to shut one down or not. That is not to say they would not get great benefit from their costing data. They might get all the assistance they wanted from that data, but there could be conditions under which measurements of effectiveness of production would be necessary or very helpful.

The next question is from Mr. P. A. G. Hills of Messrs. F. Smith & Son (England) Ltd. His question is: 'How is this situation catered for. Production in base year equals ten shillings. For subsequent years, improved methods, reduced man-hours "products" by x per cent. Saving in man-hours is used to increase quality or utility of product. Final result, selling price still ten shillings, man-hours per product the same. Therefore apparently there has been no increase in productivity. It is assumed there has been no change in any other factors, particularly price changes.'

DR. BEECHING: That I agree would not be revealed by the type of measurement suggested. I do not think it is typical of the majority of cases. When that sort of thing happens the local management is usually quite aware of it having happened, because it results from deliberate policy change or a decision on their part. Although it is not dealt with in the measurement it would scarcely go on unknown.

SIR EWART SMITH: Mr. Chairman, I am going to venture on that question to supplement my collaborator. If they produce a better product for the same price and for the same man-hours, the probability is they would sell more of them, and that their sales would go up and their length of run

would go up, but their productivity would also go up, because we all know how close the productivity is geared to length of run. There is no doubt that in general the question would in fact answer itself in that way.

May I say a few things in conclusion. First of all, I would like to congratulate Mr. Bibby on his very refreshing blast of clear cold air. As one of those to whom he was talking, not merely as author of the paper, but by virtue of my functions, I thank him for it and very much take it to heart; but I would again stress that balance in this matter as in everything else is essential. Of course we do not want elaborate fads and fancies. Some of the things which we advocate in the paper, if applied to every business indiscriminately, would not increase productivity, but cause a decrease, because there would be so many clerks needed for it. That goes without saying. On the other hand, the rule of progress is self criticism and analysis. It is my experience that when one does delve down into this sort of thing, when you even think you would get out an index, let alone use it, and when you consider the sort of factors upon which productivity depends, that does in itself have an influence in no small way. It is a stimulation of one's own faculties and one's own organization which leads one to say: 'Were we looking at this thing in balance?'

May I pick up one of the factors we have listed, variety of products, in other words, standardization. Carried to extreme in a wicked totalitarian way, heaven preserve us from it, but looked at in a sensible and logical way, by making a proper analysis of costs relative to one's length of run, and to say: 'Should not we get overall benefits, both we and our customers, if instead of making ten varieties of these things, or giving everybody who comes to us his own little fancy, we cut down to three or four and offered preferential prices for the standard thing.' It is from that sort of stimulation that I think this sort of approach can be particularly valuable.

One of the earlier speakers mentioned foundries and the difficulty of comparing outputs from different foundries. I completely agree with him. It is difficult enough to compare week by week the output from a single foundry, especially if it is working on jobbing work. I would, in that connection, mention an experience of my own where there was a small jobbing foundry making a very wide variety of castings, mostly for maintenance purposes. They dealt with a very wide variety from week to week. We wished to apply the work measurement technique; we wished to measure the output and get some logical basis on which, after we had studied our methods and improved them, we wanted to offer an incentive scheme. The first thing one thinks of is: 'Let us take as our basis the tonnage output week by week.' That is quite all right in some ways as a basis for incentive payment. It is all right when the size and complexity of casting remains much the same, but if one week the work is mainly large castings, while perhaps the following week they are mainly small castings with a low tonnage, then the bonus goes in the wrong direction so far as the men are concerned, with rather disastrous results. The people dealing with it dealt with it in this way. They took the weight of output in each week for a quarter. It varied week to week. They plotted it against the average weight of casting in each week, and they got more or less a hyperbolic curve. Then it was quite easy, working from that curve and knowing the average rate of working over the whole period to fix a bogey curve based on a rate of 60 work units. Then it was possible to give a bonus every week, based on the percentage excess over the bogey curve.

I merely mention that as an example of taking a minor problem, studying it, and considering the various ways of getting round the difficulties, breaking it down, and then taking action. The ultimate increase in output was very considerable, and was not only due to extra output, by the men, as a result of the incentive scheme, but was also due to the thorough study of methods by the management.

I think I have already talked far too long, and I certainly will not continue any longer. My collaborator and I would like to thank you very much indeed for the way in which you have listened and received the paper, which I am only too well aware is full of imperfections. It is quite inapplicable in many cases. As we said originally, it is there to talk about and to bring out, I hope, some of the aspects upon which effectiveness and efficiency do depend.

THE CHAIRMAN: I should like to say a word or two about the work the BIM is doing on this question of the analysis of productivity. We asked Sir Ewart Smith to undertake this paper not only because of the inherent interest of the subject, but because we are doing work in the BIM by way of research work into this question ourselves, and we thought we could get some valuable help from Sir Ewart Smith's handling of it. In fact the approach that we are making is rather a different one from the one which has been demonstrated and discussed today.

It seems to us that there are two possible approaches or conceptions that can be held with regard to these indices. There is the one which starts rather with the economic conception of the productivity measured against the resources of the country and broken down successively into industries and firms. I think that is rather the approach Sir Ewart Smith has adopted, although he stresses the fact that he got at his figures by building them up from the operating unit. We have rather taken another line, the indices we are interested in are those which are of most direct use to, say, a works manager, the man who has got to act upon them. It seemed to us that they were likely to be more useful if they did not attempt to arrive at a global figure at all but just specifically in a series of ratios each dealing with one particular factor which affects the productiveness and the result attributable to that factor. Whether that is the right approach, or whether it is a better approach than this other approach remains to be seen, but I would like to call your attention to this factor. There are really two quite distinct approaches, and while we are still at the preliminary stage we are just a little sceptical as to the value of attempting to globalize these indices because the number of factors are so many that changes may quite well mask each other. You might quite well have an unchanged total which did result from very serious changes, some favourable and some unfavourable, which would not be obvious.

I am not competent however, to discuss the points which have been made, but wanted to call your attention to this fact.

I would like to thank Mr. Bibby for calling attention to the importance of making these proceedings useful to the smaller concern. We have in mind that in the next winter's proceedings they should be rather more directly of interest to small concerns and organizations.

I would like to express our thanks and indebtedness to Sir Ewart Smith and Dr. Beeching. It has been a most valuable contribution and a very stimulating discussion.

Appendix I

EXAMPLE OF THE CALCULATION OF PRODUCTIVITY THROUGH THE MEDIUM OF CORRECTED FINANCIAL VALUE OF OUTPUT (SECTION 5.3)

Suppose the performance of an industrial organization, for three successive years, to be represented by the following data :

1945—BASE YEAR.

Output

Product	Amount	Selling Price	Sales Realizations
		£ s. d.	£
A	1,000,000 gals.	10. 0 per gal.	500,000
B	80,000 tons	9. 0. 0 per ton	720,000
C	15,000 lbs.	3. 5. 0 per lb.	48,750
D	20,000 tons	15. 6. 0 per ton	306,000
Total			1,574,750

Raw Materials

Material	Amount	Purchase Price	Cost
		£ s. d.	£
U	60,000 tons	3. 0. 0 per ton	180,000
V	160,000 tons	2.15. 0 per ton	440,000
W	58 tons	18. 0. 0 per ton	1,044
X	25,500 tons	5.16. 0 per ton	147,900
Total			768,944

Services

Amount		Price	Cost
			£
Gas	51,020 therms	7.3 pence/therm	1,552
Electricity ...	6,200,000 KWH.	0.45 pence/KWH.	11,625
Water	100,000,000 gals.	8.5 pence/100 gals.	3,542
Total			16,719

Allowance for plant depreciation = £321,000
 Men employed = 1,002
 Productivity = $\frac{£(1,574,750 - 768,944 - 16,719 - 321,000)}{1,002}$
 = £467 per man year.

1946

Output

Product	Amount	Selling Price	Sales Realizations	Sales Realizations at 1945 Prices
A	1,005,000 gals.	£ s. d. 10. 6 per gal.	£ 527,625	£ 502,500
B	100,000 tons	9. 9. 0 per ton.	945,000	900,000
C	18,000 lbs.	3. 5. 0 per lb.	58,500	58,500
D	21,000 tons	15.10. 0 per ton	325,500	321,300
E	80,000 gals.	1. 2. 6 per gal.	90,000	—
Total ...			1,946,625	
Total (excluding Product E) ...			1,856,625(a)	1,782,300(b)

Price Index 1946/1945 (excluding Product E)* a/b = 1.042
Corrected value of gross sales = £1,946,625 ÷ 1.042
= £1,868,000

Raw Materials

Material	Amount	Purchase Price	Cost	Cost at 1945 Prices
U	65,000 tons	£ s. d. 3.10. 0 per ton	£ 227,500	£ 195,000
V	162,000 tons	2.15. 0 per ton	445,500	445,500
W	68 tons	18. 5. 0 per ton	1,241	1,224
X	25,500 tons	5. 9. 0 per ton	138,975	147,900
Total ...			813,216(c)	789,624(d)

Price Index 1946/1945 c/d = 1.029
Corrected cost of raw materials = £833,616 ÷ 1.029
= £789,600

Services

	Amount	Price	Cost	Cost at 1945 Prices
Gas ...	52,300 therms	7.4 pence/therm	£ 1,618	£ 1,558
Electricity	6,620,000 KWH	0.45 pence KWH	12,420	12,420
Water ...	101,000,000 gals.	8.0 pence/100 gals.	3,366	3,576
Total ...			17,404	£17,554

(If services remain the same in kind, use of a price index is unnecessary)
Corrected Cost (Cost at 1945 prices) ... = £17,554
Allowance for plant depreciation ... = £340,000
Men employed = 1,356
Productivity = £(1,868,000 — 789,600 — 17,854 — 340,000) ÷ 1,356
= £532 per man year.

* In practice, the price index would be based upon prices for a selected series of products in the full range. Otherwise, prices could equally well be corrected individually.

1947

Output

Product	Amount	Selling Price	Sales Realizations	Sales Realizations at 1946 Prices
		£ s. d.	£	£
A	1,010,000 gals.	10. 6 per gal.	530,250	530,250
B	100,000 tons	9.10. 0 per ton	950,000	945,000
C	200,000 lbs.	3. 5. 0 per lb.	65,000	65,000
D	22,000 tons	16. 0. 0 per ton	352,000	341,000
E	82,000 gals.	1. 3. 0 per gal.	94,300	92,250
Totals ...			1,991,550	1,973,500

Price Index 1947/1946 = 1.009 Price Index 1946/1945 = 1.042
 (including Product E) Price Index 1947/1945 = 1.051
 Corrected value of gross sales ... = £1,991,550 ÷ 1.051
 = £1,895,000

Raw Materials

Material	Amount	Purchase Price	Cost	Cost at 1945 Prices
		£ s. d.	£	£
U	65,000 tons	3.10. 0 per ton	227,500	227,500
V	163,000 tons	2.15. 0 per ton	448,500	448,500
W	60 tons	18. 6. 0 per ton	1,098	1,095
X	25,500 tons	6. 6. 0 per ton	160,650	159,373
Total ...			837,748	836,468

Price Index 1947/1946 = 1.0015 Price Index 1946/1945 = 1.029
 Price Index 1947/1945 = 1.031
 Corrected cost of raw materials ... = £837,748 ÷ 1.031
 = £812,500

Services

	Amount	Price	Cost	Cost at 1945 Prices
			£	£
Gas ...	52,500 therms	7.5 pence/therm	1,641	1,600
Electricity	6,625,000 KWH	0.45 pence/KWH	12,422	12,422
Water ...	100,000,000 gals.	8.0 pence/100 gals.	3,333	3,542
Totals ...			17,396	17,564

Corrected Cost (Cost at 1945 prices) ... = £ 17,564
 Allowance for plant depreciation ... = £340,000
 Men employed ... = 1,350
 Productivity = £(1,895,000 — 812,500 — 17,564 — 340,000) ÷ 1,350
 = £537 per man year.

Thus

Selling price indices are

1945 Base Year	1946	1947
1.00	1.042	1.051

Raw Materials price indices are :

1945 Base Year	1946	1947
1.00	1.029	1.031

Productivity indices are :

1945 Base Year	1946	1947
1.00	1.14	1.15

Appendix II

THE MEASUREMENT OF OVERALL EFFECTIVENESS OF A PRODUCTION UNIT

It has been proposed that the comprehensive measurement of effectiveness for a production unit should be:—

Volume of output per annum.

divided by

Average number of men employed + manpower equivalent of capital equipment + manpower equivalent of services received + manpower equivalent of changes in raw materials.

Further comment is necessary upon the way in which the various quantities in the denominator of this expression should be measured.

It is suggested that all types of employee identifiably associated with the productive functions of the unit should be included in the figure for the number of men employed. Thus, the figure should include direct and indirect labour, unit clerical staff, and unit management. It should not include long term research staff, sales staff, etc., as the inclusion of such staff who are not under the control of the 'production manager' of the unit, and who do not immediately contribute to production, merely reduces the sensitivity of the measure as an indicator of the productive effectiveness of the unit.

The manpower equivalent of the capital equipment may well be calculated by dividing the cost of the equipment by the national average annual income for industrial employees of all kinds, to obtain the total equivalent man-years, and then dividing it by the expected years of life of the plant to get the equivalent number of men to be included in the total for any one year. In the case of plant existing when measurements start, the manpower charge should be based upon the present value and remaining life of the plant, while for new plant the charge should be based on purchase price and total expected life. Such charges, once fixed, would continue to be made all the while the plant remains in use.

Treatment of the problem in this manner is simple, and is not so crude as it at first appears. It might be suggested that it would be better to take account of the output per man in particular firms supplying plant, and then to consider their own use of capital equipment, and so on. Apart from the inherent difficulty of such a method, there is no reason why the unit under study should be assisted or penalized by the effectiveness of the particular firms making its equipment. Moreover, by using an average annual income figure for industry as the means of converting cost to manpower, account is taken, in a rough and ready way, of all the factors contributing to production of plant. Further refinements would be corrections to a correction.

The allowance for services, such as water, gas, electricity, etc., should be made at rates representative of the country as a whole. Such rates could well be generally agreed, and would not require very frequent change.

Separate assessment for local supply services would involve unnecessary trouble, and is clearly undesirable. As in the case of the supply of capital equipment, there is no reason why any particular unit should benefit or suffer on account of high or low efficiency in another unit outside its control.

It is suggested that allowance should be made only for changes in raw materials, relative to the base period, and not for raw materials as a whole, because we are measuring the effectiveness with which raw materials are converted to finished product. A manpower charge should not be added or deducted simply because a material is more or less expensive, but only if it is of such a nature as to decrease or increase the work of conversion. Such a charge may well be determined from direct knowledge of the effect of the change in raw materials upon the plant and men employed in the unit.

A factor which has not been mentioned, so far, is work in progress and stocks. Large stocks, or a high level of work in progress, tie up materials which might otherwise be usefully employed. They are equivalent to invested manpower which is not being used. There is, therefore, some reason why an allowance for stocks should be made in the measurement of effectiveness. This might be done by including an interest charge of, say, 5% of the manpower equivalent of the capital value of stocks. Such a correction would be rather artificial, however, and could better be omitted in most cases. A sound method of measuring effectiveness through the medium of costs would be better able to take this into account.

The examples which follow illustrate the determination of an index of effectiveness by this means, and also the combination of unit indices to give an overall index for a more complex organization.

EXAMPLE 1

DETERMINATION OF A PRODUCTIVITY INDEX FOR A SINGLE PRODUCTION UNIT

1945 BASE YEAR.

(a) Capital value of existing plant	...	...	...	...	£160,000.
(b) National average annual income per employee in industry*	...	...	...	...	£400.
(c) Manpower equivalent of plant (a/b)	...	...	...	...	400 man-years.
(d) Expected remaining life of plant	...	...	...	...	10 years.
(e) Manpower charge for plant (c/d)	...	...	...	...	40 men.
(f) Cost of services received	...	...	...	...	£4,840.
(g) Manpower charge for services (f/b)...	...	...	...	...	12.1 men.
(h) Output	...	...	...	...	120,000 units.
(i) Number of men employed	...	...	...	...	200.

$$\text{Productivity} = \frac{120,000}{200 + 40 + 12.1} = 476 \text{ units/man-year}$$

* Normally this need be revised only every few years.

1946.

No changes in plant.

Manpower charge for plant	...	...	...	...	...	...	40 men.
Cost of services received	...	...	...	...	...	...	£5,020.
Manpower charge for services	...	...	...	...	...	...	12.6 men.
Men saved by change in raw materials (Correction to be included only when necessary)	...	...	...	...	...	...	3.0.
Output	...	...	...	...	...	...	135,000 units.
Number of men employed	...	...	...	...	...	...	200

$$\text{Productivity} = \frac{135,000}{200 + 40 + 12.6 + 3} = 528 \text{ units/man-year.}$$

1947.

Extension to plant costing	...	...	...	...	...	...	£100,000.
Manpower equivalent of new plant	...	...	...	...	...	...	250 man-years.
Expected life of new plant	...	...	...	...	...	...	10 years.
Added manpower charge for plant	...	...	...	...	...	...	25 men.
Total manpower charge for plant	...	...	...	...	...	...	65 men.
Cost of services received	...	...	...	...	...	...	£7,080.
Manpower charge for services	...	...	...	...	...	...	17.7.
Base year raw materials used	...	...	...	...	...	...	—
Output	...	...	...	...	...	...	205,000 units.
Number of men employed	...	...	...	...	...	...	250.

$$\text{Productivity} = \frac{205,000}{250 + 65 + 17.7} = 616 \text{ units/man-hour.}$$

Thus, the corresponding productivity indices for this section are :—

1945 Base Year	1946	1947
100	111	129

EXAMPLE 2

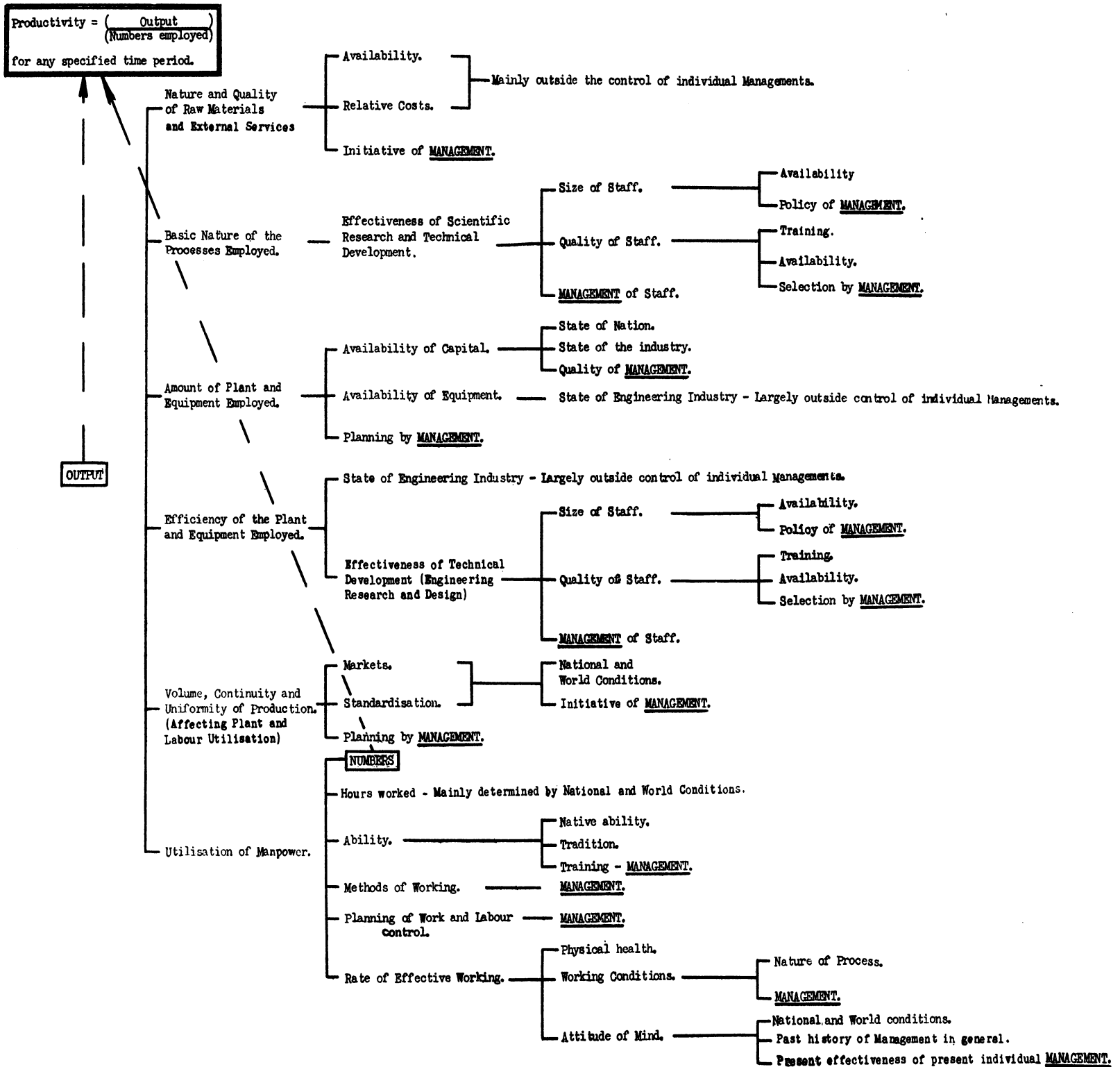
Section	Base Year.				Current Year.			
	Output in Arbitrary Units.	Number of Employees.	Manpower Charge for Plant.	Output in Arbitrary Units.	Number of Employees.	Manpower Charge for Plant.	Productivity Index.	
A	100,000	63	16	121,000	63	16	121	
B	28,000	105	35	28,000	115	35	93	
C	5,000	25	5	5,600	20	8	120	
D	1,200,000	65	45	2,010,000	100	61	114	
E	62,000	28	12	62,000	28	12	100	

The overall index for the current year, relative to the base year at 100 is :—

$$\begin{array}{rcccccc} \text{(a)} & & \text{(b)} & \text{(c)} & \text{(d)} & \text{(e)} \\ (121 \times 79) + (93 \times 150) + (120 \times 28) + (114 \times 161) + (100 \times 40) & & & & & \\ \hline & & 79 & + 150 & + 28 & + 161 & + 40 \\ & & = & 108. & & & \end{array}$$

CHART SHOWING THE FACTORS UPON WHICH PRODUCTION DEPENDS AND HENCE
THEIR RELATIONSHIP TO PRODUCTIVITY

FIG. 1



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