Productivity & Efficiency Measurement Model Development for Pre-serial & Unit Production Plants

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***Abstract*- Productivity and efficiency measurement and improvement go hand in hand, because one cannot improve what one cannot measure. Hence measuring productivity and efficiency is essential for all kinds of production plants to perform better. There is huge scope for research on measurement of the productivity and efficiency for pre-serial production plant, as there are no findings of literatures in this regard. This research is about the operations of pre-serial production plants and bottlenecks in adopting the standard methodologies of measurement of productivity and efficiency which are generally followed in serial production and batch production plants & developing a new measurement technique for productivity & efficiency for pre-serial & prototype production plants. As per the findings, the appropriate methodology for measurement of productivity and efficiency of Pre- serial production plants is not well set till now. Most of the companies who operates pre-serial production plants adapted the methodologies which are suitable only for serial production.**

As compared to serial and batch production plants, the pre-serial production plants work totally differently. In serial production plants the product is optimized and all the relevant data which contributes in the measurement of productivity and efficiency is available. The pre-serial plants are responsible for product optimization. In these plants the product optimization is primary objective and process is secondary. Hence we cannot finalize the inputs like cycle time, machining time; labor usage till the product is finalized. The value of input measures will keep on changing during optimization of product and process. Hence using these values for measurement of productivity makes no sense. Once the product is optimized then the suitable processes will get optimized and the trails will takes place. The results from trails will be considered as the input measures for productivity measurement. As the working methodology and process of serial and pre-serial production plants differs from each other, there is a need to develop a measurement technique which can efficiently measure the productivity of pre-serial plants.

The project comprises of defining a new measurement model/methodology for pre-serial plants and as per the pre-study it has been decided that the author will divide the production process into micro processes and define the standard for each process which will be considered as standard and compared with actual parameters which will leads to find out productivity and efficiency of the pre-serial production plants. This horizontal deployment of this methodology can be done to batch production and also prototype production plants with suitable modifications.

I. INTRODUCTION

Productivity and efficiency measurement and improvement go hand in hand, because one cannot improve what one cannot measure[1]. Hence measuring productivity and efficiency is essential for all kinds of production plants to perform better. There is huge scope for research on measurement of the productivity and efficiency for pre-serial production plant, as there are no findings of literatures in this regard. This paper discusses about the operations of pre-serial (prototype) production plants and bottlenecks in adopting the standard methodologies of measurement of productivity and efficiency which are generally followed in serial production and batch production plants.

Pre-serial production plants collect and evaluate the data related to product design and process, which establishes scientific evidence that a process is capable of consistently delivering quality products. The development of the actual product of required quality from design (CAD model) takes place in these plants. The objective of these plants is to design, develop and optimize a product as well as process which is suitable for flexible manufacturing system. The scope of the pre serial production work will start from freezing of CAD model. Then the design of appropriate tool or dies starts, followed by fabrication. The fabricated tool is then measured and tested for the specifications. The parts are then produced with the help of these tools and inspected and tested for defects. The defects are then analyzed and root cause for the same will be identified. The cause for defect may be improper process parameters, poor design. The second level of production takes place once the previous problems are solved. Like this a single part may take 6 to 7 levels of modifications to achieve desired quality. The same development process carried out for all the parts which are going to make an assembly. In this phase different assembly sequences and processes are performed and the efficient sequence and process is selected on trial and error basis. The suitable assembly layout is then built and the same assembly sequence is followed to measure the cycle time and cost incurred to perform this assembly.

As per the findings of author, the appropriate methodology for measurement of productivity and efficiency of Pre-serial production plants is not well set till now. Most of the companies who operates pre-serial production plants adapted the methodologies which are suitable for only for serial production. These methodologies fail to give proper results because of the following major reasons.

- Cycle time is one of the basic inputs for productivity and efficiency calculation. But in pre-serial production plants the cycle time is set on trial and error basis at the end of development phase. Hence using assumed cycle time for calculation makes no sense.
- As there is no fixed quantity of parts to be produced, it is very difficult to calculate the cost incurred for the production.
- As there is no set procedure to do the operations, it is very difficult to measure the efficiency of worker; hence it is not possible to calculate the manpower capacity utilization.
- In these pre-serial production plants at a time there may be more than one alternative products get developed. Hence calculation of the overhead costs for particular product may not be possible.
- As there is no cycle time set for production, the measurement of capacity utilization of machines and equipment is not possible. Hence calculation for machine cost for a particular product is not possible.
- As the assembly and production processes are built based on the trial and error bases, these plants should be well equipped with all kind of machineries and resources. Hence, while calculating the machining cost it is not feasible to consider only the machine which is decided to use for serial production.

II. LITERATURE REVIEW

Productivity models are used to measure the Total factor productivity and partial productivities. Various models have been suggested by different authors so as to fit to different productivity measurement scenario such as business level, national accounts or industry level. However all of them should satisfy the basic productivity equation which is defined as productivity = Output ÷ Input. There are some well-known approaches / methods adopted for analysis of productivity. These are stated below

a. Labor productivity based on gross output [1]

It is defined as the ratio of quantity index of gross output to quantity index of labor input[2]. It shows the time profile of how productively labor is used to generate gross output. The purpose of this method is gross-output based labor productivity traces the labor requirements per unit of (physical) output. It reflects the change in the input coefficient of labor by industry and can help in the analysis of labor requirements by industry. This method gives ease of measurement and readability. The limitation for this method is labor productivity is a partial productivity measure and reflects the joint influence of a host of factors. It is easily misinterpreted as technical change or as the productivity of the individuals in the labor force.

b. Labor productivity based on value added[2]

It is defined as the ratio of quantity index value added to quantity index of labor input. It is very easy for measurement and readability but labor productivity is a partial productivity measure and reflects the joint influence of a host of factors. It is easily misinterpreted as technical change or as the productivity of the individuals in the labor force. Also, value-added measures based on a double-deflation procedure with fixed-weight Laspeyres indices suffer from several theoretical and practical drawbacks.

c. Capital-labor MFP based on value added

It is defined as the ratio of quantity index value added to quality index of combined labor and capital input. Quantity index of combined labor and capital input is equal to Quantity index of (different types of) labor and capital, each weighted with its current-price share in total value added [8]. The purpose of this method is to analysis of micro-macro links, such as the industry contribution to economy-wide MFP growth and living standards, analysis of structural change. This method is easy for aggregation across industries, simple conceptual link of industry-level MFP and aggregate MFP growth, but not a good measure of technology shifts at the industry or firm level. When based on value added that has been double-deflated with a fixed weight Laspeyres quantity index, the measure suffers from the conceptual and empirical drawbacks of this concept.

d. Capital productivity based on value added [4]

It is defined as the ratio of quantity index value added to quantity index of capital input. The purpose of this method is to find changes in capital productivity indicate the extent to which output growth can be achieved with lower welfare costs in the form of foregone consumption. But capital productivity is a partial productivity measure and reflects the joint influence of a host of factors. There is sometimes confusion between rates of return on capital and capital productivity.

e. Craig & Harris (CH) model[4]

In this model[3] the total productivity of a firm is determined as the ratio of total output to the sum of input factors of labor, capital, raw material & other miscellaneous goods and services.

Where $P_t = \frac{Q_t}{L+C+R+Q}$

Pt= Total Productivity

L= Labor input factor, C= Capital input factor, R= Raw material and purchased parts input factor

Q= other miscellaneous goods and services input factor ,Qt= Total Output

The input factors are calculated as L= ∑ KNiKWk

Where NiK=Number of employees in category K in period I ,Wk =Base period wage for category K

Raw material and purchased parts factor is calculated as $Ri=\sum tvtjmj$

Where Ri= material input for iperiod,Vtj = Volume of material type j consumed in period t,

mj= Base period cost for material j The output is calculated as $Qt=\sum iPjUij$

Where Qt= Revenue due to visible output in period I, Pj= Price per unit for item j in base period,

Uij= Number of production units of item type j produced in period i.

f. Kendrick-creamer model

Kendrick and Creamer (1955) introduced productivity [8] indices at the company level in their book “Measuring company productivity”. Their indices are basically two types; total productivity and partial productivity. It can be calculated as below. Total productivity index for given period = (Measured period output in base period price) / (Measured period input in base period price) and partial productivity such as labour, capital or material productivity index can be calculated as; partial productivity = (Output in base period price) / (Any one input in base period price).

III. DISCUSSION & PROBLEM DEFINITION

As compared to serial and batch production plants, the pre-serial production plants work totally differently. In serial production plants the product is optimized and all the relevant data which contributes in the measurement of productivity and efficiency is available. The pre-serial plants are responsible for product optimization. In these plants the product optimization is primary objective and process is secondary. Hence we cannot finalize the inputs like cycle time, machining time; labor usage till the product is finalized. The value of input measures will keep on changing during optimization of product and process. Hence using these values for measurement of productivity makes no sense. Once the product is optimized then the suitable processes will get optimized and the trails will takes place. The results from trails will be considered as the input measures for productivity measurement. As the working methodology and process of serial and pre-serial production plants differs from each other, there is a need to develop a measurement technique which can efficiently measure the productivity of pre-serial plants.

The project comprises of defining a new measurement model/methodology for pre-serial plants. This model will be advanced ‘Productivity accounting model’ which take all the aspects of pre-serial production plant & it’s working. As per the pre-study it has been decided that the author will divide the production process into micro processes and define the standard for each process which will be considered as standard and compared with actual parameters which will leads to find out productivity and efficiency of the pre-serial production plants. This horizontal deployment of this methodology can be done to batch production and also prototype production plants with suitable modifications.

IV. DESIGNING OF EXPERIMENTS

4.1 Selecting Industry

Productivity & efficiency are the same phenomenon for all type of industries. But for this project we have selected automotive pre- serial production plant for the study. AS mentioned the research is focused on the pre-serial & unit production plants.

4.2 Selecting Units

For calculating the productivity & efficiency the inputs & outputs should be expressed in the same units. We have considered Minutes for the time & INR for the cost.

4.3 Selecting Model

There are many models for measuring productivity & efficiency are in practice. The ‘Productivity accounting model’ which is nothing but multifactor productivity measurement model suits to the research as the reference model.

V. CONCLUSIONS

As per the findings, the appropriate methodology for measurement of productivity and efficiency of Pre-serial production plants is not well set till now. Most of the companies who operates pre-serial production plants adapted the methodologies which are suitable for only for serial production.

As compared to serial and batch production plants, the pre-serial production plants work totally differently. In serial production plants the product is optimized and all the relevant data which contributes in the measurement of productivity and efficiency is available. The pre-serial plants are responsible for product optimization. In these plants the product optimization is primary objective and process is secondary. Hence we cannot finalize the inputs like cycle time, Machining time; Labor usage till the product is finalized. The value of input measures will keep on changing during optimization of product and process. Hence using these values for measurement of productivity makes no sense. Once the product is optimized then the suitable processes will get optimized and the trails will takes place. The results from trails will be considered as the input measures for productivity measurement. As the working methodology and process of serial and pre-serial production plants differs from each other, there is a need to develop a measurement technique which can efficiently measure the productivity of pre-serial plants.

The author defined (Annexure 2 & 3) new measurement model/methodology for pre-serial plants and as per the pre-study it the author divided the production process into micro processes and define the standard for each process which will be considered as standard and compared with actual parameters which will leads to find out productivity and efficiency of the pre-serial production plants. This horizontal deployment of this methodology can be done batch production and also prototype production plants with suitable modifications.

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Annexure 1:

TABLE INDICATING COMPARISON MATRIX FOR PRODUCTIVITY MEASUREMENT METHODS

Name of the productivity model	Definition	Benefits	Limitation
KendrickCreamer model	Total Productivity Index for given period = (Measured period output in base period price) / (Measured period input in base period price) and partial productivity i.e. labour, capital or material productivity index can be calculated as: Partial productivity = (Output in base period price) / (Any one Input in base period price)	Suitable for computing productivity indexes at the company level	Not suitable for the computation of TFP index in case of industries since it does not take into account all the inputs pertaining to industry such as energy, business services etc.
Craig-Harris model	Pt = Qt ÷ (L+C+R+Q) Where; Pt = total productivity, L = labour input, C = capital input, R = raw material input and Q = Other miscellaneous goods and services input, Ot=out put.	Suitable the computation of productivity for firm level and service sector and yields physical productivity	Not suitable for the computation of the TFP status of a pre-serial industry since it does not take into account all the inputs relevant to a pre-serial industry
American Productivity Centre model	Profitability = Sales / Cost = (Output quantity) (Price) / (input quantity) (unit cost) = (Productivity) (Price recovery factor) Where; productivity = output / inputs Price recovery factors = a factor which captures the effect of inflation	Suitable for accounting productivity at the business level and easy to compute productivity with the managerial data like profitability and price recovery factor.	Not suitable industrial use, since productivity measure in relation to an industry considers physical quantity of goods produced which may not be properly represented by profitability which depends on the demand of the goods produced.
Productivity accounting model	Total productivity = (Monetary value of production) ÷ (Monetary value of all inputs required for production) Partial productivity = (Monetary value of production) ÷ (Monetary value of any input required for production)	This model is one of the best models. It fulfills almost all the requirements of accounting for productivity. This model is based on accounting data. It takes into account all possible outputs and inputs used, keep out external factors such as price risk etc. In this model, output means monetary value of production and input means monetary value of all the inputs i.e. material, labour and overhead expenses.	Since it takes care of all types of inputs, requires monetary equivalent of inputs and outputs and keep out external factors such as price rise etc. this model has got wide applicability both in business sector and manufacturing and service sector

Annexture-2 Productivity Model

Project Level cost matrix

Labor

			Unit Time	Volume	Total Time
Production	Technology 1	Operation 1	1	15	15
		Operation 2	10	6	60
		Operation 3	25	9	225
		Operation 4	2	8	16
	Technology 2	Operation 1	5	7	35
		Operation 2	6	5	30
		Operation 3	9	6	54
		Operation 4	8	5	40
Quality	Part 1	Feature 1	7	9	63
		Feature 2	5	8	40
		Feature 3	4	4	16
		Feature 4	2	9	18
	Part 2	Feature 1	5	8	40
		Feature 2	9	5	45
		Feature 3	8	6	48
		Feature 4	4	9	36
Logistics	Movement 1	Type 1	9	8	72
		Type 2	8	5	40
		Type 3	5	21	105
		Type 4	6	4	24
	Movement 2	Type 1	4	5	20
		Type 2	2	99	198
		Type 3	6	8	48
		Type 4	2	2	4
			Conolidated time		1292
			Hourly rate		10
			Labour cost		12920

Machine & equipment

Machine	Hourly Rate	Hours Used	Total Cost
A	10	9	90
B	20	8	160
C	52	2	104
D	20	4	80
Consolidated machine cost			434

Resources

Resources	Unit Cost	Volume	Total Cost
A	5	2	10
B	6	5	30
C	8	6	48
D	5	5	25
	Resource Cost		113

Land

Zone	% use	/ Zone/ Unit	Time Used	Total Cost
A	50	250	2	250
B	25	44	6	66
C	25	558	8	1116
D	8	541	4	173.12
		Land Cost		1605.12

Material

Material	Unit Cost	Volume	Total Cost
A	25	36	900
B	2	88	176
C	56	65	3640
D	25	96	2400
	Material cost		7116

Project Cost Input	**22188.12**

Project A Productivity	
Project Cost Input	**22188.12**
Project Sales	**13150**
Project Productivity (%)	**59.26594953**

Plant Productivity	
Plant Cost Input	**93870**
Project Sales	**31472**
Project Productivity (%)	**33.5272185**

Plant Level cost matrix

Labor		Machine & equipment			
Wages	25000	Machine	Hourly Rate	Hours Avalable	Total Cost
Incentive	21000	A	10	100	1000
Rewards	3600	B	20	100	2000
Training	2500	C	52	100	5200
Facilities	5000	D	20	100	2000
Total Cost	57100	Consolidated machine cost			10200

Material				Land Cost	150000
Material	Unit Cost	Volume	Total Cost		
A	5	568	2840		
B	6	548	3288		
C	8	569	4552		
D	5	5214	26070		
	Material cost		36750		
	Plant Cost Input		**93870**		

Sales

Project Sales				Plant Sales	
Units	Unit Price	Volume	Total Price	Project	Revenue
A	25	526	13150	A	13150
B	15	265	3975	B	3975
C	52	258	13416	C	13416
D	56	562	31472	D	31472
	Total Capital		62013	Total	62013
	Logistic cost		2650		
	Tax		2560		
	Revenue		56803		

Annexure- Efficiency Model

Actual Time					Standard Time			
			Time					Time
Production	Technology 1	Operation 1	1		Production	Technology 1	Operation 1	1
		Operation 2	10				Operation 2	26
		Operation 3	25				Operation 3	14
		Operation 4	2				Operation 4	26
	Technology 2	Operation 1	52			Technology 2	Operation 1	48
		Operation 2	45				Operation 2	4
		Operation 3	25				Operation 3	5
		Operation 4	8				Operation 4	6
Quality	Part 1	Feature 1	7		Quality	Part 1	Feature 1	6
		Feature 2	5				Feature 2	8
		Feature 3	4				Feature 3	4
		Feature 4	2				Feature 4	5
	Part 2	Feature 1	5			Part 2	Feature 1	5
		Feature 2	7				Feature 2	9
		Feature 3	9				Feature 3	8
		Feature 4	4				Feature 4	4
Logistics	Movement 1	Type 1	8		Logistics	Movement 1	Type 1	9
		Type 2	6				Type 2	9
		Type 3	9				Type 3	5
		Type 4	8				Type 4	6
	Movement 2	Type 1	4			Movement 2	Type 1	5
		Type 2	3				Type 2	5
		Type 3	11				Type 3	6
		Type 4	5				Type 4	2
	Conolidated time		265			Conolidated time		226

			Volume	Total Actual	Total Std	Efficiency %
Production	Technology 1	Operation 1	15	15	15	100.00
		Operation 2	6	60	156	260.00
		Operation 3	9	225	126	56.00
		Operation 4	8	16	208	1300.00
	Technology 2	Operation 1	7	364	336	92.31
		Operation 2	5	225	20	8.89
		Operation 3	6	150	30	20.00
		Operation 4	5	40	30	75.00
Quality	Part 1	Feature 1	9	63	54	85.71
		Feature 2	8	40	64	160.00
		Feature 3	4	16	16	100.00
		Feature 4	9	18	45	250.00
	Part 2	Feature 1	8	40	40	100.00
		Feature 2	5	35	45	128.57
		Feature 3	6	54	48	88.89
		Feature 4	9	36	36	100.00
Logistics	Movement 1	Type 1	8	64	72	112.50
		Type 2	5	30	45	150.00
		Type 3	21	189	105	55.56
		Type 4	4	32	24	75.00
	Movement 2	Type 1	5	20	25	125.00
		Type 2	99	297	495	166.67
		Type 3	8	88	48	54.55
		Type 4	8	40	16	40.00
		Total Efficiecy		2157	2099	**97.31**