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ANALYTICAL FRAMEWORK TO EVALUATE THE EFFECTIVENESS OF OPERATIONS IN AN INDUSTRIAL ENVIRONMENT FOR IMPROVISATION IN ITS PRODUCTIVITY – SOME ISSUES

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Abstract:
Inspite of being one of the most repeated words in all spheres of activities, the concept of productivity remain elusive and enigmatic. People talk any sort of thing in the name of productivity and nearly all of them are correct. It appears that endless string of words may be coined using productivity as the suffix. In this application paper, the author makes an attempt to measure the productivity of a continuous production system comprising of various interconnecting plants by two approaches and discussed the limitations and the advantages of both the approaches.

1. Introduction:

Peter Mauson, Kenneth I Carlaw and Nathan Mc Lellan (2003) provides a review of conceptual and methodological issues in measuring productivity. In his work, attention is given to the concept of productivity and technological change. Susan G. Powers (1998) discusses the cyclical pattern of multifactor productivity and focusses on the measurement of capital input, specifically, the measurement of capital discards. William D. Nordhaus (2000) introduces a new approach to measure the industrial productivity based on income-side data that are published by the Burea of Economic Analysis (BEA). Charles Kui-Wai (2003) discusses the usage of Cobb-Douglas production function to measure the productivity of Chinese economy.

The methodology discussed for measuring the productivity in this paper has been applied to a continuous process manufacturing organization consists of several inter connecting plants viz., Gasification, Ammonia, Urea and Steam Generation. The output from the manufacturing organization is the nitrogenous fertilizer "urea" . Coal is the principal raw material for the manufacturing process. The outpuit from one plant becomes the input for the next plant in the chain.

In such a complex manufacturing system, simply measuring the productivity as the ratio of output of the final product to the initial input fed to the process will not be helpful for any control purposes. In such a continuous manufacturing chain, it is desirable to compute the productivity at different stages of manufacture. This helps the production manager to identify the weak areas in the chain so that control action can be initiated to put them back on to the rails. Quantification of productivity of different plants also helps to create a healthy competitive environment amongst different plants of the organization.

Two approaches have been discussed in this paper viz., the measurement of factor productivity indices and Plant Productivity Factor for different plants.

2. **Productivity**:

Usual literature defines productivity conceptually as an attitude of mind and prevention of all kinds of waste. Mathematically, it is shown as a ratio of output to input, i.e.

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}}$$

When both output and input are expressed in the same units, productivity reduces to a number. Quite often, it is also represented as an index as a percentage of output to input. It is also to be noted that both unit less as well as productivity in units (for example, coal mine productivity in tones per man-hour) are accepted criteria. There are valid reasons for use of each one of them. Fact remains that one should not be too rigid in the text of the definition and be pragmatic in its computation, application and interpretation.

Another very common and often mixed up problem is the distinction and relationship between production and productivity. Production is the output and is an absolute figure. It can be increased, inter alia, by proportionate increase in input. In such a situation, while the production increases, the productivity does not really go up. Productivity may be shot up by increasing production with constant or less than proportionate increase in input. Any inter-firm comparison of productivity should also ensure that the firms being compared in terms of factor productivity are indeed comparable. A firm having old machineries can not be compared in terms of productivity with an other having the state-of-the-art technology even though they belong to the same industry sector. Only after ensuring this, one may infer about the level of productivities in the firm.

3. **Total Productivity Measure (TPM) of the Production Unit**:

In this method, productivity indices are computed for various factors of production viz., Labour, Equipment, Material and Other inputs. The following relations are used in computing the factor productivity indices.

$$\underset{\text{(A)}}{\text{Labour Productivity}} = \frac{\text{Value of the total output in Rs/-}}{\text{Value of Wages \& Salaries in Rs/-}}$$

Value of the total output in Rs/-

Equipment Productivity = --
(B) Value of Repairs & Maintenance and Depreciation in Rs/-.

Value of the total output in Rs/-
Material Productivity = --
(C) Value of all Materials Input including Power in Rs/-

Value of the total output in Rs/-
Other Inputs Productivity = ---------------------------------------
(D) Value of other expenses in Rs/-

The Total Productivity Measure (TPM) of the unit has been computed by integrating the above indices by using the following relation.

$$TPM = \frac{1}{1/A + 1/B + 1/C + 1/D} \qquad \text{---------- (I)}$$

The Productivity Indices, thus computed, are presented in the table – (1).

Table – (1) Productivity Indices of the Production Unit

Year	Labour Productivity	Equipment Productivity	Material Productivity	Other Inputs Productivity	Total Productivity Measure
1984—85	23.58	3.27	1.86	8.36	0.9940
1985—86	13.63	2.03	1.52	4.62	0.6951
1986—87	18.63	4.42	1.91	6.34	1.0400
1987—88	13.66	1.96	1.51	3.02	0.6100
1988—89	13.59	2.65	1.65	3.46	0.7430
1989—90	9.90	2.27	1.50	2.75	0.6362
1990—91	6.23	3.09	1.06	1.56	0.4834
1991—92	12.92	10.64	1.50	2.15	0.7672
1992—93	10.20	8.84	1.17	1.74	0.6096

1993—94	16.27	15.89	1.29	2.17	0.7350
1994—95	6.44	5.54	0.88	0.91	0.3889
1995—96	8.75	8.47	0.90	1.01	0.4285

The above method of computing the Total Productivity Measure (TPM) gives the performance of the entire production unit in an integrated way. The productivity indices of various factors of production indicate how efficiently and effectively these factors of production are put to use, in realizing the objectives of the organization. When these indices are computed year wise, over a period of time, it helps in comparing the performance of these factors of production on year-to-year basis. However, when this method is applied to a production unit comprising of various inter-connecting plants, it does not indicate the performance of individual plants. Hence the possibility of evaluating the plant wise performance is missing in this method.

4. **Inter Plant Productivity Model (IPPM)** :

The objectives and the computational details of the model are presented in the subsequent paragraphs.

4.1 **Objectives of the model**:

The model evaluates the performance of individual plants based on three critical operating parameters and has the following objectives:

a) To create a competitive environment amongst different operating plants.
b) To improve the consumption efficiencies.
c) To reduce the downtime of equipments.
d) To reduce the overtime element.

4.2 **The Scheme**:

A factor known as Plant Productivity Factor (PPF) is proposed to be calculated which is based on three sub-factors viz., Specific Consumption Efficiency Factor (SCEF), Minimum Loss Factor (MLF) and Overtime Minimisation Factor (OMF). Depending on the relative importance, weightages are attached to all these sub-factors as indicated in table – (2).

Table (2). Sub-factors & weightages for the productivity model

Sl. no.	Productivity sub-factor	Weightage
01	Specific Consumption Efficiency Factor (SCEF)	0.40
02	Minimum Loss Factor (MLF)	0.40

03	Overtime Minimisation Factor (OMF)	0.20
	Total	1.00

The Plant Productivity Factor is then computed using the following relation.

PPF = 0.40(SCEF) + 0.40(MLF) + 0.20(OMF) -------(II)

4.3 Computational Details of the Model:

The production unit under study is having four interconnecting operating plants and the computational procedure for SCEF, MLF and OMF are discussed in subsequent paragraphs of this paper.

4.3.1 Computation of Specific Consumption Efficiency Factor (SCEF):

The Specific Consumption Efficiency Factor for each plant is computed every month taking the standard specific consumption and actual specific consumption of the inputs. In each plant, different inputs are fed to the production process. All the inputs are not of equal importance. For example, in Plant-1, the value of the coal consumed is more than the value of power or fuel oil consumed. Therefore, higher weightage is given to coal when compared to power or fuel oil. Similarly in Plants-(2) & (3), the value of coal consumed is more than the value of power or steam consumed. Hence, more weightage is given to coal when compared to power or steam. In Plant—(4), the value of ammonia consumed is more than the value of power or steam consumed. Therefore, higher weightage is given to ammonia. The details are presented in table –(3).

Table—(3) Computation of SCEF of different plants

Plant	**Inputs**	Standard sp. consumption	Actual sp. consumption	Weighted ratio
Plant--1	Coal	SC_1	SC_2	0.50 (SC1 / SC2) ---(a)
	Power	SP_1	SP_2	0.30 (SP_1 / SP_2) ---(b)
	Fuel Oil	SF_1	SF_2	0.20 (SF_1 / SF_2) ---(c)
	SCEF for Plant--1			(a) + (b) + (c)

Plant--2	Coal	GC_1	GC_2	0.50 (GC_1/GC_2) ---(d)
	Power	GP_1	GP_2	0.30 (GP1/GP2) ---(e)
	Steam	GS_1	GS_2	0.20 (GS_1/GS_2) ---(f)
	SCEF for Plant—2			(d) + (e) + (f)
Plant--3	Coal	AC_1	AC_2	0.50 (AC_1/AC_2) ---(g)
	Power	AP_1	AP_2	0.30 (AP1/AP2) ---(h)
	Steam	AS_1	AS_2	0.20 (AS_1/AS_2) ---(i)
	SCEF for Plant—3			(g) + (h) + (i)
Plant—4	Ammonia	UA_1	UA_2	0.50 (UA_1/UA_2) ---(j)
	Power	UP_1	UP_2	0.30 (UP_1/UP_2) ---(k)
	Steam	US_1	US_2	0.20 (US_1/US_2) ---(l)
	SCEF for Plant—4			(j) + (k) + (l)

4.3.2 **Computation of Minimum Loss Factor (MLF)**:

In all continuous production systems, the loss of production will be booked , on daily basis, against the equipments and plants responsible for the same. For example, on a particular day, there is a loss of production of 500 MT of the finished product due to the breakdown of some equipment (say, raw gas blower) in Plant--2. Then, this loss of 500 MT is booked to the equipment "raw gas blower" of Plant--2. Thus, the total loss in each plant can be obtained for each month. Subsequently, the percentage loss in each plant is calculated. For a given percentage loss, the Minimum Loss Factor (MLF) is obtained from the table –(4).

Table—(4). Percentage loss Vs. MLF

Percentage loss	MLF
0—10	0.90
11—20	0.80
21—30	0.70

31—40	0.60
41—50	0.50
51—60	0.40
61—70	0.30
71—80	0.20
81—90	0.10
91—100	0.00

Thus, the MLF is calculated for each plant every month.

4.3.2 Computation of Overtime Minimisation Factor (OMF):

The manpower is deployed on overtime due to various reasons such as unforeseen breakdown of equipments during odd hours, absenteeism of employees etc., The rate of overtime wages is double the rate of normal wages. By proper planning, this overtime component can be minimised. For example, by adopting proper preventive and predictive maintenance policies, the equipment breakdowns can be minimised. Similarly by motivating the human resources, the industrial absenteeism could also be brought down. However, in continuous production systems, the overtime element can not be avoided totally. The overtime amount incurred in each plant is computed every month. Then, the overtime as a percentage of OT entitled employees is worked-out plant wise, every month. Subsequently, the Overtime Minimisation Factor is obtained from the table—(5) for the corresponding overtime percentage.

Table—(5). Overtime percentage Vs. Overtime Minimisation Factor

Overtime percentage	OMF
0	1.00
1—9	0.80
10—19	0.60
20—29	0.20
30—39	0.10
40—49	0.05
50 & above	0.00

Thus, the Overtime Minimisation Factor is computed every month for each plant.

4.4 Computation of PPF:

After computing the SCEF, MLF and OMF, the Plant Productivity Factor (PPF) for each plant is computed month wise, by using the relation (II) presented in paragraph (3.2) of this paper. The PPF thus obtained for a period of five(5) months is presented in table—(6).

Table—(6). Computation of Plant Productivity Factor (PPF)

Sl. no.	Plant / Factor	Month (1)	Month (2)	Month (3)	Month (4)	Month (5)	Average
1	Plant--1						
	SCEF	0.7258	0.7661	0.7332	0.8519	0.7653	
	MLF	0.2000	0.5000	0.2000	0.8000	0.7000	
	OMF	0.0000	0.0000	0.0000	0.0000	0.0000	
	PPF	0.3703	0.5064	0.3733	0.6608	0.5861	0.4994
2	Plant--2						
	SCEF	0.8089	0.8172	0.7196	0.9404	0.7187	
	MLF	0.8000	0.7000	0.8000	0.9000	0.7000	
	OMF	0.0000	0.0000	0.0000	0.0000	0.0000	
	PPF	0.6436	0.6069	0.6078	0.7362	0.5675	0.6324
3	Plant--3						
	SCEF	0.8089	0.8172	0.7196	0.9404	0.7187	
	MLF	0.9000	0.7000	0.8000	0.6000	0.5000	
	OMF	0.0000	0.0000	0.0000	0.0000	0.0000	
	PPF	0.6836	0.6069	0.6078	0.6162	0.4875	0.6004
4	Plant--4						
	SCEF	0.9277	0.9166	0.9159	0.9370	0.9000	
	MLF	0.9000	0.9000	0.9000	0.5000	0.9000	
	OMF	0.0000	0.0500	0.0000	0.0000	0.0000	
	PPF	0.7311	0.7266	0.7264	0.5748	0.7200	0.6958

5. Conclusions:

The Inter Plant Productivity Model (IPPM) has the capability of "intra-firm" comparison. This creates an atmosphere of competitiveness in the production unit amongst various plants which ultimately results in overall improvement in the organization. This model also has the capability of identifying a weak-link plant in the production unit so as to enable the management to take remedial measures in-order to improve the overall productivity of the organization. It is also recommended that the plant productivity factor can be computed month wise, so that the limitations in any plant can be immediately identified and suitable remedial measures are taken.

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