Journal of
INDUSTRIAL
TECHNOLOGY

Volume 18, Number 2 - February 2002 to April 2002

A Consolidated Approach to Productivity Assessment

By Dr. Bruce Marsh

KEYWORD SEARCH

Management
Manufacturing
Production
Quality

Reviewed Article

The Official Electronic Publication of the National Association of Industrial Technology • www.nait.org

Dr. Bruce Marsh is an Associate Professor with the Department of Industrial Technology at Texas A&M University in Kingsville where he teaches courses in Fluid Power, Energy and Power, Dimensional Metrology, Quality Assurance, Manufacturing Productivity and Data Analysis and Decision Making in Industrial Technology. He is also the academic advisor for the Student Chapter of the Fluid Power Society.

A Consolidated Approach to Productivity Assessment

By Dr. Bruce Marsh

Introduction

Various factors are impacting the way manufacturing and service companies operate today, factors such as an interconnected and interdependent world, shifts in economic demographics, global markets and competition, ecological concerns, and a sustainable future. According to Sumanth (1998), the impact of these factors is motivating companies to focus additional efforts on:

- long-term results over short-term gains,
- global markets in addition to domestic markets,
- strategic activities over operational activities,
- strategic visions along with practical actions,
- external stakeholders along with internal employees,
- product and service quality over productivity, and
- employee participation over pure individualism.

Although one of the identified trends indicates a greater emphasis on product and service quality instead of productivity issues and concerns, this is not to say that these issues and concerns should be dismissed. In actuality, productivity assessments and evaluations should be continued to include a more holistic focus of the organizations as a whole instead of a narrow focus on selective aspects such as labor and capital productivities and time and motion studies. Interestingly, many Industrial Technology programs around the country have recognized the importance of productivity-related issues and concerns within manufacturing and service activities and have taken it upon themselves, both past and present, to introduce students to productivity-based concepts and principles such as time and motion studies, cost-based productivity assessments and evaluations, and production planning and control. An expected understanding of productivity-related principles and concepts has also been integrated into the NAIT Certification Examination.

Assessing Productivity

Productivity is a measure of the efficiency and effectiveness to which organizational resources (inputs) are utilized for the creation of products and/or services (outputs). This definition was clarified further, (Sumanth, 1998; Chambers and Pope, 1996; and Industry Canada, 2001), by indicating that productivity measurement (change) is aggregate and is concerned with measuring how the ratio Y/X changes over time, where Y measures an aggregate output and X measures an aggregate input. It was further indicated that productivity measurement is both a measure of input utilization and an assessment as to whether or not input utilization is growing faster than output. production.Much of the foundation upon which productivity assessments have been conducted has centered on cost ratios. Deo and Strong (2000) provided additional support for cost-based productivity assessment when they indicated " . . . . those who are involved in manufacturing and are responsible for reducing the cost of production should consider measuring productivity in terms of cost. Measuring productivity in this way can help identify resources and operations that could be improved to raise productivity at functional and firm-wide levels" (p, 21). They further indicated that the cost-based approach not only helps technical professionals evaluate their decisions and actions in terms of money saved in production but also works as a motivating force for people involved in improving the effectiveness of manufacturing systems. Sumanth (1998), who also supports cost-based productivity assessment, indicated that gains in productivity could be achieved by following one or more of the following five strategies and one or more of four assessment methodologies:

- Strategy 1: Increase output for the same level of inputs;
- Strategy 2: Increase output and also decrease inputs;
- Strategy 3: For the same output level, decrease inputs;
- Strategy 4: Increase output at a faster rate than inputs;
- Strategy 5: Decrease inputs at a faster rate than output.

With respect to assessment methodology, one of the best-known measures of productivity, *partial productivity*, relates total output to one class of input. Examples of industry-based partial productivity measures include:

- output per man-hour, a measure of labor productivity,
- annual revenue per employee, a measure of labor productivity,
- flight hours per employee per year, a measure of labor productivity,
- maintenance hours per technician per year, a measure of labor productivity,
- output per ton of material, a measure of material productivity,
- interest revenue generated per dollar of capital, a measure of capital productivity,
- output revenue per dollar of energy consumed, a measure of energy productivity.

A second measure of productivity, *factor productivity*, relates total output to the sum of associated labor and capital inputs. Both *Partial* and *Factor* productivity measures have been used by governments, industries, and individual companies to compare and contrast their economic standing with other countries, documented industry levels, and benchmarked values.

A third, and relatively new, approach to the assessment of productivity, *total productivity*, relates total outputs to the sum of all tangible input factors (human, materials, capital, energy, other expenses, etc.). A fourth assessment approach, *comprehensive total productivity*, is an extension of the total productivity approach in that it incorporates both tangibles and company-specific intangible factors into the productivity assessment. According to Sumanth (1998), there are approximately 30 different intangible factors that can be assessed by companies, all of which fall into one of seven categories: customer-, market-, society-, process-, employee-, vendor-, and owner-related. Both the *Total* and *Comprehensive Total* approaches consider quantifiable factors and supply the company with a holistic perspective of the economic health and the efficiency of the firm's assets – it's divisions, branches, products, process, etc. Both of these two approaches, if used in conjunction with partial productivity measures, help direct and focus management's attention toward the strengths and weaknesses of individual plants and firm operations, as well as areas of equipment investment, employee training, and continuous improvement. Examples of the various productivity assessment methodologies and the manners in which they are calculated can be seen in Table 1. In addition to a tabular assessment of productivity, graphic displays of productivity results can be seen in Figure 1.

As indicated in Figure 1, there has been a decrease in material productivity (MPV) with minor deceases in energy (EPV) and other expense productivity (OEPV). On the other hand, an increase has been achieved in human productivity (HPV) with small increases in capital (CPV) and factor productivity (FPV). When the plant is viewed holistically with respect to total productivity (TPV), an overall decrease in productivity has occurred.

Benchmarking operations and operational units

Regardless of the assessment method or mix of methodologies selected for integration, *productivity benchmarking,* is an important aspect for goal setting decision-making and goal achievement determination. Benchmarking productivity entails the calculation of a productivity index (PI_t) based on a ratio of the current period productivity value (PV_t) to a specified, earlier period productivity value (PV_o). If the (PI_t) value is greater than 1.00, an increase in productivity has been achieved; if the (PI_t) is less than 1.00, productivity has decreased. The percent change in productivity between specified periods can be determined using the following formula:

Percent Change in Productivity =

$[(PV_t / PV_o) -1] * 100$ or

$(PI_t -1) * 100$

Figure 1. Productivity Comparisons for the Years 2000 and 2001

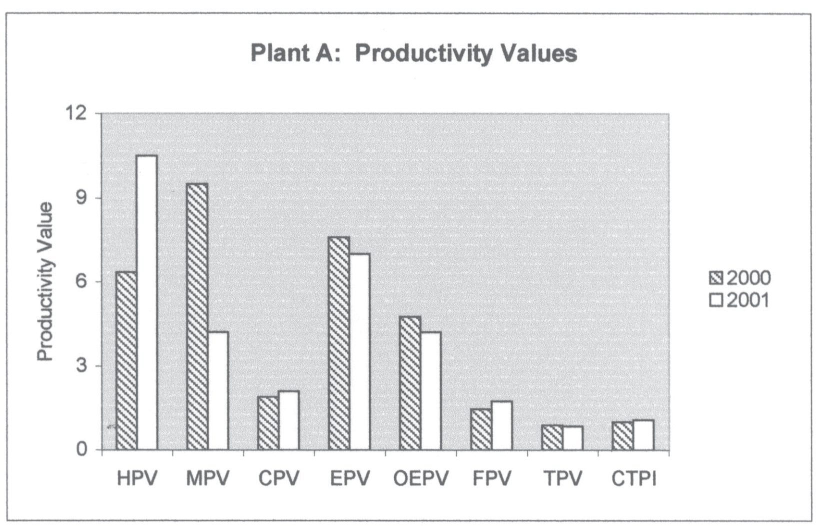


Table 1. Productivity Data, Calculations, and Supporting Formulas

Plant A: Financial Data	2000	2001	Calculations
Value of Finished Units	12,000	10,000	O1
Value of Partial Finished Units	2,000	2,000	O2
Dividend from Securities	2,000	5,000	O3
Interest from Bonds	2,000	3,000	O4
Other Income	1,000	1,000	O5
Total Tangible Output	19,000	21,000	SUM(O1 + O2 + O3 + O4 + O5)
Total Salaries	3,000	2,000	S
Total Materials	2,000	5,000	M
Total Fixed Capital	5,000	5,000	FC
Total Working Capital	5,000	5,000	WC
Total Energy	2,500	3,000	E
Other Expenses	4,000	5,000	OE
Total Tangible Input	21,500	25,000	SUM(S + M + FC + WC + E + OE)
Break-Even Point	0.77	0.80	1-(Working Capital/Total Tangible Input)

Partial Productivities	2000	2001	Calculations
Human Productivity Value (HPV)	6.33	10.50	Total Tangible Output / Total Salary Expense
Human Productivity Index (HPI)	1.00	1.66	HPV_{2001} / HPV_{2000}
Material Productivity Value (MPV)	9.50	4.20	Total Tangible Output / Total Material Expense
Material Productivity Index (MPI)	1.00	0.44	MPV_{2001} / MPV_{2000}
Capital Productivity Value (CPV)	1.90	2.10	Total Tangible Output / (Fixed Capital + Working Capital)
Capital Productivity Index (CPI)	1.00	1.11	CPV_{2001} / CPV_{2000}
Energy Productivity Value (EPV)	7.60	7.00	Total Tangible Output / Total Energy Expense
Energy Productivity Index (EPI)	1.00	0.92	EPV_{2001} / EPV_{2000}
Other Expense Productivity Value (OEPV)	4.75	4.20	Total Tangible Output / Total Other Expenses
Other Expense Productivity Index (OEPI)	1.00	0.88	$OEPV_{2001}$ / $OEPV_{2000}$
Factor Productivity			
Factor Productivity Value (FPV)	1.46	1.75	Total Tangible Output / (Total Salary Expense + Total Capital)
Factor Productivity Index (FPI)	1.00	1.20	FPV_{2001} / FPV_{2000}
Total Productivity			
Total Productivity Value (TPV)	0.88	0.84	Total Tangible Output / Total Tangible Input
Total Productivity Index (TPI)	1.00	0.95	TPV_{2001} / TPV_{2000}
Comprehensive Total Productivity			
Intangible Factor Value (IFV)	0.80	0.90	Results of Company Specific Assessment Methodologies
Intangible Factor Index (IFI)	1.00	1.13	IFV_{2001} / IFV_{2000}
Comprehensive Total Productivity Index (CTPI)	1.00	1.07	TPI_{2001} * IFI_{2001}

Note 1: 2000 index values (1.00) are benchmark values to which future years (2001) are compared.

Note 2: Comprehensive Total Productivity Index (CTPI) calculations require the determination of the Total Productivity Index (TPI), an Intangible Factor Value (IFV), and an Intangible Factor Index (IFI) before calculation can be completed.

Input Percent Assessment	2000	2001	Calculations
Human	13.95	8.00	(Total Salaries / Total Tangible Inputs) * 100
Material	9.30	20.00	(Total Materials / Total Tangible Inputs) * 100
Capital	46.51	40.00	(Total Capital / Total Tangible Inputs) * 100
Energy	11.63	12.00	(Total Energy / Total Tangible Inputs) * 100
Other Expense	18.60	20.00	(Other Expenses / Total Tangible Inputs) * 100
Total Inputs	100.00	100.00	

One of the primary purposes for benchmarking productivity is to determined if an improvement in productivity has been achieved after a change or perceived improvement has been made to one or more input factors. According to Sumanth (1998), there are 70 different techniques available for improving productivity, all of which fall into one of five categories—technology-, material-, employee-, product-, and process or task-based. In most instances, productivity benchmarking should be integrated into the productivity assessment methodology or mix of methodologies selected for integration (partial, factor, total, or total comprehensive) using one or more of the following criterions:

- change in productivity over a fiscal period (ratio of fiscal year 2001 to fiscal year 2000 or ratio of 1st Quarter of 2001, 2nd Quarter of 2001, etc to fiscal year 2000).
- change in productivity between quarterly periods (ratio of 2nd Quarter of 2001 to 1st Quarter of 2001).
- change in productivity between seasonal periods (ratio of 1st Quarter of 2001 to 1st Quarter of 2000).
- change in productivity before and after a specific change or improvement (ratio of current period to some earlier period).
- change in productivity between the actual period value and the forecasted period value (ratio of actual productivity to predicted productivity).

An example of benchmarking using indices can be seen in Table 1 and its integration with the 2000 Benchmark value of 1.00 can be seen in Figure 2.

Before decisions are made on the direction and priority that should be assigned to productivity improvement efforts, one needs to consider firm- or plant-based input percentages. In essence, a greater return on improvement efforts can be achieved if those inputs that possess a greater percentage of total inputs are emphasized above all others. Sometimes a significant increase in an input percent combined with a decrease in productivity can also indicate areas of concern. For example, Table 1 and Figure 3 both indicate that for the year 2000 the material input only composed 9.3% of total inputs but for the year 2001 the material input accounted for 20.0% of total inputs. In addition, the material input experienced a substantial decrease in productivity which is reflected in both its productivity value and index value (Figures 1 and 2).

Micro Level Productivity Assessment

One of the unique features of a partial/total productivity assessment is the ability to provide productivity indices at not only the firm level, but also at the most micro level of firm operations. For example, a computer company may require productivity assessments (indices) at the product level (laptop versus desktop), plant level, division level, or at the corporate level. This same micro level assessment approach can be applied to most firms and service companies—banks have checking accounts, saving accounts, investment accounts, local branches, regional branches, and corporate operations; fluid power service companies have sales departments, service/design departments, distribution facilities, local branches, regional branches, and corporate operations. Examples such as these can be found in companies large and small within manufacturing, construc-

Figure 2. Productivity Indices and Benchmark Comparison

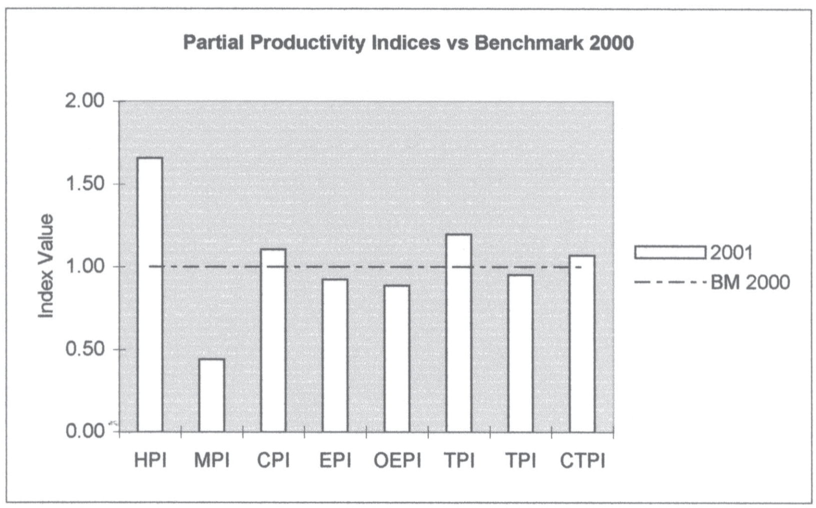
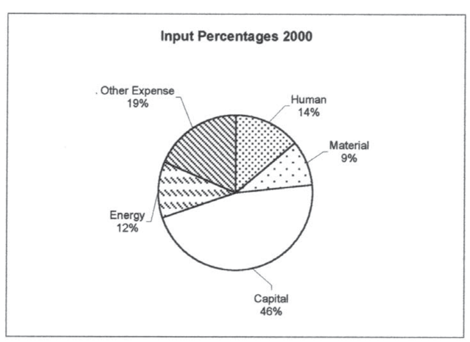
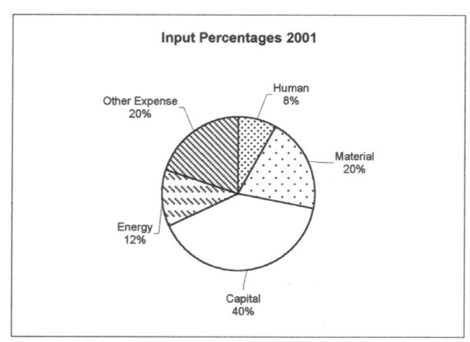


Figure 3. Comparison of Input Percentages for the Years 2000 and 2001





tion, and service operations; one such example can be seen in Table 2.

In this example, three plants (Plants A, B, and C) are compared and contrasted to identify their inherent strengths and weaknesses. In addition to this comparison, a firm-wide assessment has been conducted to determine the overall impact of the three plants on corporate operations. The principal advantage of a micro level assessment is the ability to conduct comparative assessments of operational units that possess differing financial statures, structures, and products and to determine the overall impact of these units on the firm as a whole. The results shown in Table 2 and Figures 4 and 5 provide support for the following micro level findings:

- *Plant A* experienced a decrease in partial productivity within the material, energy, and other expense categories.
- *Plant B* experienced a decrease in partial productivity within all input categories except human.
- *Plant C* experienced a decrease in partial productivity within the energy input only.
- *Plant B* experienced a decrease in factor productivity (labor and capital inputs combined).
- *Plants A and B* experienced a decrease in total productivity.
- The *Firm* as a whole experienced a decrease in energy and other expenses productivity. The decrease in energy productivity is attributable to all three plants, in particular *Plant A*. The decrease in other expenses productivity is attributable to *Plants A and B* only.
- Although the *Firm* as a whole experienced an increase in total productivity for 2001, this increase could be linked to overall efficiency levels and gains within *Plant C* (both *Plant A and B* experienced decreases in total productivity).
- Note: In Table 2., corporate financial data is based on the sum of plant data. In some instances, corporate operations possess their own internal set of inputs and outputs, separate and distinct from plant operations. In this type of financial structure, corporate financial data for productivity analysis should be based on the sum of plant financial data and the financial data of corporate operations.

Based on an analysis of the results in Table 2 along with input percent breakdown of each plant and the firm as a whole, productivity improvement efforts could be directed toward the following areas:

- efforts to improve productivity should initially concentrate on material, energy, and other expenses inputs within all plants and the capital input within *Plant B*.
- efforts to improve productivity should be prioritized based on a sequential order. Onene possible scenario could be : (1) energy, (2) material, (3) other expense, (4) capital.

If improvement efforts were direct toward the energy, material, and other expense inputs (50% of total inputs), the company should expect an increase

Figure 4. Micro Level Comparison of Firm's Productivity Values

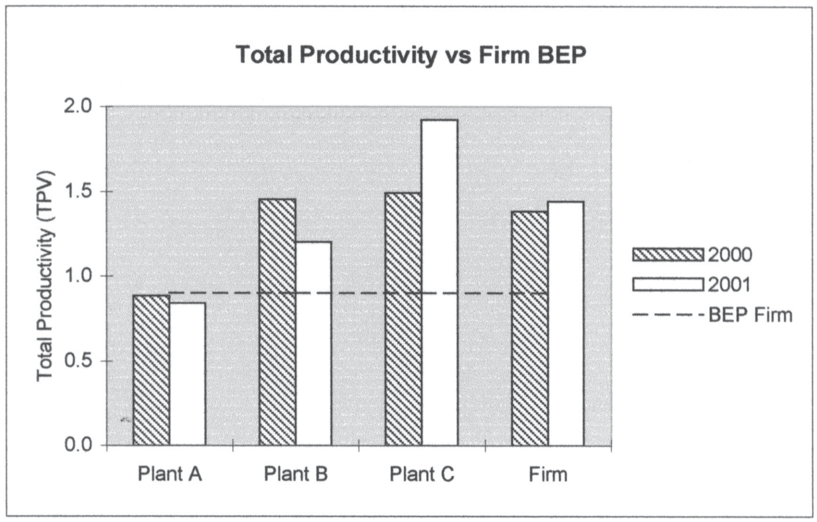


Figure 5. Micro Level Comparison of Firm's Productivity Indices

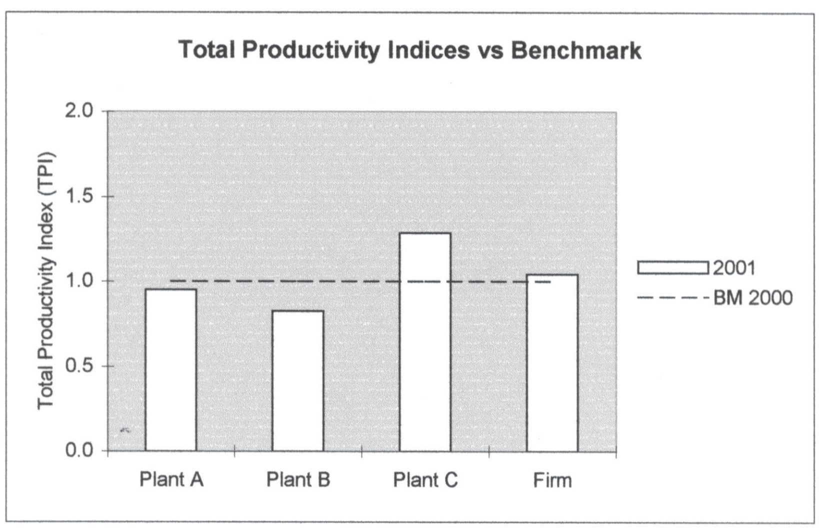


Table 2. Micro Level Productivity Assessment

Plant and Firm Financial Data	Plant A 2000	Plant A 2001	Plant B 2000	Plant B 2001	Plant C 2000	Plant C 2001	Firm 2000	Firm 2001
Value of Finished Units	12,000	10,000	55,000	60,000	80,000	100,000	147,000	170,000
Value of Partial Finished Units	2,000	2,000	3,000	10,000	10,000	10,000	15,000	22,000
Dividend from Securities	2,000	5,000	2,000	3,000	5,000	6,000	9,000	14,000
Interest from Bonds	2,000	3,000	5,000	2,000	5,000	4,000	12,000	9,000
Other Income	1,000	1,000	2,000	2,000	3,000	3,000	6,000	6,000
Total Tangible Output	**19,000**	**21,000**	**67,000**	**77,000**	**103,000**	**123,000**	**189,000**	**221,000**
Total Salaries	3,000	2,000	14,000	16,000	20,000	18,000	37,000	36,000
Total Materials	2,000	5,000	10,000	14,000	15,000	12,000	27,000	31,000
Total Fixed Capital	5,000	5,000	5,000	10,000	15,000	10,000	25,000	25,000
Total Working Capital	5,000	5,000	5,000	6,000	3,000	5,000	13,000	16,000
Total Energy	2,500	3,000	8,000	12,000	6,000	8,000	16,500	23,000
Other Expenses	4,000	5,000	4,000	6,000	10,000	11,000	18,000	22,000
Total Tangible Input	**21,500**	**25,000**	**46,000**	**64,000**	**69,000**	**64,000**	**136,500**	**153,000**
Break-Even Point	0.77	0.80	0.89	0.91	0.96	0.92	0.90	0.90
Productivity Assessments	Plant A	Plant A	Plant B	Plant B	Plant C	Plant C	Firm	Firm
Partial Productivities	2000	2001	2000	2001	2000	2001	2000	2001
Human Productivity Value (HPV)	6.33	10.50	4.79	4.81	5.15	6.83	5.11	6.14
Human Productivity Index (HPI)	1.00	1.66	1.00	1.01	1.00	1.33	1.00	1.20
Material Productivity Value (MPV)	9.50	4.20	6.70	5.50	6.87	10.25	7.00	7.13
Material Productivity Index (MPI)	1.00	0.44	1.00	0.82	1.00	1.49	1.00	1.02
Capital Productivity Value (CPV)	1.90	2.10	6.70	4.81	5.72	8.20	4.97	5.39
Capital Productivity Index (CPI)	1.00	1.11	1.00	0.72	1.00	1.43	1.00	1.08
Energy Productivity Value (EPV)	7.60	7.00	8.38	6.42	17.17	15.38	11.45	9.61
Energy Productivity Index (EPI)	1.00	0.92	1.00	0.77	1.00	0.90	1.00	0.84
Other Expense Productivity Value (OEPV)	4.75	4.20	16.75	12.83	10.30	11.18	10.50	10.05
Other Expense Productivity Index (OEPI)	1.00	0.88	1.00	0.77	1.00	1.09	1.00	0.96
Factor Productivity								
Factor Productivity Value (FPV)	1.46	1.75	2.79	2.41	2.71	3.73	2.52	2.87
Factor Productivity Index (FPI)	1.00	1.20	1.00	0.86	1.00	1.38	1.00	1.14
Total Productivity								
Total Productivity Value (TPV)	0.88	0.84	1.46	1.20	1.49	1.92	1.38	1.44
Total Productivity Index (TPI)	1.00	0.95	1.00	0.83	1.00	1.29	1.00	1.04
Comprehensive Total Productivity								
Intangible Factor Value (IFV) company-based	0.80	0.90	0.85	0.95	1.50	1.65	1.05	1.17
Intangible Factor Index (IFI)	1.00	1.13	1.00	1.12	1.00	1.10	1.00	1.11
Comprehensive Total Productivity Index (CTPI)	1.00	1.07	1.00	0.92	1.00	1.42	1.00	1.16

Note 1: 2000 index values (1.00) are benchmark values to which the current year (2001) is compared.

Note 2: Comprehensive Total Productivity Index (CTPI) calculations require the determination of the Total Productivity Index (TPI), an Intangible Factor Value (IFV), and an Intangible Factor Index (IFI) before calculation can be completed.

Input Percent Assessment	Plant A 2000	Plant A 2001	Plant B 2000	Plant B 2001	Plant C 2000	Plant C 2001	Firm 2000	Firm 2001
Human	13.95	8.00	30.43	25.00	28.99	28.13	27.11	23.53
Material	9.30	20.00	21.74	21.88	21.74	18.75	19.78	20.26
Capital	46.51	40.00	21.74	25.00	26.09	23.44	27.84	26.80
Energy	11.63	12.00	17.39	18.75	8.70	12.50	12.09	15.03
Other Expense	18.60	20.00	8.70	9.38	14.49	17.19	13.19	14.38
Total Percent	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

to the bottom line if improvements are deemed successful. It should be noted that this same analysis could have been conducted on the plants and firm on a quarterly basis or on divisions within a single plant or on departments within a single division.

Benefits associated with total/ partial productivity integration

One of the inherent advantages of productivity integration, whether partial, total, or a combination of the two, is the ability to use existing company data with very little modification to the format in which it is available. In most instances, this information is available for preceding years, thus, historical and/or benchmark values can be easily established to create trendline or seasonal variation charts and graphs. In many case studies presented by Sumanth (1998) only two key people were brought together to preform the assessment, one from accounting and one from information systems. This is not to say that these individuals are required for productivity integration. In essence, anyone acquainted with accounting principles, spreadsheet programs, and technological systems could conduct productivity assessments (i.e., industrial technologists).

Traditionally, the impact of new technologies on productivity is seen in terms of their effect on efficiency and labor productivity. According to Sumanth (1998), labor productivity and other partial productivity measures should be avoided when studying the impact or integration of new technologies because these indicators suffer from an inability to explain the impact of the technology on all resources and all output produced. In many instances, there is an interaction between the use of various input resources, as well as an effect on the output, whenever a new technologys are introduced. Considering the impact of technology on only partial productivity measures such as labor or capital could lead to a distorted picture. It is the joint and simultaneous impact of all inputs on the output that should be considered when studying the effect of any new technology before and after installation; in other words, a total productivity assessment.

Conclusions

Productivity rates vary among individual industries and companies. These differences are reflected by many factors including the productivity method selected for integration, new technology integration, employment of advanced production methods, and increased output due to economies of scales. According to deDecker (1999), the decision to hire additional employees should be linked to the revenues needed to pay for the new employees; if not, the productivity of the department and the profits of the organization may realize a decrease.

Through a greater understanding of partial and total productivity assessment approaches along with a more focused integration, various benefits can be realized for an organization, benefits such as, a greater understanding of resource utilization; the ability to set, monitor, and evaluate company-specific goals; and the ability to successfully integrate technology planning into decision-making activities. A continued or expanded emphasis on productivity-based concepts and principles by Industrial Technology programs around the country is an important ingredient in preparing students for production/ management positions within manufacturing and service activities. An expanded emphasis on the NAIT Certification Examination with respect to a more in-depth understanding of productivity-related principles and concepts should also be considered. As a final note, the real value of any assessment system is not simply the performance data collected but the value realized when the data is used to shape the company for a maximum impact on business results and overall profitability.

References

Chambers, R. G. and Pope, R. D. (December 1996), Aggregate productivity measures. American Journal of Agricultural Economics, pp. 1360-1365.

deDecker, B. (July 1999). A measure of productivity. Aircraft Maintenance Technology, p. 92-93.

Deo, B. S. and Strong, D. (May/June 2000). Cost: The ultimate measure of productivity. Industrial Management, pp. 20-23.

Sumanth, D. (1998). Total productivity management. Boca Raton, Flordia: CRC Press LLC.

Industry Canada. (2001). A primer on productivity. In Strategis: Canada's Business and Consumer Site [Online]. Available: http://strategis.ic.qc.ca/SSG/pr00016e.html.