WORK PERFORMANCE MEASUREMENT IN DIFFERENT MANUFACTURING PLANTS WITH THE SAME PRODUCTS.

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ABSTRACT

The aim is to find a way that is simple and easy to compare for measuring the production performance of different plants, all of which make the same products and have the same reference standards. The difficulty lies in introducing the proper adjustment coefficients for the different realities, taking into account the lay-out, the employee characteristics, the production mix, the organisational complexity, the output and whatever else turns out to be relevant.

The model includes an evaluation at the level of the individual and of the individual work positions, as well as at the level of the department and the production plant. An application is presented for linking the remuneration of the employee in question to the above-mentioned index. The simulation model applied to this case gave results that are interesting and positive enough to justify its application in reality.

KEYWORDS: Work and material productivity, quality, performance measurement, worker, department, remuneration and results.

1. INTRODUCTION

This paper intends to measure and compare the performance efficiency of manual labour in different production plants, but producing the same products.

The products have important dimensions, ranging from one cubic metre to parallelepipeds that are three or four cubic metres in volume, and weighing hundreds of kilos, made from relatively expensive material and requiring a high labour content.

The production can be assumed to be of one basic type and intended for mass production if the products are considered one at a time, but for small-medium production if the differences between individual families are taken into consideration.

The question has various particular features, since each plant has a different factory lay-out, similar but not identical equipment and work positions, while the movement systems are often very different and the production mix, daily output and work hours are not easy to compare.

In this context, it is necessary to adapt the classic global evaluation of performance efficiency, given by the ratio between the target standard and the output effectively realised, to each individual plant.

This personalisation may be more or less difficult according to the main purpose behind the comparison, whether it is mainly about managing the department or specifically aimed at each single work position.

The main aim is to provide a clear comparison between the work performances of each individual plant and each single work position, in order to assign an appropriate performance index, which is exact and progressive over time, at both levels of the analysis.

Such a performance index may simply be used for handling the inefficiencies, work loads, costs and improvements for the benefit of Management Control, or it may also become a means of linking employees' retribution to results.

In the second case, the measurement and comparison require a delicate organisation, bearing in mind the general sensibility towards economic aspects and the need for a single model to be applied identically in all of the different sites.

The gain-sharing model must be the same for all the plants involved, with the same basic means of evaluation.

2. REFERENCE HYPOTHESES

The principal reference hypotheses are based on the following assertions:

1. planning of the products is centralised in a single organisational unit to ensure a homogeneous set-up,
2. forecasting the standard production costs is, consequently, centralised in a single organisational unit and is partly integrated with the planning phase,
3. industrialisation and output choice are also centralised, with the involvement of the specific production plant only in the final phase,
4. given the above considerations, the fundamental plant lay-out at the basis of the standard costs refers to a standard factory organisation, and does not take into account the effective circumstances of the actual production sites,
5. the work cycle is fundamentally the same in all the plants, with differences due only to internal movement and the number of work positions assigned to the various production capacities,
6. the manual contribution to the work activity is very important and the work cycle is dependent upon the human activity and not the equipment,
7. performance is compared according to a single general product standard, which evaluates the human work time, the defectiveness with regard to acceptable and unacceptable product standards, the relative standard repair operations, the standard material waste and the standard production waste,
8. the choice of assigning products to one production plant rather than another is a function of the period circumstances and the relative operational programming and scheduling, without further consideration for technical efficiency,
9. the main performance criteria for measuring and evaluating are, therefore, those which can be traced either directly or indirectly to the activity of the individual worker,
10. the high work content of the product means that motivational differences between the various workers assume an importance for the results, due to the appropriateness of differing skills in individual performances, or in groups of workers involved in homogeneous activities,
11. the different production mix, which is a function of the demand, with the possible combination of new or repeated products with larger or smaller batches and with variable product complexity, leads to differing degrees of performance difficulty and adaptability to change,
12. it is, therefore, advisable to foresee and encourage a certain solidarity between workers, giving rise to a two-way learning process and improved performance,
13. it is necessary to draw up a general multi-factor evaluation model for the performances, which takes the differences into account, but which seeks to evaluate the common elements by means of appropriate indices that constantly adjust to the changing operational circumstances,

14. the measurement system may be used to create a system linking worker remuneration in the realities of the different production plants to his/her own results, on the basis of the standard values used as reference, which are determined at a central level and are the same for everybody.

Given that the reference standards are not specific to every production plant, it is necessary to draw up a model for measuring performance and combining the different production factors which takes into account the characteristics of every production department.

This model should give an index that is as simple as possible and which can incorporate all the differences of the individual work positions and the specific plants, giving an immediate, homogeneous and transparent comparison between the same.

This index should be able to measure the performance results in an equivalent way, since it balances the main variables (for example, the complexity of the product, programming for different batches, the product succession, the mix of new and repeat products, the output per unit time, the performance capacities of the employees, the training, etc.)

3. THE MEASURING MODEL

The model is drawn up as a multi-factor system, characterised by multiple coefficients for each item analysed, in order to take into account the variability in operational circumstances in the various plants.

Measuring may be carried out separately at the level of individual workers and work stations, or at the global level of the department.

In each case, the multi-factor index (I) can be traced back to the following basic formula:

$$I = \alpha_{n,t} (\Sigma \beta_i F_i)$$

with the following meaning for the various symbols:

(I) = multi-factor index for measuring performance,

$\alpha_{n,t}$ = complexity coefficient for each individual site (n) over the time period under consideration (t)

F_i = correspondence of each individual evaluation element to the standard, according to an equal comparison for all

β_i = weight attributed to each single factor (i) in the sum from 1 to M (factors considered) in the correspondence mentioned above.

It is assumed that the index (I) improves as it increases.

3.1. Complexity coefficient $\alpha_{n,t}$

The complexity coefficient for each single plant assumes that there is the possibility of personalising the measurement of the result (F) with respect to the standard, attributing it with various integrations on the basis of the effective management situations existing in the department (n) in the period (t).

Given the above formula, it is supposed that $\alpha_{n,t}$ is equal for all the factors and that it can be placed outside the sum of the expression $I = \alpha_{n,t} (\Sigma \beta_i F_i)$.

Generally speaking, the model foresees a rising value of $\alpha_{n,t}$ when there is an increase in the different models to be produced (K1), an increase in the new models to be produced (K2), a decrease in the concentration of the models (K3), an increase in the average difficulty index for the models (K4), and an increase in the number of workers in the department considered (K5).

In particular, the complexity index is given by the product of the various (K) above, expressed in index numbers from 1,00 (no influence) upwards, as a function of the increase in complexity.

Figure 1 shows the trends expressed above.

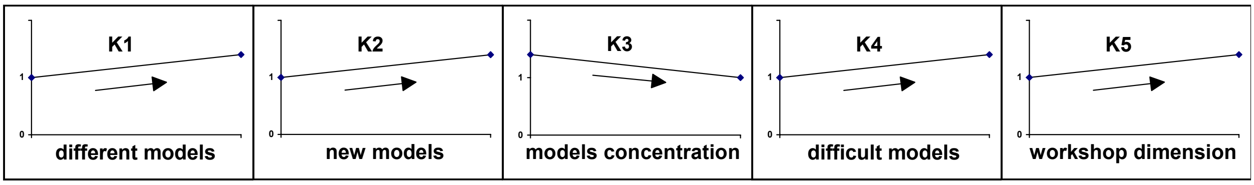

Fig.1 – Complexity coefficient $\alpha_{n,t}$

Therefore, the complexity coefficient $\alpha_{n,t}$ is calculated like this:

$$\alpha_{n,t} = (K1) \text{ x } (K2) \text{ x } (K3) \text{ x } (K4) \text{ x } (K5)$$

The values of the various (K) coefficients may be set on the basis of the historical data for all the plants, with the creation of appropriate adjustment tables.

The adjustment tables will obviously be different where an individual worker or work station is referred to, rather than a whole department.

3.2. Correspondence of single factor F_i

Where production factors are concerned (for example, materials, labour, etc.), the correspondence of the single factor F_i, compared to the standard, is normally indicated by the ratio between the evaluation of the standard production for that factor, compared with the effective consumption or definitive use of that factor

Where the performance of the production system is concerned, the correspondence is given by the ratio between the measured performance index and the standard target, or vice versa.

Given the definition of the problem, it is essential that factor correspondence measurements be relative and not absolute.

By way of example, it is useful to define the defectiveness for the quantity actually produced and not for the absolute number over the course of the day or month and, likewise, the waste materials should be compared with the target percentage (or p.p.m.) for the materials used and not simply their total weight per month.

3.3. Weight of each individual factor β_i

The weight (β_i) represents the element used to add up the indices of the various factors in such a way as to keep account of the different economic importance or the strategic importance attributed to each factor item in that period.

For example, an improvement in the percentage of the labour factor with respect to the waste material factor has much less effect, with the consequence that ($\beta_{material}$) should be greater than (β_{labour}).

It is immediately apparent that the sum of the various (β_i) should amount to 1 in order to give a single representative global index.

Sometimes it is possible to adopt an intermediate step, using another parameter as backup indicator (G_i) of the result, which may substitute the weight values (β_i) totally or in part.

In this last case, the correspondence factor (F_i) is shown in abscissa and the backup indicator parameter (G_i) in ordinate, characterised by scales with different values and more complicated links, in function of more global evaluations.

These evaluations may be either of a simple economic nature, or of economic trends or even of the improvement tendency.

Figure 2 shows some evaluation examples for an indicator F, which improves as it rises.

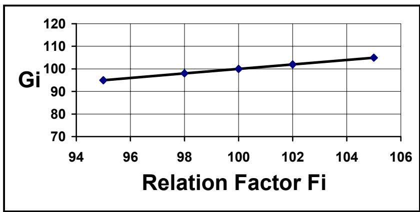

Fig.2,a – Linear relation between F_i and G_i

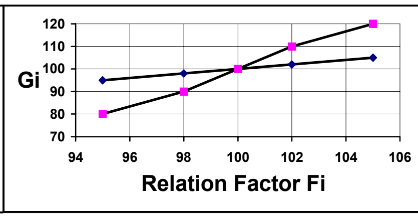

Fig.2,b – Non linear relation between F_i and G_i

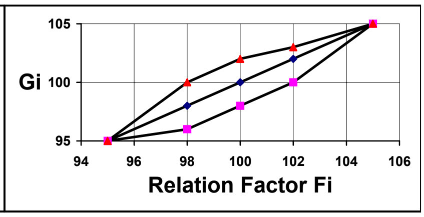

Fig.2,c – Different way to reach the target

Figure 2,a shows a linear relation between the factor correspondence (F_i) and the backup indicator (G_i); figure 2,b compares the previous linear trend with a new trend that penalises with (G_i) those values lower than the standard and, at the same time, rewards the higher values; figure 2,c points out a different way to reach the objectives, with a different interpretation of the initial starting effort as low values rise towards higher improvement values.

The value (G_i) can be used together with an adjustment of the weights (β_i) directly in the calculation of $I = \alpha_{n,t} (\Sigma \beta_i F_i)$ in the place of F_i as multi-factor indicator (I).

3.4. The addition rather than multiplication model

In other cases, it may be useful to break up the multi-factor evaluation into single factor evaluations which can be added together according to the following alternative model (I*):

$$I^* = (I^*_1) + (I^*_2) + \ldots\ldots\ldots (I^*_m) = \alpha_{n,t} (G_1) + \alpha_{n,t} (G_2) + \ldots + \alpha_{n,t} (G_m).$$

This second model is based on the sum and is usable when there is an explicit need to divide up the various contributions or when wishing to introduce a hierarchy into the various factors.

A typical example of this application is when forecasting a part of the workers' remuneration, which is subject to measurement and to the global results only and exclusively where the first indicator (I^*_1) shows a positive result.

4. APPLIED SIMULATION

Given the above definition, it is interesting to see its application to a classic case of result (I) linked remuneration (£), for a company with numerous plants and having the characteristics mentioned in paragraph 2.

Therefore, we obtain the data indicated previously: the standard performance objectives for the main factors, the collection of production and consumption data for the individual factors, the main measurement indices for the quality and productivity performances in great detail (from the single work position to the department to the whole plant).

4.1. Adapting the general model to the specific case

The application includes an initial choice of the relevant factors for monitoring; namely, the work factor, the consumption of the main basic material used in making the products and the quality of conformity performance by means of measuring the product defectiveness.

The work productivity (η) is measured at the level of the individual worker, by means of the ratio between the measured effective production in standard time and the presence at the work station.

The productivity of the most relevant material (λ) is measured by means of the greater consumption percentage than standard, with the lower limit considered equal to 0.

The quality (δ) is measured by means of the average importance of the defects, given points over the average product with reference to the historical defectiveness- target standard value.

The performance measurement refers to the individual level of each single worker (Iw) and to the department (Is).

Likewise, complexity indices (α) are obtained for individual workers (α_w) and department (α_s).

The addition version of the model, described in paragraph 3.4, will probably be used most.

4.2. Formula and individual contribution.

The basic application formula for the index (I*) is the following:

$$I^* = [(Iw) + (Is)] = [(\alpha_w)(G_{\eta w} + G_{\lambda w} + G_{\delta w}) + (\alpha_s)(G_{\eta s} + G_{\lambda s} + G_{\delta s})]$$

The meaning of the symbols has been given above, but it is necessary to point out the measurement unit (I*), which is the same as that used for the passage from (F_i) to (G_i) in paragraph 3.3, shown in figure 2,c.

In this specific case, the right link should be established between (F), expressed as index number, and (G), expressed in monetary unit per hour worked (£/hour), as shown in figure 2c.

The monetary values in the simulation require that adequate performances give (G) values that can compare with the basic remuneration.

The global value of (G) should be between 0% and 10% of the total remuneration and must derive from an economic return due to improvement in the correspondent (F), according to the normal rules of gain sharing (for example, 1/4 to price competitiveness, 1/4 to investments, 1/4 to the worker himself with G value, 1/4 to company capital).

Therefore, it is important to note that the result takes account of an individual share in order to underline the improvement trend for each single worker, and of a department share in order to emphasise the sense of belonging to the company and the solidarity between workers, as well as the responsibility to train less motivated colleagues.

Finally, it is necessary to multiply the value obtained (I*), expressed in (£/hour), by the number of hours the worker is present (p) during the time period being considered for remuneration (month, quarter, year), and by another coefficient (ρ), which takes account of the effective activity and position of the worker.

Measurement of the presence (p) of the individual worker is immediate because it derives from the normal management procedure, but it is more interesting to measure the position coefficient (ρ).

The position coefficient (ρ) may be a function of various elements, such as the individual contract category, the individual ability to carry out duties (multifunctional), the individual's main duty and his/her technical training.

The final result is given by the following expression:

$$R = (p) \times (\rho) \times (I^*).$$

4.3. Verifying sensitivity

The verification is done by using the model results on a historical series of real performance data for two years, in order to test the values of the complexity coefficient (α), by means of the parameters (K1), (K2), (K3), (K4), (K5), both at individual and department level, of the gain sharing law set between the index (G) and the factor correspondence (F) at individual and department level, and the index of individual position (ρ).

The verification is made on the assumption that the said model will lead to individual performance results (R) that are in line with the historical situation for all the plants in question and that any eventual differences, where acceptable, are clearly due to different production performances.

In reality, the sensitivity check gives its full approval to those sectors that are directly connected to the production system and indicates the need for an improvement in those departments that are not directly connected with production.

The solution to this weak point lies simply in varying certain values of the coefficient (ρ).

5. CONCLUSIONS

In conclusion, we can affirm that this model successfully evaluates the performance of individual workers, departments and the various plants, by means of the appropriate index, (I) if it is a multi-factor multiplication model, or (I*) if it is a multi-factor addition model.

Given that the reference standards are the same for all the plants, specific personalisation using complexity coefficients (α) gives an immediate comparison, once the variation intervals have been defined.

The applied simulation in question makes it possible to validate the variation ranges of coefficients, with the consequent applicability of the model itself.

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