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Multifactor Productivity Measurements Model (MFPMM) as Effectual Performance Measures in Manufacturing

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Abstract: The main objective of this study is to compare the productivity measures typically used in manufacturing plants with the currently available theories of productivity measures. The study focuses upon the shortcomings of current measures and scope of improvement. It aims to determine the significance of introduction of the modern techniques. A case study has been carried out in a manufacturing plant. The existing productivity measures are analyzed and observed that the plant does not have proper and systematic productivity measures to monitor the productivity performance. Multifactor Productivity/Performance Measurements Model (MFPMM) is applied to monitor the productivity levels. Productivity measurement in the plant was assessed using six criteria - validity, completeness, comparability, inclusiveness, timeliness, and cost-effectiveness. As more criteria are met, the results of the measurement become more meaningful. Analysis on current productivity measures reveals that the present measures are far behind from being adequate and the firm faces a low productivity level. The MFPMM has the scope to portray the firm's performances in a comprehensive manner. The study attempts to provide an insight into productivity measurement and analysis, and improvement activities, including the phase of productivity measurement, and evaluation of the productivity level applicable in a manufacturing plant. The research identifies performance/productivity measure related shortcomings and their causes in a typical manufacturing plant and suggest solutions to overcome that. The ideas presented may be applied to other manufacturing settings.

Key words: Productivity, Productivity measurement, MFPMM, Manufacturing

INTRODUCTION

Productivity performance measurement has always been an important aspect in manufacturing. This is a long-term or progressing measure. This measurement is essential to benchmark and improve a company performance. Measurement steers human and system behavior. The results can be used to monitor the changes in productivity levels and provide the direction for improvement. Hence, the appropriateness of and accuracy in productivity measurement is vital.

Manufacturing plants have long been trying to apply various techniques to set different productivity indicators. However, the results of productivity measures have not always been able to represent the actual performance. Poor productivity performance faced by a manufacturing plant may often cause due to improper productivity measurement. For instance, many small and medium scale plants (SMIs) use a single/partial productivity indicator, which considers only one input viz. labour productivity. This is not sufficient to monitor the performance of the whole process and this may lead to costly mistakes. Ineffective partial productivity measurement cannot properly evaluate performance of the plant and may lead to make a wrong plan for performance improvement which may end up with more money and wasting of precious time.

Ideally, most manufacturing plants would like to find the method for the overall productivity improvement strategy. However, manufacturing plants that are searching for improvement strategies are still likely to find that they are unable to take full advantage of the modern methodologies and techniques. Part of this can be attributed by fear of changes, complexity in working culture, lack of management commitment and shortfall of personnel competency on appreciation and understanding of productivity.

Therefore, a study is felt necessary to identify the problematic areas and determine the solutions for

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improving productivity in such areas. This study provides a basis to determine the useful application of productivity measurement techniques sbased on six criteria. The main purpose of the research is to study how significant is the current and the actual level of productivity measures in order to represent the plant productivity.

The objectives of the study are:

- To identify the effectiveness of the current productivity measures.
- To identify and determine the problems those are causing low productivity in the factory.
- To suggest a productivity measurement system for monitoring productivity improvement.
- To suggest improvement techniques in order to overcome the identified pitfalls.

Related Literature:

Over two century ago, the term productivity was used in the Journal de l'Agriculture (Tangen, S., 2005). It has been applied in many different circumstances, particularly in relation to economic system, at various levels of aggregation. Productivity is the ratio of what is produced by an operation of process to what is required to produce it, or put simply the ratio of actual output to input over a period of time. Inputs might include transforming and transformed resources (such as materials, equipment, customers and staff) and the outputs are goods and services (Schroeder, R.G., 1985; Slack, N *et al,* 2001).

In industrial engineering, productivity is generally defined as the relation of output (i.e. produced goods) to input (i.e. consumed resources) in the manufacturing transformation process. However, there are numerous variations on this basic ratio which is often too wide, a definition to be useful in practice. Examining the term from different perspectives, Tangen (2005) summarize a number of these variations found in different literatures (Table 1).

Table 1: Examples of definitions of productivity

Definition
Productivity - faculty to produce
Productivity is what man can accomplish with material, capital and technology. Productivity is mainly an issue of personal manner. It is an attitude that we must continuously improve ourselves and the things around us.
Productivity - units of output/units of input
Productivity - actual output/expected resources used
Productivity - total income/(cost + goal profit)
Productivity - value added/input of production factors
Productivity is defined as the ratio of what is produced to what is required to produce it. Productivity measures the relationship between output such as goods and services produced, and inputs that include labor, capital, material and other resources.
Productivity (output per hour of work) is the central long-run factor determining any population's average of living
Productivity - the quality or state of bringing forth, of generating, of causing to exist, of yielding large result or yielding abundantly
Productivity means how much and how well we produce from the resources used. If we produce more or better goods from the same resources, we increase productivity. Or if we produce the same goods from lesser resources, we also increase productivity. By "resources", we mean all human and physical resources, i.e. the people who produce the goods or provide the services, and the assets with which the people can produce the goods or provide the services.
Productivity is a comparison of the physical inputs to a factory with the physical outputs from the factory.
Productivity - efficiency * effectiveness = value adding time/total time
Productivity - (output/input) * quality = efficiency * utilisation * quality
Productivity is the ability to satisfy the market's need for goods and services with a minimum of total resource consumption.

The basic content seems to be the same in many definitions of productivity. However, within the similar definitions, there are three broad categorizations: i) the technological concept: the relationship between ratios of output to the inputs used in its production; ii) the engineering concept: the relationship between the actual and the potential output of a process; and iii) the economist concept: the efficiency of resource allocation.

Although the definition of productivity appears straightforward, for three major reasons it is difficult to deal with (Andersson, T.D., 1996; Fitzsimmons, J.A. and M.J. Fitzsimmons, 1997: Witt, C.A. and S.F. Witt, 1989). First, the outputs are usually expressed in different forms to the inputs. Outputs are often measured in physical terms such as units (e.g. cars produced), tonnes (of paper), kilowatts (of electricity), or value (euros) for example. However the inputs are usually physically different and include measures of people (numbers, skills, hours worked or costs) or materials (tonnes and costs) for example. Second, the ratio by itself tells us little about performance. A ratio of 0.75 is of little value unless it is compared with previous time periods, or a benchmark, or the potential productivity of the operation. Third, many different ratios can be used (both financial and non-financial, that can be used to create productivity ratios).

Total factor productivity (TFP) is the ratio of the total output of all products and services to the total resource inputs which can be disaggregated into separate product and service productivity, single factor productivity (SFP), e.g. the output of product X over the input resources for product X. Productivity combines the concepts of effectiveness and efficiency, where effectiveness is the degree to which end results are achieved to the required standard (Slack, N., 1997). Growth is a function of total factor productivity (TFP), which is the aggregation of partial productivities (Heap, J., 2007).

$$Total\ productivity = \frac{Total\ output\ (sales, inventory, change, etc. in\ money\ unit)}{Input\ (Labour + material + capital + energy + other\ expense)} \quad (1)$$

Craig and Harris (Craig, C.E. and R.C. Harris, 1973) provided a total productivity model at the firm level. The formula is $P = \frac{O}{L+M+C+R+Q}$; Where Pt = total productivity; L = labour input factor; C = capital input factor; R = raw material and purchased parts input factor; Q = other miscellaneous goods and services input factor and O_t = total output.

According to (Kaydos Kaydos, W., 1991), productivity and subsequently performance measurement have been regarded as a prerequisite for continuous improvement. When focusing on the industries, national, and international levels, many approaches have been designed by economists such as the total factor productivity (TFP), or Bureau of Labor Statistics (BLS) multifactor productivity techniques (Duke, J. and V. Torres, 2005; Meyer, P.B. and M.J. Harper, 2005; Tsai, W.H., *et al*., 2006). At the organizational, functional, program, and project levels, there have been several concepts and ideas involving in the measurement/assessment work. The balanced scorecard concept (Kaplan, R.S. and D.P. Norton, 2004). has often been cited. The Sink and (Tuttle Sink, D.S. and T.C. Tuttle, 1989) approach has been widely adapted by public/private organizations. Harper (Harper, J., 1984) also develops a performance measurement framework at the organizational/functional levels. The concepts initiated by Sink (1985) , and Harper (1984) share one similar aspect - the use of a ratio-format KPI that primarily relies on quantitative data (Hoehn, W.K., 2003). At the group and individual levels, there were many concepts such as motivational methods based on industrial psychologists and performance appraisals for salary structure/workload analysis extended by human resource specialists, and piece-rate/standard times determined by industrial engineers (Takala, J. *et al,* 2006). Sumanth (1985) considers the impact of all input factors on the output in a tangible sense. Total productivity (Schroeder, R.G., 1985), total productivity in firm (Slack, N., *et al,*2001) and total productivity of products (Andersson, T.D., 1996) are defined as mentioned below.

$$Total\ productivity = \frac{Total\ tangible\ output}{Total\ tangible\ input} \quad (2)$$

$$Total\ productivity\ in\ a\ firm = \frac{Total\ output\ of\ the\ firm}{Total\ input\ of\ the\ firm} \quad (3)$$

$$Total\ productivity\ of\ product\ i, TP_i = \frac{Total\ output\ of\ product\ i}{Total\ input\ for\ product\ i} \quad (4)$$

Where Total tangible output = Value of finished units produced + Value of partial units produced + Dividends from securities + Interest from bonds + other income and Total tangible input = Value of (human + material + capital + energy + other expense) inputs used. For a better detail, types of tangible inputs are listed as follow:

- Human - Workers, Managers, Professionals, Clerical staff.
- Fixed capital - Land, Plant (buildings and structures), Machinery, Tools and equipment, and others
- Working capital - Inventory, Cash, Accounts receivable, Notes receivable.
- Materials - Raw materials, Purchased parts
- Energy - Oil, Gas, Coal, Water, Electricity and etc.
- Other expense -Travel, Taxes, Professional fees, Marketing, R&D, etc.

If *0* and *t* represent subscripts corresponding to base period and current period respectively, then the total productivity index for the firm and for a product are $(TPIF)_t = \frac{TPF_t}{TPF_0}$ $(TPI)_{it} = \frac{TPF_{it}}{TPF_{i0}}$

Basically, total productivity index of firm and product *i* can be used to evaluate productivity between base and current periods. This lends itself to productivity evaluation, planning, and productivity improvement in a scientific manner. Gold (1980) proposed a financial-ratio approach to productivity measurement. His measure focuses on the rate of return on investment, and it attributes profit sense to five specific elements of performances: product prices, unit costs, utilization of facilities, productivity of facilities, and allocation of capital resources between fixed and working capital. He combines these five elements in the following equation (5) in order to measure the productivity of a company by the rate of return on its invested capital.

$$\frac{Profit}{Total\ investment} = \left[\frac{Product\ revenue}{Output} - \frac{Total\ costs}{Output}\right] X \frac{Output}{Capacity} X \frac{Capacity}{Fixed\ investment} X \frac{Fixed\ investment}{Total\ investment}$$

It is generally agreed that productivity represents one of the major areas reflecting the term performance, especially for an organization or a production unit (Hoehn, W.K., 2003; Sumanth, D.J., 1985;Helo, P., 20050 . Based on Sink and Tuttle (1989) , there are seven performance criteria; i.e. profitability, productivity, quality of work life, innovation, quality, effectiveness, and efficiency. It is vital for an organization to become continuously more productive in order to sustain its growth Harper (1984).

The MFPMM was developed by the American Productivity Center in 1977 (nowadays known as the American Productivity and Quality Center) for measuring productivity and price recovery, and for explicitly relating these results with profitability at the organizational/ functional levels Sink (1985). Its primary focus is on a manufacturing/production unit with tangible outputs and inputs. It is suitable for a process that is stable, implying not-so-often changes in products being offered (Tuttle Sink, D.S. and T.C. Tuttle, 1989). Finally, the MFPMM can easily adapt the data from a typical accounting system. Figure 1 shows its major components. Multifactor productivity is the ratio of output to the sum of two or more inputs in the same breadth of time. For example:

$$Multifactor\ productivity = \frac{output}{(Material + Labour)\ Inputs} = \frac{output}{(Material + Labour + Machine)\ Inputs}$$
$$= \frac{output}{(Machine + Capital)\ Inputs} = \frac{output}{(Machine + Capital + Labour)\ Inputs}$$

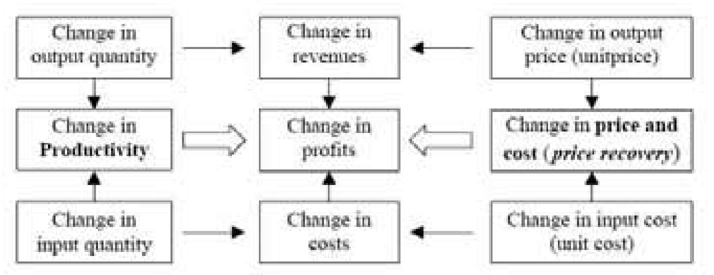

Fig 1: Nine basic components for the MFPMM.

The multifactor productivity measurement model (MFPMM) is a comprehensive and analytical to measuring changes in productivity. This model uses the techniques to break the total variation into price effects and productivity effects. The analyses can be done on both inputs and outputs in more flexible forms. Therefore the MFPMM offers a valid productivity model.

Research Design and Framework:

The MFPMM was selected to be applied to a plant. The monthly productivity performance was measured comparing to the previous period or last period. In MFPMM, the inputs are man-hour, material, and energy. Figure 2 shows the framework of the research. The research was carried out in three phases: i) Study the present productivity measurement and its relevance or shortcomings to performance measures; ii) Selection of the appropriate productivity measurement model and its introduction; and iii) Determination of the appropriate improvement techniques.

Multifactor Productivity Measurement Model (MFPMM) Analysis via Spreadsheet:

A simplified model using Microsoft Excel spreadsheet is developed to fulfill the requirements of its formulas. Basically, the productivity measurement model consisted of 19 columns for data entry. That was done to evaluate the performance of the plant in terms of productivity, price recovery, and profitability. Figure 4 shows the outline of simplified MFPMM using Microsoft Excel

The first six (1-6) columns of the MFPMM are input data columns. Column 1 represents quantities of outputs the organizational system produced and/or sold and quantities of input resources consumed in order to produce those outputs for period 1, which is the base-period. Column 2 represents the unit price for outputs and unit cost for inputs during period 1. Column 3 reflects the value (quantity x price) for each row element. Therefore, column 3 represents revenues for outputs and costs inputs. Column 4 - 6 is the same as column 1 - 3 except that they are data for period 2 or the current period. The next three (7-9) columns in the MFPMM are titled “Weighted change ratio”. Column 7 represents price-weighted and base-period price index changes in quantities. Column 7 holds constant the effect of prices and just examines the price-weighted changes in quantities of outputs. Column 8 represents quantity-weighted and current-period index changes in unit prices and unit costs.

Column 8 holds constant the changes in quantities of outputs and inputs and examines the changes in unit prices and unit costs from period 1 to period 2. Column 9 examines the simultaneous impact of changes in price and

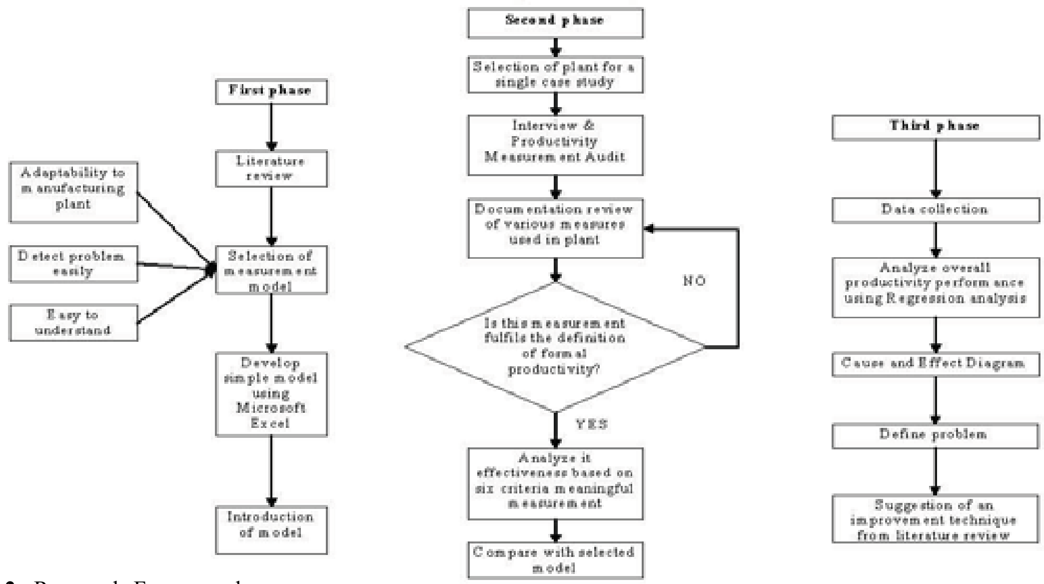

Fig 2: Research Framework.

quantity from period 1 to period 2 for each row in the model. Column 10 and 11 are labeled “cost/revenue ratios”. They indicate the ratio of input row elements for column 3 and 6. Column 10 is the cost-to-revenue ratio for period 1 and column 11 is the cost-to-revenue ratio for period 2. Column 12 and 13 are titled “Productivity Ratios”. Column 12 reflects the output-to-input ratios for period 1, while column 13 reflects the output-to-input ratios for period 2. Columns 14 - 16 are titled “Weighted performance indexes”. Column 14 reflects price-weighted productivity indexes. Column 15 represents quantity weighted price recovery indexes. Column 16 depicts profitability indexes. Finally columns 17 - 19 reflect the money equivalence of corresponding cells in column 14 - 16. In other words, these columns indicate what impact on productivity (column 17) and price recovery (column 18). The total impact on profits from productivity and price recovery is indicated in column 19.

The Case Study:

Current Measurements in BAC Plant:

BAC Plant has been divided into several main departments which are administrative, store, production, accounts, and sales departments. Each department recorded the performance of the activities on a daily basis and summarized that at the end of the month in order to evaluate the performance of the plant. The existing performance measurement in the plant is shown in Table 2. It is observed that the plant does not have proper measurement system to measure and evaluate its productivity. However, the measurements which fulfilled the definition of productivity are pre-expansion yielding and silo to machine yielding. Although it used proper measurement to evaluate the performances of the labor, but this does not give a measure of operating efficiency. Therefore, more comprehensive Multifactor productivity measurement model (MFPMM) is proposed for the plant.

Data Analysis and Discussions:

Figure 4 shows the outline of simplified MFPMM using Microsoft Excel. From its contents, two graphs are produced and represented column 14 - 16 and column 17 - 19. The left hand side graph shows about the changes of performance in February based on the weighted performance index which included productivity index, price recovery index, and cost-effectiveness index for different types of resources. The right hand side graph shows the monetary effect on profits. That means there would be an impact on profit if there is any change in productivity, change in price recovery, and simultaneous change in productivity and price recovery.

Performance in February Compared to January:

From Figure 4 (column 7-19), the effect of factors are analyzed and the summary of the studies are shown in Table 3. As a summary, the unproductive use of energy indeed did not create a drain on profit due to increase in price recovery. However, to improve productivity, the crucial problem areas would be the amount of fuel and electricity consumptions too. Also, the material had brought negative impact on the profit although the material productivity improved due to the decrease in price recovery index. Therefore, the management should look for the better price for the material cost or adjustment on the price of output.

The questions arise if it were meaningful or reflecting the real material productivity in the plant. Therefore, these measures are compared to the aforesaid 6 criteria to define the significance of the measurement.

Table 2: Existing performance measurements in a plant

Productivity Measurement	Evaluation
$\%\ of\ overtime\ Vs\ total\ sales = \dfrac{Total\ overtime\ worked\ (hr)}{Total\ sales\ (RM)}$	This measure indicated the overtime expenses for the sales value. An increase in the total overtime work indicates the cost increase and this affects the profitability of plant. This measure does not fulfill the definition of the productivity.
$\%\ of\ oT\ Vs\ total\ man-hour = \dfrac{Total\ overtime\ worked\ (hr)}{Total\ man-hour\ (hr)}$	This measure has indicated overtime contributes in total man-hours. This measure only tells the top management the percentages of overtime used. This measure does not fulfill the definition of the productivity because this measure does not have any output from the production system or process.
$Ratio\ of\ OT\ paid\ to\ prod.\ ton = \dfrac{Overtime\ (RM)}{Prod.\ tonnage\ (kg)}$	This measure indicated the paid for overtime in order to produce 1 kg of output. As compared to the definition of productivity, this ratio is the inverse of productivity.
$Pre-expansion\ yielding = \dfrac{Production\ tonnage\ (kg)}{Raw\ material\ (kg)}$	According to the person in-charge, pre-expansion yielding was a measure of efficiency of pre-expansion process. However, this measure valuates the efficiency of raw materials in order to produce final output in kg. According to the definition of output, this measure fulfills the measurement of productivity.
$Silo\ to\ machine\ yielding = \dfrac{Production\ tonnage\ (kg)}{Expd.(EPS)\ material\ (kg)}$	After pre-expansion process, the raw materials became expanded polystyrene (EPS) resins. Again it measured the efficiency of EPS in order to produce final output in terms of kilogram. This measure fulfills the definition of productivity.
$Fuel/water\ index = \dfrac{Fuel/water\ consump.(liter)}{Production\ tonnage\ (kg)}$ $Electrical\ index = \dfrac{Elect.\ consumption\ (kW)}{Production\ tonnage\ (kg)}$	Three measurements were used to evaluate the performance of energy consumption in production department. Water and fuel were measured in liters whereas the electricity was measured in kilowatt. These measures mean that 1 kg of output requires how much of energy (water, electrical and fuel). These measures are the inverse of productivity.
$\%\ reject\ during\ WIP = \dfrac{Total\ reject\ (kg)}{Total\ Produced\ (kg)}$	This measure evaluated the quality performance in production during WIP. An increase in percentage value, it means that the rejection is high, quality problem has occurred in the production process and this does not bring benefit to the plant. This measure is not a productivity measures since there is no input in the formula. It is a quality performance measure.
$\%\ Defect\ in\ finished\ goods = \dfrac{Total\ defect\ (pcs)}{Total\ quantity\ (pcs)}$	This measure was taken after completion of finished goods. Quality of defect in products is examined. It evaluates the amount of defect compared to the total quantity of product. An increase in percentage means that quality of product is deteriorated in which it might require rework or otherwise scrap. This would rather reduce the profitability of the plant. This measure is not productivity measures because there is no output as a denominator in the measurement system. It is more related to quality performance measure.

Effectiveness of Current Productivity Measurement in BAC Plant:

The productivity measurement in the BAC plant was based on raw material and expanded polystyrene (EPS) material. The formulas used for measurement are stated below. Raw materials are converted to EPS through pre-expansion process and produced into final product in moulding machine. Therefore productivity measurements are measured in 2-stages which are before and after the expansion. Figure 3 explained the two stages of the process and its related measurements.

1. Pre-expansion Yielding = Production tonnage(kg) / Raw material(kg)
2. Silo to machine Yielding = Production tonnage (kg) / EPS material(kg)

Validity:

Pre-expansion yielding measures the raw material required in resin form to produce total production tonnage whereas silo to machine yielding measures the EPS material used to produce the total production tonnage.

Material quantity is calculated based on the closing stock balance. The exact weight after expander and the amount sent to silo was not known. The quantity issued from store to silo was based on weight

Table 3:

Study	Column	Effects/Impacts
Effect of weighted price with change in quantity	7	28% and 31% increase and 4% decrease in material, energy and labor (man-hr) respectively. The overall 25% increase in overall inputs and eventually 28% increase in output.
Effect of weighted-quantity with change in price	8	4% increase in material, labor (man-hr) and energy consumption remain same. 4.2% increase in overall inputs and hence 6% increase in output price.
Effect of simultaneous change in price/cost and quantity	9	34% increase in revenue, 4% decrease in labor (man-hr) cost, 35% increase in material cost, 31% increase energy cost and 30% increase in overall input cost.
Cost compared to revenue generated	10-11	1% increase in material and 4% and 1% decrease in labor (man-hr) and energy cost respectively
Productivity ratio and Price-weighted productivity indexes	12-14	34.7% and 0.9% increase labor and material productivity respectively. 1.8% decrease energy and eventually 2.6% increase in overall productivity.
Weighted -quantity price recovery indexes	15	Respectively 4% increase both in labor and energy and 2% decrease in material price recovery, but the overall price recovery index remain constant.
Cost-effectiveness indexes	16	41% and 2% increase in labor and energy respectively, 1% decrease in material and 3% increase in total input
Impact of productivity change on profits	17	Labor and material productivity contributed 14040.50 and 3352.45 RM more, but the energy reduced the profit by 2187.55 RM.
Impact of price recovery change on profits	18	The price recovery of labor and energy contributed 2312.71 and 4662.73 RM more respectively, but material reduces 6048.19 RM.
Simultaneous impact on profits from productivity and price recovery changes	19	Although material was created a drain on profits about RM 2695.75, increase of productivity and price recovery in labor and energy improve the profits. All inputs contributed positively to profits RM 16417.65.

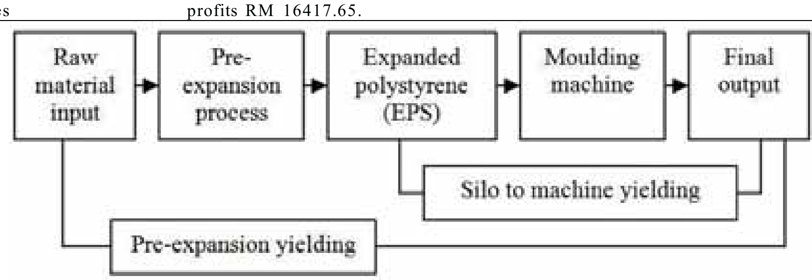

Fig 3: Two stages of process.

of material (which had not been expanded).This weight of material was then added to the weight of opening balance in silo (which material had been expanded). As the total sum of the weight issued to machine come from two different conditions, the total weight calculation is not valid. Therefore, silo-to-machine yielding (production tonnage/quantity issue from silo to machine) does not accurately reveal the productivity of the plant. It only can show the performance of machine in order to produce final product.

Completeness:

Completeness refers to the thoroughness with which outputs or result delivered and all inputs, or resources consumed, are measured and included in the productivity ratio. Pre-expansion yielding and silo-to-machine yielding obviously did not include all the inputs and outputs. It only included the materials beads used to produce output. Thus, it cannot reflect the overall productivity performance which consumed others resources such as energy, labor and capital.

Comparability:

Productivity between two periods is a relative measure. The yield measured in the BAC Plant can be compared if there is no change in price or cost of the material. However, when there are varieties in product or change in price or cost, the productivity measure has less significance. In case of price rise, the total value of the output will rise, even if nothing else changes and the resultant productivity index will indicate a false increase. Therefore, the material productivity in the plant may not suitable for comparison because the measure does not include any weighted unit which can give the constant value.

Inclusiveness, Timeliness and Cost-effectiveness:

From the point of inclusiveness, the productivity measurement system in BAC Plant only included the production activities, but not others activities such as quality, and purchasing. On timeliness, the measurement applied once a month. This could not reveal all problems and no action could be made as soon it was required. On cost-effectiveness, the system measured the material used for production but not the cause of interruption to the ongoing production efforts of the plant.

Multifactor Productivity Model (MFPMM)

	Period 1			Period 2			Weighted change ratio		
	Quantity	Price	Value	Quantity	Price	Value	Quantity	Price	Value
	col 1	col 2	col 3	col 4	col 5	col 6	col 7	col 8	col 9
Output (kg)	69237.00	4.70	325413.90	89224.00	4.90	437197.60	1.29	1.04	1.34
Total Outputs			325413.90			437197.60	1.29	1.04	1.34
Direct labor M-HR	14058.00	3.00	42174.00	13436.00	3.00	40308.00	0.96	1.00	0.96
Total Labor			42174.00			40308.00	0.96	1.00	0.96
Material (kg)	74700.00	3.88	289836..00	95400.00	4.11	392094.00	1.28	1.06	1.35
Total Material			289836.00			392094.00	1.28	1.06	1.35
Fuel (liter)	95602.00	0.78	74569.56	125197.00	0.78	97653.66	1.31	1.00	1.31
Electricity(kW)	36791.75	0.20	7358.35	50756.00	0.20	10151.20	1.38	1.00	1.38
Water(liter)	310065.00	0.01	3100.65	367195.00	0.01	3671.95	1.18	1.00	1.18
Total Energy			85028.56			111476.81	1.31	1.00	1.31
Total Inputs			417038.56			543878.81	1.25	1.04	1.30

Table Continued.

	Cost/Revenue ratio		Productivity ratio		Weighted Performance Indexes			Ringgit effects on profits		
	Period 1	Period 2	Period 1	Period 2	Change in productivity	Change in price recovery	Change in profitability	Change in productivity	Change in price recovery	Change in profitability
	col 10	col 11	col 12	col 13	col 14	col 15	col 16	col 17	col 18	col 19
Output (kg)										
Total Outputs										
Direct labor M-HR	0.13	0.09	7.72	10.40	1.35	1.04	1.41	14040.58	2312.71	16353.29
Total Labor	0.13	0.09	7.72	10.40	1.35	1.04	1.41	14040.58	2312.71	16353.29
Material (kg)	0.89	0.90	1.12	1.13	1.01	0.98	0.99	3352.45	-6048.19	-2695.75
Total Material	0.89	0.90	1.12	1.13	1.01	0.98	0.99	3352.45	-6048.19	-2695.75
Fuel (liter)	0.23	0.22	4.36	4.29	0.98	1.04	1.03	-1557.72	4089.19	2531.47
Electricity(kW)	0.02	0.02	44.22	41.31	0.93	1.04	0.97	-668.68	403.51	-265.17
Water(liter)	0.01	0.01	104.95	114.20	1.09	1.04	1.13	323.78	170.03	493.81
Total Energy	0.26	0.25	3.83	3.76	0.98	1.04	1.02	-1902.62	4662.73	2760.11
Total Inputs	1.28	1.24	0.78	0.80	1.03	1.00	1.03	15490.41	927.24	16417.65

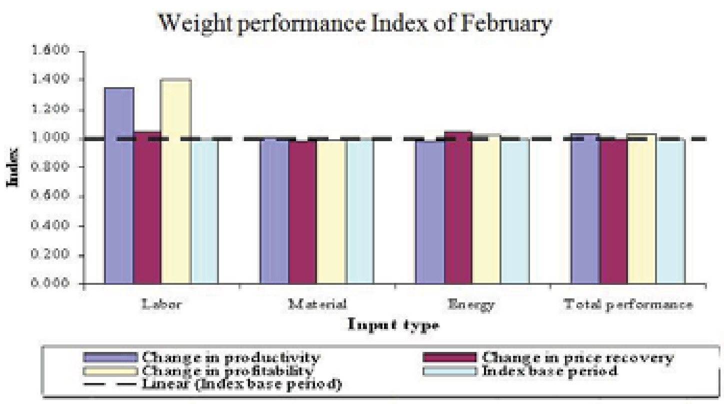

Fig. 4a:

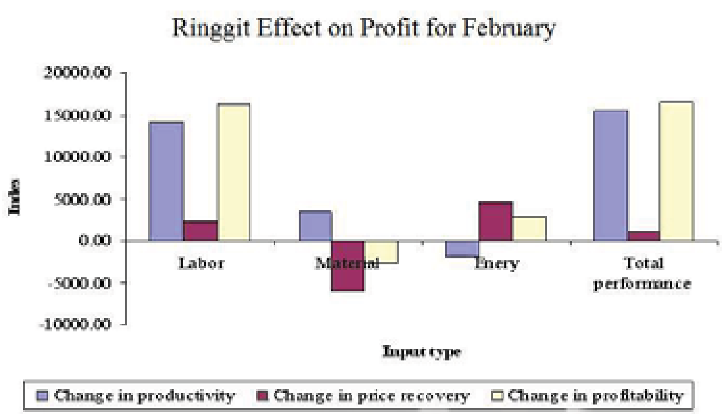

Fig 4: MFPMM for February compared to January

From the above discussion, the silo-to-machine yielding was not a valid productivity measure since it did not bring any meaningful measures to the plant. However, the pre-expansion yielding can be referred as a material productivity ratio. Summarily, the current productivity measurement cannot accurately reflect the productivity of the plant.

Comparison Between Productivity Measurement in BAC Plant and MFPMM:

BAC Plant use pre-expansion yielding and silo-to-machine yielding as a productivity measure. However, the silo-to-machine yielding is not a valid productivity measure as discussed. Therefore, the pre-expansion yielding is referred as productivity measurement in BAC plant and compared with MFPMM. As compared to MFPMM, pre-expansion yielding is less comprehensive than MFPMM in terms of completeness and comparability.

The MFPMM model is more comprehensive in term of completeness where it includes all outputs and inputs. In this study, the MFPMM consider three types of inputs which are man-hour, material, and energy. In pre-expansion yielding only material in use was considered. So, it could not pinpoint the problem related to energy consumption and labor. Therefore, pre-expansion yielding did not expose the overall productivity of the plant. This may not happen in MFPMM model where the model assists in determining the area that brings serious problem.

In terms of comparability, MFPMM has considered the impact of changes in cost of resources consumed and changes in prices of outputs. MFPMM model holds constant price and cost changes over time. MFPMM also hold constant price and cost but check for change in quantity which results in change of productivity. Besides, MFPMM hold constant quantity but observe for change in the price and cost which result in change of price recovery. As a summary, MFPMM is more comprehensive than pre-expansion yielding as it can be used:

- To obtain an overall, integrated measure of productivity for the firm.
- To provide an analytical audit of past performance
- For budgetary control of current performance
- For constant price financial statements
- To assess and evaluate bottom-line impact of profitability as a result of productivity shifts
- To track the results of specific productivity improvement efforts, such as quality circles, quality control, incentive systems, and technological innovation
- To measure initial distribution of benefits flowing from gains and losses in the productivity of the firms
- To assist with setting productivity objectives and general strategic planning with regard to capacity utilization, marketing efforts, cost management, staffing, quality management, pricing strategies and so forth.

Conclusion:

The objectives of the study have been achieved and these are summarized as follows:

- Multifactor productivity measurement model (MFPMM) as the price-weighted, indexed, and aggregated multifactor productivity measurement model, is a comprehensive model compared to partial measurements. MFPMM enable an organization to monitor historical productivity performance and measure how much, in terms of financial or profit is affected by productivity growth or decline. Besides, it can help determine the problem areas for improvement.
- This study presents a simple program developed by using Microsoft Excel spreadsheet program to analyze and monitor MFPMM. This is suitable to be used in manufacturing plants as Microsoft Excel is common software. MFPMM can be highly interactive in a computerized online system possessing with several appealing software features that make it a valuable decision support system.
- The overall productivity performance of BAC plant related to low productivity in material, energy and labor is not satisfactory as evidenced from regression analysis. The crucial problem was labor productivity which was caused by poor work method. Work method study has been partially applied to analyze the workstations behavior. Improvements in several tangible terms have been reported and found to be appealing. Proper method study and job design can produce excellent results. The *suggested* improvement can reduce the waiting time and travel distance by redesigning the plant layout and activity.

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