

ASSESSMENT OF PRODUCTIVITY IN HIGHWAY MAINTENANCE

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●PRODUCTIVITY is a word much used and often misused in industrial relations. It is generally assumed to be applicable only to human labor. It can equally well be, and is, applied to the use of other resources employed in human endeavor—materials, machines, transport, etc. The greatest attention however has always been given to the problems of assessing human effort and output, so this association is natural. The problems are greatest with labor productivity but the principles used in assessing it can be applied to assessing productivity in the use of other resources. However, for the purposes of this paper, only labor productivity is considered, and in general that of the technical and manual labor force rather than that of the administrative services. In highway maintenance, the problems of labor productivity assessment differ only in detail from those of other undertakings and industries.

WHAT IS PRODUCTIVITY ?

Labor productivity has been defined as "the ratio of output to the corresponding input of labor" (1). This definition covers all possible definitions of what are and are not labor input and product output. The ratio can be expressed in two ways, either:

1. The unit labor requirements, i. e., the amount of labor required to produce a unit of output; or
2. The productivity of labor, i. e., the number of units of output produced by a unit of labor.

The ratio as defined by the first expression is the one most generally used since it allows direct addition of labor requirements of different operations and processes.

The labor productivity of an operation or group of operations is purely the relation between the labor employed and the products produced. It takes no account of a number of factors which can affect the value determined, such as the working conditions, the efficiency and skill of the labor, the excellence of the technology and management applied to the work, or the economic value of the product. Productivity figures alone therefore are of little value unless they are compared with other figures either for the same group for a different period or for other groups. Effective comparisons can only be made if factors which can influence productivity can be identified and their effects evaluated.

Productivity can be studied at different levels, from that of the individual operative through small groups (gangs or crews), larger groups (complete organizations or factories), complete industries, to the whole national effort. Assessment at different levels may entail some differences in the methods of evaluation used, so in setting up a system to assess productivity, one must be clear on the objectives. For the highway maintenance engineer at the state level, one would want assessments from crews, through supervisors' areas and districts, to an overall state assessment. Productivity assessment of individual operatives is probably not necessary, except for special purposes.

ASSESSMENT OF PRODUCTIVITY

Assessment is often complicated by the diverse natures of the labor input and the product output that also are frequently difficult to define and to measure in comparable terms.

Measuring the Labor Input

Labor input is usually measured in terms of the time during which the labor is employed and the numbers engaged, such as man-hours or man-days, according to the scale of the operations, the period over which the assessment is being made, and the level at which it is being considered. In the broadest sense of productivity, the time measured should be the time during which the labor is available for work. On lower levels of assessment using hours, time not worked for specific reasons can be and often is excluded. At higher levels, when measuring in days, variations in the length of the working day are usually ignored so the man-day can be a variable quantity. When considering productivity over a year, it is debatable whether absences for holidays, sickness, or other reasons should be excluded from the input; usually they are not. Thus the values obtained at different levels of assessment will often differ but this is acceptable since the required aspect is different. No direct measure of the quality of the effort is made, i. e., how hard individuals work. Variations in this will produce different measures of productivity for apparently similar situations of input.

The labor input is basically of two kinds—the labor directly involved in carrying out the actual productive work and the labor which, though not directly taking part in the work, assists indirectly and is essential to it; e. g., immediate supervision, transport drivers, and maintenance staff. Administrative staff are not usually included in assessments of labor productivity. At higher levels of assessment, it is easier to take into account the indirect labor since it usually operates within the group being studied. At lower levels, the indirect labor is often only partly engaged in assisting an individual or small group, but its activities may control the productivity of those being studied. Measurement of this participation is often difficult. Frequently at these lower levels, the indirect labor is not included in the direct labor assessment but studied separately.

Measurement of labor in this manner takes no account of differences in skill, abilities, age, sex, etc. A labor force is seldom homogeneous, and members of it are not always interchangeable. On the other hand, improvements in technology may allow reductions and changes in the skills and type of labor used, without altering the numbers employed. Thus, productivity may remain unaltered, but the cost of the products may be reduced by the use of lower paid, less-skilled workers.

Measuring the Product Output

Output is measured in terms of saleable or acceptable products. These may be wholly or partially finished and should include saleable by-products but not waste. Product output can be in many different forms, such as goods produced, repairs made, and services provided, some of which may be difficult to measure in physical terms. Where the output is in a single form these difficulties are easier to overcome but most organizations, of which highway maintenance departments are an example, have a multiplicity of products remains the same for different assessment periods, or for different organizations where such are being compared, an aggregation of the individual items can be made for purposes of comparison. Where the proportions of the mix vary, complications arise.

The nature of the products should be taken into account. They may vary in quality, and different materials and equipment may be used to produce them and so produce a different mix of the output requiring separate measurement. Not only should differences in materials be considered but also differences in the state of the input materials; i. e., they may be raw materials for complete processing or brought in semi-processed.

Making the Assessment

The primary object in assessing productivity is to determine changes between different periods for the same organization or between organizations. When there is a single product, the productivity is usually expressed as the unit labor requirement and direct comparisons can be made, bearing in mind the factors which can affect the labor and the product. For true measures of the productivity of the organizations concerned, all

labor employed and all time available for work together with the whole acceptable output should be included. Only in exceptional cases, mainly where one is studying operative-controlled productivity on a low level, should deductions for unavoidable delays be made from the time worked; e. g., time lost because of failures by the indirect labor or the weather. The more usual case however is one of a complex mix of products and the productivity can only be expressed as a gross labor requirement in relation to the total output. In determining changes in productivity some attempt has to be made to adjust or redefine the output. One period is usually taken as the base and other months or years can be adjusted to show either the labor requirement for an output similar to that of the base period or the output for the same amount of labor as employed in the base period. Where the mix of the output varies, use has to be made of weighting factors to equate the different proportions. Alternatively, the outputs can be evaluated in monetary terms. Neither method is simple nor entirely satisfactory.

Productivity is usually expressed as an index with the base period as 100. When expressed in terms of unit labor requirement, a reducing index indicates increased productivity. In terms of the productivity of labor, an increasing index indicates increased productivity.

PRACTICAL APPLICATION OF PRODUCTIVITY

It will be seen that at best labor productivity measured in accordance with the comprehensive definition merely gives the labor content of work. In comparison with other figures for other periods and organizations, it indicates changes or differences in productivity and their relative magnitude compared to some arbitrary base. There is however no indication whether productivity in the base is good or bad unless some predetermined standard is introduced. For productivity assessments on a large scale, for a whole industry for instance, this situation is acceptable to some extent, provided that the general situation and product output are not subject to rapid change. It allows progress to be measured but needs investigations in depth to reveal reasons for changes and differences. For short-term labor control, particularly where the mix of products varies from period to period, of say a week or a month, a more precise form of measurement of the input and output is required. This requirement is met by the use of performance standards which provide a means of measuring output in the same terms as labor input and introduce an arbitrary but logically based standard for comparison.

THE USE OF PERFORMANCE STANDARDS

The concept of performance standards is to establish a standard amount of work or labor input, measured in man-time units, required to produce a unit of output. This necessitates employing the right type of labor, working at a standard (good) rate which can be maintained throughout the working day, using the right methods, tools, equipment and materials, and producing a product of the right quality. Once these standards have been established for all possible operations within an organization, all output can then be measured in terms of similar units; i. e., man-hours, man-days, etc. By totaling output in these terms the relative productivity can be obtained as a ratio of total labor input to total output expressed solely in terms of the labor needed to achieve that output, whatever the mix of products produced. This is known as the effective performance or EP. Ratios between EPs for different periods or organizations are the same as those for absolute productivity, provided in the latter case the standards used are the same.

Once the system for measuring EP has been set up, many of the difficulties associated with the measurement of labor productivity disappear. Each type of labor, task, and product has its own standard which is measured in the same terms so no problems arise from varying labor forces, different products, different methods and materials, and advances in technology. Furthermore the measurement obtained is immediately meaningful in that it is related to a known standard performance. This basically is the method used in highway maintenance in Great Britain, though, for various reasons, a modified EP is usually produced as explained subsequently.

The success of the method depends upon the care with which the performance standards are established. This is done using conventional work-measurement techniques, applied to an adequate number of repetitions of each activity or operation by observers well-trained to rate work to the same standards. In determining the standards, allowances are made for rests and personal needs, the giving and receiving of instructions, observing site safety precautions, and other contingencies. The performance is expressed in standard minutes per unit of output or standard minute value (SMV) for each operation. (In Great Britain, it is usual to work in standard minutes for all calculations until the weekly total per operative or gang is reached when times are converted to standard hours.) It is not always necessary to split operations down to the work of individual operatives. For many tasks, the work can be measured as gang work, using predetermined gang sizes and methods.

It is essential that the work measurements on which the standards will be based are made on work carried out using efficient methods and these should therefore be established by method studies before any work measurements are made. Failure to do this may well result in apparently high Effective Performances which bear little relation to the real facts and are therefore highly misleading. In such cases, the standard performance is usually set too low, and, if it is to their advantage to do so, the operatives will easily exceed the standard by modifying their working methods.

It is often impossible to measure all the work likely to occur. Maintenance departments are sometimes given unusual tasks which occur too infrequently for reliable measurements to be made of them. However, provided these can be kept to a minimum, some arbitrary figure can be given to them as they occur. (When used in conjunction with incentive bonus schemes, a maximum proportion of about 15 percent of unmeasured work is usually acceptable, but every opportunity should be taken to measure such tasks.)

All employment can be measured and this includes time spent in traveling between sites, the work of transport drivers, store clerks, etc. It is axiomatic that the quality of the work must be up to the standards set within the organization. Work that has to be repeated because of poor quality, incorrect positioning, and other reasons is only accounted for once in the measured output, but the reworking time is included in the labor input.

THE CONTROL SYSTEM

Any control system is only as good as the data put into it; in this case, the entries on the operative's or gang's work sheets. The entries on these can be quite simple and need no complicated timing. In Great Britain, a typical work sheet, made out weekly for individual operatives (since these are also the basis for payment) would have the following headings: (a) section and item numbers, which identify the type and exact item of work by reference to the appropriate part of the performance standards manual (the data for all measured work applicable to the department); (b) written description of work with dimensions; (c) output unit (cu yd, tons, etc.); (d) output quantity in appropriate units; (e) standard minute values for the output units (e.g., 72.0 SM per ton); and (f) total standard minutes for the total quantity.

A separate box is provided on the form for unmeasured work and also one for time lost for reasons beyond the control of the operative. (This is not always necessary but the majority of highway departments in Great Britain using performance standards have bonus schemes for which this information is needed to avoid penalizing operatives undeservedly.) The gross total of standard minutes gives the work done during the week while the gross hours worked give the labor input. Figures can be totalled to give inputs and outputs for gangs, areas, or districts, and weekly values for EP can be calculated.

The weekly work sheets are usually processed at the department's headquarters, not at the divisional or district offices, but the results are passed back in weekly summaries. The Ministry of Transport and Local Authorities' Committee on Highway Maintenance (the Marshall Committee) in its report (2) suggested a control system based upon performance standards and gave an example of weekly control summary based upon a typical gang. This summary also brought in costs and earnings to show how these were affected by the EP and total outputs. Table 1 gives this summary in a modified form from that published in the report. The budget figures for the year are

TABLE 1
EXAMPLE OF WEEKLY CONTROL SUMMARY FOR A TYPICAL GANG

Week Ended	Output (SH)	Actual Hours	Gross Wages (£)	Memoranda			Indices	
				EP	Earnings (£/actual hour)	Unit Cost (£/SH)	Output	Cost
Budget	312	400	200	78	0.50	0.64	100	100
Last quarter	335	440	228	76	0.52	0.68	107	106
7/5/69	300	400	208	75	0.52	0.69	96	108
7/12/69	320	400	204	80	0.51	0.64	102	100
7/19/69	309	400	204	77	0.51	0.66	99	103
7/26/69	312	400	196	78	0.49	0.63	100	98

given as a weekly average together with the average weekly figures for the last quarter. These indicate the target and the previous average performance with which the current weekly performances may be compared.

The heading "Output (SH)" gives the weekly output budgeted and actually achieved, in standard hours. The "Hours" are the gross hours actually worked and paid for at a fixed rate, the amount paid being given under "Wages" which includes overtime and bonus, if any.

Under "Memoranda" are shown: (a) the EP which is standard hours divided by actual hours (the figure of 78 is a typical target performance); (b) earnings which are wages divided by actual hours; and (c) unit cost which is wages divided by standard hours and indicates the actual cost to the department of the useful work done at an hourly rate.

The "Indices" shown are: (a) output or standard hours worked divided by budget standard hours multiplied by 100, which is a measure of the output in relation to the budget; and (b) cost or actual unit cost divided by budget unit cost multiplied by 100, which indicates the profitability to the highway maintenance department of the work done.

This summary would only be seen up to divisional or district level, but, based upon such summaries, consolidated monthly or quarterly returns for performances of gangs and areas would be submitted to higher levels of management.

All control systems should be capable of development and change and the one described here should be no exception to this rule. Standard performances must be kept under constant review and modified as techniques, materials, equipment, and skills change. The channels of communication and the information passed should also be monitored for possible modification. As regards information passed, the guiding principle should be to collect and then pass to management at appropriate levels, only that information that it really needs for its task. Otherwise it will be overwhelmed with too many facts and may well overlook the information it really needs to act on. Management by exception could well be practiced.

CURRENT PRACTICE IN GREAT BRITAIN

Nearly all the highway maintenance departments in Great Britain that have developed performance standards have done so with the object of setting up incentive bonus schemes. Wages, governed by national and regional agreements, tend to be low for highway work, and consequently it is difficult to attract and retain the right type of labor. Bonus schemes are designed to encourage workers to increase productivity by giving them a share in financial benefits obtained as a result of increased productivity. They thereby increase earnings and so make the employment more attractive. Effective performances are calculated within the structure of the bonus schemes and therefore are a measure of the individual's or gang's performance rather than that of the organization as a whole, including the management. This is because the performance, often called "pay performance," is calculated on a slightly different basis from that used for calculating EP.

The principle in bonus schemes is that the operative is not penalized for time lost due to circumstances not under his control such as wet weather, lack of materials, or incorrect instructions. Time lost due to these causes is deducted from the gross hours worked so that pay performance is usually higher and never less than effective perfor-

mance. Although such time lost does not affect their pay, it reduces the amount of work on which they can earn bonus, and so operatives tend to have a salutary effect on their supervision in preventing avoidable delays such as failure to supply materials. Again, hours worked on making good work of substandard quality are counted but not the reworked output, unless this was due to faults of supervision, i. e., outside the control of the operatives. Reworking thus tends to reduce bonus and gives some incentive for at least a reasonable standard of workmanship. A maintenance department, which pays its area supervisors a bonus based upon the performance of their gangs, does not deduct any time lost except that due to weather. This particularly encourages lower management to organize their forward planning, supply of materials, and so forth in the most effective way to produce maximum EP.

One maintenance department is known to calculate the true effective performance independently of its bonus scheme data. It presents the performance to the divisional engineers in the form of a labor profit and loss account in monetary terms. A standard "unit cost" based upon labor wages and on-costs is calculated (similar to the figure in Table 1 given as "budget-unit cost" except that here on-costs have not been included). The actual "unit cost" is calculated from the EP for the period and the wages paid. The difference is the profit or loss per standard hour worked, which, multiplied by the total number of standard hours worked, gives the actual profit or loss. As an example, assume that the basic cost of labor including on-costs is £0.60 per hour and the target EP is 67. Then the target cost of a standard hour worked = $100 \div 67 \times 0.60 = \text{£}0.90$. If the EP is 75, the actual cost per SH is $100 \div 75 \times 0.60 = \text{£}0.80$. The "profit" is $\text{£}0.90 - \text{£}0.80 = \text{£}0.10$ per SH worked. On a monthly total of 5,000 standard hours, the profit would be $5000 \times \text{£}0.10 = \text{£}500$. Good and bad performances are thus forcefully illustrated.

This same department also gives different divisions different targets or EPs since one-half is a developing residential area and the other half is largely agricultural. It takes into account the varying conditions that arise such as availability of suitable labor, traveling distances, and interference to work by traffic. Targets are changed monthly and are determined on the basis of an average between the standard performance and actual performance over the two previous months. This enables the good division to keep ahead of its target consistently and gradually draws the poor division up by always giving it a target somewhat ahead of, but related to, its performance.

A few highway departments have developed performance standards without bonus schemes, but, so far as is known, they do not calculate EPs. Their main use of the performance standards is in the preparation of their annual work programs. They are also, of course, widely used for this purpose by departments with bonus schemes.

INSTALLING THE CONTROL SYSTEM

Until recently, most maintenance departments have installed their systems of control through performance standards by setting up their own work study section and carrying out all the necessary method study and work measurement or by employing consultants. A very large effort is required at a considerable cost and it may well take up to 3 years or so to complete all the necessary measurements. The cost is often a reason for the smaller highway departments' hesitating to go over to such a system, though the improved productivity and control usually brings about financial savings sufficient to pay for the initial cost after a few years of operation.

It seems logical therefore that departments which have not yet produced their own performance standards should be able to take over the standard from another. There are objections to this such as differing local conditions, methods of working, and equipment. However, these difficulties can be overcome and in several instances such "transplant" schemes are being successfully carried out. The donor department, in addition to providing the data, gives technical advice and trains the personnel who will administer the system in the recipient department. It still takes some considerable time to complete the transplant but the heavy cost of the work measurement is avoided (the recipient only pays for the personnel time directly involved) and the recipient also benefits greatly from the experience of the donor. Methods of working have to be

changed to those of the donor since the standards are conditioned to the donor's methods, but this is usually to the advantage of the recipient as the donor's methods will have been carefully worked out by method study.

So far this transplant system has been found to work satisfactorily only between rural highway departments (counties) but it should be possible to develop ways of exchanging systems between urban highway departments also. (One problem is that all highway work is often not under the control of a single department in urban authorities.)

A local government advisory organization, the Local Authorities' Management Services and Computer Committee, is studying the problems of installing such systems and advises highway and other departments on appropriate methods and staffing. It is also building up a considerable bank of data on performance standards which is available to all local authorities and should enable more extensive use of transplant schemes to be made.

Although there are nearly 1,000 highway maintenance departments in Great Britain, the major proportion of the highway network is controlled by 300 or so counties, cities, and large towns. It is mainly among these that are found the departments which calculate performance in some way (by either pay performance or effective performance). To encourage the remainder to improve their efficiency, the Marshall Committee suggested a method by which maintenance departments could make approximate tests of their own EPs. In these, sample studies are made and EPs worked out using national performance standards. (These are broadly based standards produced by the Committee and are accurate enough for test purposes, but not for regular use.) Tests have shown that increases in EP up to 100 percent are possible. It is hoped that the use of such tests will encourage the greater use of these control systems and result in considerable gains in productivity.

CONCLUSIONS

Direct assessment of productivity is cumbersome to make and not very effective for controlling labor forces used in highway maintenance. However, the modified approach through performance standards to determine effective performance is indispensable for a proper control of labor utilization.

Setting up the control system involves a considerable effort but, once installed, it is easy to run and gives a number of side benefits including a valuable means of preparing annual programs by providing accurate information on which estimates of the labor and financial resources needed can be based. The system can be incorporated with an incentive bonus scheme where desired, but it is preferable for the bonus scheme to be a side benefit. Otherwise the real object, that of monitoring labor productivity in the organization, becomes obscured.

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