

AN ABSTRACT OF THE THESIS OF

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Title: PREVAILING OPINIONS ABOUT PRODUCTIVITY

PERFORMANCE AND IMPROVEMENT

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Abstract approved: \_\_\_\_\_

Dr. James V. Riggs

The intent of this study was to survey opinions of producing managers and industrial engineers concerning several aspects of productivity. The survey was conducted by means of a questionnaire. The number of questionnaires administered was 540. Useful responses were 145 (27%). In addition to English, there were versions of the questionnaire in Spanish, French, and Servo-Croatian. Besides the United States, they were sent to Mexico, Japan, Korea, France, Yugoslavia, and England.

The answers to the questionnaire indicated that an equal interest existed between the respondents and their organizations with respect to their concern on productivity measurement and improvement programs.

One of the main topics of interest in this research was the estimation of the importance given to the achievement of four proposed goals ("Efficiency", "Effectiveness",

"Performance", "Vitality"). The results indicated that the preferences varied with the type of organization involved. The non-profit organizations gave equal preference to the four goals, whereas the profit organizations gave a slight preference to the achievement of the goal, "Efficiency".

An investigation was also made to determine what tactics were most suitable to achieve the four previously mentioned goals. The preferences varied, again, with the type of organization. The non-profit organizations tended to use tactics which included more human participation, whereas the profit organizations preferred tactics which were more related to technical factors.

An estimation of the effect of the tactics on the goals was performed. For the profit organizations, the effect of the tactic "Machines" was noteworthy. The results indicated that, although there was a high expectation to increase "Efficiency", there was also a considerable expectation of decreasing the organizations' vitality.

Another aim of this work was to inquire into the preference of the respondents for the use of productivity ratios in three promising areas of application (i.e. evaluation of capital investment proposals, control of operations, achievement of social objectives). The most promising areas were the control of operations and the evaluation of capital investment proposals.

There existed a difference of opinion concerning the consideration of mandatory capital investments in productivity measurements. Almost half of the respondents suggested to consider those investments in a different form, while others suggested the contrary.

The respondents showed a slight preference about the opinion that a wage increase should be granted when an increase in productivity occurred. An analysis of variance indicated that differences of opinion existed among three criteria (i.e. the respondents' criterion, the organizations' criterion, and the criterion based on a strict analysis of data) concerning the sharing of productivity gains. The main differences occurred with respect to the percentage of productivity earnings that should be retained in the organization.

In summary, results of the survey indicate the current thinking of practitioners, representing a broad spectrum of organizations, toward productivity improvement and how productivity considerations should influence management decision making.

Prevailing Opinions about Productivity  
Performance and Improvement

by

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# PREVAILING OPINIONS ABOUT PRODUCTIVITY PERFORMANCE AND IMPROVEMENT

## I. INTRODUCTION

The subject of this opus is the analysis of the responses to a survey dealing with several topics about productivity. The goals of the survey were:

1. To see if there was a difference in the degree of involvement of the respondents and their organizations in productivity measurement and improvement programs (Chapter IV).
2.
  - a) To ascertain the importance given to four groups of proposed goals that are sought when a productivity improvement is pursued, and to investigate if some factors, such as the type and size of the respondents' organizations, influenced the ratings (Chapter III).
  - b) To know the respondent preference given to six proposed tactics in accordance with their promise to improve productivity, and to determine if some factors, such as size and type of the organization, influenced the ranking of the tactics (Chapter IV).
  - c) To inquire into what effect the implementation of six suggested tactics will have on the four proposed goals (Chapter IV).
3. To inquire into the preference of the respondents for the use of productivity ratios in three promising

areas of application and to account for some suggested ratios that could have been appropriate for the respondents' organizations (Chapter V).

4. a) To observe the opinions of the respondents concerning the distribution of productivity gains (Chapter VI).
- b) To investigate how mandatory capital investments producing social benefits should be related to the measurement of productivity (Chapter VI).
- c) To determine if there existed a difference of opinion among three criteria (i.e. the respondents' criterion, the organizations' criterion, and the criterion based on a strict analysis of data concerning the sharing of productivity gains (Chapter VI).

The survey was conducted by means of a questionnaire.<sup>1</sup> In addition to English, there were also versions of the questionnaire in Spanish, French, and Servo-Croatian. These questionnaires were sent to 540 individuals. Of these, only 145 persons correctly responded to the questionnaire. This represents the 27% of the total responses.<sup>2</sup>

The sample was drawn, mainly, from a directory of people attending a symposium on productivity. Other

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<sup>1</sup>(A copy is included at the end of the chapter.)

<sup>2</sup>This percentage could be considered quite high when it is taken into account that the questionnaire took about two hours to complete.

respondents were former students from the department of Industrial and General Engineering at Oregon State University, as well as persons whom either the author or his advisor, Dr. James L. Riggs, thought might be interested in participating.

For the analysis, the responses were classified with respect to three factors: Type of respondents' organizations, size of respondents' organizations, and the respondents' business position. The different categories for these factors are presented next:

Factor: Size of the organization

Let  $x$  represent the number of employees.

Level 1:	Size 1	$x \leq 100$	}	S1
	Size 2	$100 < x \leq 1000$		
Level 2:	Size 3	$1000 < x \leq 10,000$	}	S2
	Size 4	$x > 10,000$		

Factor: Type of organization

Level 1:	H:	Health institution	}	NON- PROFIT
	ES:	Education and Service		
	GOV:	Government		
Level 2:	IND:	Industry (mining, fishing, manufacturing, etc.)	}	PROFIT
	RC:	Retail and commerce		

Blocking factor: Position of the respondent in the  
organization

Level 1:	LL: Low level management	}	INDEPENDENT
	SE: Self employed		
	IP: Independent		
	OT: Other		
Level 2:	Ml: Medium level management		
Level 3:	SS: Staff specialist		
Level 4:	TM: Top management		

It should be noted that the organizations in the first level of the factor "Type of organization" were those which were more non-profit oriented. The ones in the second level were more profit oriented.

Taking into consideration these factors and their levels, a three-way classification of the respondents is presented in Table I. 1. A sample of the questionnaire is presented next.

TABLE I.1. CLASSIFICATION OF RESPONDENTS

Type of Organization	Size	B U S I N E S S   S T A T U S *			
		Independent	Medium Level	Staff	Top Management
Non-Profit	S1	9	6	4	5
	S2	3	5	9	4
Profit	S1	8	11	7	11
	S2	7	25	19	10

S1    1 < Employees ≤ 1000

S2    Employees > 1000

\* Two respondents did not give enough information to be classified.

May 1977

Department of  
INDUSTRIAL ENGINEERING  
Corvallis, Oregon 97331  
United States of America  
Telephone (503) 754-4645



Dear Sir:

You are being asked to participate in a worldwide survey about productivity. Its purpose is to determine the current methods employed in productivity analysis and the uses made of the productivity measures. The survey is designed to obtain representative views from different areas of management, classes of organization, and types of culture. Results of the survey will be reported at the International Productivity Congress to be held next September in Australia. Your reply is important!

There are just four pages in the survey. Please answer the questions completely and thoughtfully, especially those that rely on subjective judgment. A stamped, addressed envelope is enclosed for your reply. If you have further inquiries or comments, direct them to Dr. James L. Riggs at the letterhead address.

Your prompt reply will be greatly appreciated, and we will be pleased to send you a summary of the survey results if you check the box below. Thank you.

☐ Send survey results to ☐ address above ☐ other address \_\_\_\_\_

#### DATA ABOUT RESPONDENT

- The type of organization in which you work is most closely described as  
☐ National government ☐ Manufacturing/Mining Industry  
☐ State/local government ☐ Agriculture/Timber/Fishing  
☐ Health/Education/Service ☐ Retail/Commercial/Transportation
- Number of people employed in the organization with which you are now associated (if it is a government agency or a conglomerate industry, report the size of the unit, division or branch for which productivity data would be reported) is  
☐ Under 100 ☐ 101 to 1000 ☐ 1001 to 10,000 ☐ over 10,000
- Comments \_\_\_\_\_  
 Category that most closely describes your current position is  
☐ self-employed ☐ middle-level manager ☐ staff specialist  
☐ top management ☐ lower-level manager ☐ line operator  
☐ independent professional ☐ other \_\_\_\_\_
- Circle the number of years of formal education you have  
 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 +  
 grade school' high school' college post graduate
- To what extent has your organization emphasized productivity measurement and improvement programs, and to what extent have you been personally involved (Mark with an x on the scale below the organizational emphasis, and with a y the extent of your personal involvement.)

Approximate Measurements				Extensive Measurements	
Not used	Just mentioned	made but not used	made and utilized	made but not widely applied	made and applied vigorously
0	1	2	3	4	5
				6	7
					8
					9
					10

Comments \_\_\_\_\_

Figure I.1 Page One of the Questionnaire.

# SELECTION OF OPERATIONAL CHANGES TO IMPROVE PRODUCTIVITY

**Perspective:** Productivity improvements are usually the result of intentional operational changes. Depending on the type and state of current operations, certain changes are more likely to result in improvement than others.

**Scenario:** Your organization is about to initiate productivity-improvement plans. Several target activities and potential outcomes are identified in the matrix below. You have been asked to rank or rate the targets according to their promise for improving productivity in the organization in which you now work. Follow the directions below.

Comments: \_\_\_\_\_

## POSSIBLE OUTCOMES

RANKING OF CHANGE TARGETS: 1 through 6 +	GREATER ORGANIZATIONAL VITALITY: More initiative and involvement, more worker stability, greater cooperation and job satisfaction, etc.			
	HIGHER PERFORMANCE: Improve quality of output, increased flexibility, fewer breakdowns and accidents, etc.			
	IMPROVED EFFECTIVENESS: Growth in total revenues and/or profits, better decision making and communications, better utilization of resources, etc.			
	IMPROVED EFFICIENCY: Lower total operating costs, savings in labor and machine time, less waste of material, fewer damages, less remake, etc.			

CHANGE TARGET					
<b>MACHINES:</b> Replace manual labor by machines, get faster or more reliable equipment (automate).					
<b>MANAGEMENT:</b> Better coordination and budgeting, more inspiring leadership (motivate).					
<b>PROCESSES:</b> Improve scheduling and material flow, more accurate-faster data flow (computerize).					
<b>WORK DESIGN:</b> Modify job content, improve work methods, restrain workers (enrich jobs).					
<b>ENVIRONMENT:</b> Make safer or more pleasant working conditions, reorganize structure (innovate).					
<b>PROGRAMS:</b> Raise pay, revise policies, try goal-setting (MBO) programs (all participate).					

Probable success of targets in achieving each outcome: indicated by (+), (-) or (0).

## OUTCOME RATINGS on 1 through 10 scale -

**Directions for Completing above matrix:** (Make an entry in every cell of the matrix.)

**Target Ranking** - Rank change targets in a 1 to 6 order of their probable success in improving productivity in your present organization. Base rankings on what has worked for you or what you believe would work. 1 is the best and 6 is the worst.

**Target or Outcome Relationship** - Indicate the probable effect on each outcome of the implementation of each change. In each circle insert one of the following symbols.

- (+) change will have a positive effect on the outcome; likely successful
- (-) possible negative effect on outcome
- (0) change should have no effect or there is equal likelihood of either a positive or negative effect on the outcome.

**Outcome Ratings** - Rate the value of each outcome in producing a measurable improvement in productivity. Select the rating for each from 1 through 10 according to the scale below.

Productivity decreases or is unchanged		May produce a small improvement		Certain to make a small improvement		May raise productivity significantly		Certain to yield large improvement	
1	2	3	4	5	6	7	8	9	10

Figure I.2 Page Two of the Questionnaire.



### AUXILLIARY PRODUCTIVITY RATIOS FOR EVALUATING INVESTMENT PROPOSALS CONTROLLING OPERATIONS, AND ATTAINING SOCIAL OBJECTIVES

**Perspective:** Productivity has traditionally measured the output of goods with respect to an input of production, usually workers hours. The purpose of the comparison is to detect changes in ratio levels and relate them to their causes. Productivity measurements also establish bases to roughly compare operations in various sectors of the national economy and in equivalent operations in other countries.

Both the types of productivity measurements and their uses can be extended. Auxiliary productivity ratios, such as "Safety Productivity" which could relate the cost of injuries to hours worked, can supplement existing criteria for decision making. Three areas of application appear promising:

1. Evaluation of capital investment proposals - ratios to supplement the "net-income/amount-invested" criterion to rate specific gains expected from an investment.
2. Control of operations - ratios to supplement process efficiency measures that can provide early warnings of future operational difficulties.
3. Achievement of social objectives - supplements to the "benefit/cost" criterion that define and rate how well a project satisfies conditions deemed desirable for the welfare of society.

**Scenario:** You are developing supplementary productivity ratios to use in your current area of work. The aim in generating new ratios is to improve investment decisions (I), operational control (C), and general welfare satisfaction (S). Five suggested ratios are given and these are to be rated with respect to their value for each of the potential uses (I, C, and S) in your organization. Also, define and rate other productivity ratios that you feel would be appropriate. For example, a ratio appropriate to a delivery service would be "amount delivered/fuel consumed," and it could be rated as very important in deciding which vehicle to invest in, less important for rating the performance of vehicles in operation, and quite important as a measure of a national drive to cut gasoline consumption.

**Directions:** Rate each productivity ratio as to its value in each use (I, C, and S) in your type of work. Develop and rate additional ratios that you feel would be useful. Make the 1 to 10 ratings according to the scale below (Enter 0 if the ratio is not valid for an application in your organization).

Deceptive indicator of value	Appropriate Consideration	Measures factors or interest	Important indicator of achievement	Vital measure of criticality		
				1	2	3
Productivity Ratio		Description		(I)	(C)	(S)
Employment ratio = $\frac{\text{Value added } (\$)}{\text{People employed } (\#)}$		Selling price of units, minus materials and components to produce the units, compared to equivalent number of full-time employees of the organization.				
Energy ratio = $\frac{\text{Units Produced } (\#)}{\text{Energy used } (\text{kw-hr})}$		Comparable amounts of output (equivalent value units) per energy input measured in equivalent standardized units.				
Work Ratio = $\frac{\text{Employee hours worked } (\text{hr})}{\text{Employee hours paid } (\text{hr})}$		Person-hours of productive time spent on assigned work compared to total hours for which wages were paid.				
Material ratio or $\frac{\text{Material in Product}}{\text{Total Material Supplied}}$ $\frac{\text{Recycled Material Used}}{\text{Total Material Supplied}}$		Amount of a certain type of material that is actually in the final product, or amount that is recycled from prior use, compared to the total amount of that material consumed in producing the product.				
Social ratio = $\frac{\text{Social Objectives } (\# \text{ or } \$)}{\text{Sales or Budget } (\# \text{ or } \$)}$		Units that measure a socially desirable condition, such as convertible currency earned or minority workers employed, compared to the amount of activity as measured by the output or operating budget of the unit.				

Figure I.3 Page Three of the Questionnaire.

Productivity Ratio	Description	(I)	(C)	(S)
(Other Productivity Ratio)				
(Another Productivity Ratio)				

#### PRODUCTIVITY ANALYSIS

**Perspective:** It is recognized that productivity ratios do not necessarily reflect the efficiency of operations, do not provide reliable comparisons over a span of years, and do not always reveal the effect of individual input or output components. Nevertheless, the ratios still influence managerial decisions.

**Scenario:** Your organization has a productivity pattern, corrected to a base-year index, shown in the table below. Assume that net profit increased at a commensurate rate with total productivity gains each year. (Also assume the national inflation rate is zero.)

	1974	change	1975	change	1976
Net output (1)	100	15%	115	13%	130
Labor input (2)	50	0	50	14%	57
Capital input (3)	40	25%	50	4%	52
Labor productivity (1) + (2)	2.0	15%	2.3	0	2.3
Capital productivity (1) + (3)	2.5	-9%	2.3	9%	2.5%
Total productivity (1) + (2 + 3)	1.11	4%	1.15	4%	1.19

1. Is the increase in total productivity from 1974 to 1975, at no increase in labor input, sufficient reason to grant a wage increase to workers? ☐ Yes ☐ No  
If yes, about how large an increase is reasonable? \_\_\_\_\_ %  
Comments \_\_\_\_\_

2. If the decrease in capital productivity resulted from a mandatory capital investment to conform to a new law restricting pollution, should this social benefit be recognized differently in the productivity measure? ☐ Yes ☐ No  
If yes, how? \_\_\_\_\_

3. Who should benefit from the 4% gain in 1976? What percentage of the total profit for that year should be distributed to each of the following parties, based on...

... an unbiased analysis  
of data

\_\_\_\_\_ % to consumers  
\_\_\_\_\_ % to workers  
\_\_\_\_\_ % to owners  
\_\_\_\_\_ % retained in  
100% organization

... what your organization  
would likely do

\_\_\_\_\_ % to consumers  
\_\_\_\_\_ % to workers  
\_\_\_\_\_ % to owners  
\_\_\_\_\_ % retained in  
100% organization

... your personal opinion

\_\_\_\_\_ % to consumers  
\_\_\_\_\_ % to workers  
\_\_\_\_\_ % to owners  
\_\_\_\_\_ % retained in  
100% organization

Comments \_\_\_\_\_

Figure I.4 Page Four of the Questionnaire.

## II. LITERATURE REVIEW

### Introduction

The creation of more jobs and better utilization of scarce resources are demands that can be satisfied by increasing productivity. The fulfillment of these demands will bring, as a consequence, a stronger position in the international market and a better standard of living. These are desirable natural goals as delineated by De Witt<sup>8</sup> (1976) and Kehlbeck<sup>17</sup> (1975). The second author indicated in his article that, "A basic problem in the U.S. is that the rate of growth of productivity is less than most other major countries of the world." He indicates that some of the causes of this situation are mainly three factors: lagging outlays in research and development; paucity of capital investment for the purchase of new machinery; and the costly federal regulations for environmental and safety factors.

The previously mentioned benefits derived from increases in productivity and the decreasing current trends in productivity growth are good reasons for greater concern about means to raise productivity and explain the increased emphasis devoted to productivity research.

Some comments about an excerpt of what has been presented on the productivity literature are shown in this chapter. The discussion includes the following topics: a) the productivity concept; b) tactics to improve productivity.

## Productivity Concept

### A) Productivity Definitions

Productivity is an amorphous concept as Eilon et al. (1976) establish. Several quotations are presented next to show different points of view about this concept.

"Productivity means that balance between all factors of production that will give the greatest output for the smallest effort."  
P. Drucker (1973).

36 "Productivity expresses the relationship between goal achievement (output) and resources expended (input)" H. B. Thorreli (1960).

"For productivity is the power to produce economic goods and services. Productivity may be the relation between the total output and input of a period, or it may be the relation between the increment in output associated with the addition of one unit of a given factor of production, that is, it may be 'average' or 'marginal'" S. Fabricant (Dunlop 1970).

"The simple definition of productivity is that is the relationship of some volume of output to a volume of input...They (productivity ratios) do not measure the volume of production; they do not indicate how hard anyone works. Productivity is a measure of the use of resources or of the degree of their use. It is often an indicator, but not identical to, a measure of efficiency"  
Leon Breenberg, Industrial Relations Research Association (1975).

24 "Productivity - the ratio of some measure of output to some measure of input, is usually attributed to the improved efficiency of some specific resource such as capital, money, materials, or technology" J. E. Ross (1977).

18 "Productivity is a measure of production efficiency; a ratio between output & input" Gordon McBeath (1974).

35 "Productivity is defined for our purposes as output per employee hour, quality considered" Sutermeister (1976).

34 "Productivity is defined as the ratio of performance toward organizational objectives to the totality of output parameter" W. T. Stewart (1978).

2 "Productivity is the magnitude of productiveness; the amount of goods & services produced by a unit of a productive factor in a specific period of time, or the average amount of goods and services produced by a unit of the productive factor in a specific period of time" W. Fenske (1965).

15 "Productivity, therefore, is concerned with how well we achieve our objectives and the total resources required to achieve them" F.E. Cotton (1976).

2 "The most commonly used definition of productivity is real output per hour of work. Productivity in this sense is a rough measure of the effectiveness with which we use our most important resource" H. Stein (1971).

Comic strip by Tim Downs redacted. Do not have permission to use.

15 A survey concerned with work productivity and job satisfaction was reported in 1975 by R. A. Katzell et al. (1975), from New York University. They sent questionnaires

to 2450 chief executives and to 950 industrial relations offices listed in the American Management Association. The overall rate of return was 16%. Besides, questionnaires were sent to union leaders who were enumerated in the Directory of National Unions and Employee Associations.

Among the formulated inquiries was:

"Please tell us what you yourself mean by "productivity" by indicating whether you AGREE or DISAGREE with each of the following statements."

The results obtained by Katzell et al. are reported in Figure II.1.

#### B) Effectiveness and Efficiency Definitions

"Effectiveness" and "efficiency" were terms that were frequently used in the previous quotations about productivity. Sometimes they were considered as its synonym. Some definitions of these terms are:

Effectiveness, as established by Thorreli (1960), is "The adequacy of an organizations' programs and thus pertains to the degree of goal attainment."

F. E. Cotton (1976) defines this concept as the extent to which the objectives are reached or needs are met.

Efficiency, the other previously mentioned concept, is elucidated by Thorreli (1960) as "...The ratio of the results actually obtained with the available resources to the maximum results possible with these same resources."

### Meaning of Productivity

"Please tell us what you yourself mean by 'productivity' by indicating whether you AGREE or DISAGREE with each of the following statements."

	% Agreeing	
	<u>Unions</u>	<u>Management</u>
Productivity means <u>quality</u> of output as well as <u>quantity</u> .	80	95
Productivity refers to the output per man hour in any one company or organization.	77	90
Productivity means the overall efficiency and effectiveness of the operation.	84	83
Productivity includes such intangibles as disruptions, "shrinkage," sabotage, and other indicators of trouble in the organization, even when their impact on output cannot be measured easily.	55	73
Productivity includes such factors as rate of absenteeism and turnover as well as measures of output.	70	70
Productivity includes measures of customer or client satisfaction	46	64
Productivity includes such intangibles as employee loyalty, morale and job satisfaction.	57	55
Productivity refers to the ratio of output to input by industry or section of the economy, not by individual organization.	30	22

Figure II.1. Differences in the meaning of productivity interpreted by union and management (From Katzell et al., 1975).

"A ratio of output to input" is the simple definition by F. E. Cotton (1976). The definition of B. Gold, Eilon et al. (1976) is that "Efficiency is the relationship between the actual and the potential output for any process."

The definitions of effectiveness presented here can be considered as equivalent, but those about efficiency only agree in the case of the ones presented by Thorreli and Gold. These two differ from the one from Cotton. The latter just defines efficiency as the ratio of output to input, but the former compare output to an attainable standard. As it is established by Thorreli, this standard is often to be determined in the fields of natural science; but it is generally impracticable about a business phenomenon. In his article he quotes H. A. Simon (1957), who mentions that the standard to which output is referred is difficult to establish in Social Sciences because there does not exist a law of conservation of energy which prevents the output from exceeding the input.

#### C) Comments

It was remarked in Section B that there were differences in the definitions of the terms "Efficiency" and "Effectiveness". Therefore, it should also be expected that some differences of opinion about the definition of productivity would exist. Some comments regarding these discrepancies in criterion are presented next:



As it can be noticed, the definitions of Cotton, Thorrelli, and Stewart have more tendency to match the definition of effectiveness. They define productivity as related to the achievement of goals.

The most common tendency found in the definitions is that productivity is a ratio of output to input. This can be noticed in the definitions by Mark, Fabricant, Greenberg, J. E. Ross, McBeath, Stewart, and Thorrelli. The definitions of Stewart and Thorrelli include both tendencies in their definitions.

Also presenting the relation between output and input, but in a more specific way, are the definitions of H. Stein and Suttermeister that employ output/hour of work, which is the most traditional ratio to measure productivity. The reasons why this ratio is commonly used are stated by L. Greenberg (13):

"It is an important factor in estimating future labor requirements, it is related to wages and labor cost and to wage and price control programs, and in demand. It is also recommended...as a measure which is more easily understood than the alternatives."

① Criticisms to the use of this ratio are stated by S. Eilon et al. (1976):

- "1. Output per man-hour does not measure productive efficiency as a whole, or even the productive contributions of labor.
2. Increases in output per man-hour may or may not be desirable, and may or may not reduce unit labor costs.
3. Even if increases in output per man-hours are accompanied by only proportionate increases in hourly wage rates, production

costs are more likely to increase than to remain unchanged in "capital-dominate" industries, such as the steel industries."

Some contradictions can be found between the definitions by Greenberg and McBeath. The former establishes that, "... is often an indicator, but not identical to, a measure of efficiency". The latter identifies a complete relationship between productivity and efficiency as he establishes: "Productivity is a measure of production efficiency..."

#### Improving Productivity Techniques

Most of the approaches to obtain an increase in productivity realize that to obtain better productivity, one should try to improve both human and technological factors. Nevertheless, it can be noticed in the different approaches certain preference of the factors to modify.

The suggestions to an improvement by Reed (1976) and Norman and Bahiri<sup>25</sup> (1972) have more tendency to the technical factors. The efforts of these authors are mainly to the reduction of costs. Their techniques are more closely identified with the Scientific Management and Quantitative Techniques.

Reed suggests a Pareto analysis for the improving of productivity. His procedure is as follows:

- 1st Identify and estimate avoidable costs.
- 2nd Establish problem priorities on the basis of relative magnitude of the estimate avoidable costs.
- 3rd To seek means to reduce the avoidable costs in order of magnitude.

Some identified cost reduction areas and suggested solutions are presented in Figure II.2.

Norman and Bahiri (1972) suggest the next tactics of productivity improvement.

1. Improve Costing Systems
2. Rationalization of Product Variety
3. Improve Production Scheduling and Control, and inventory control.
4. Low cost Automation. Improve mechanical handling and pre-tooling arrangements.
5. Study the economics of machining and group technology.
6. Value engineering and analysis and improved materials utilization.
7. Improve maintenance systems and replacement policies.

To the contrary, the books by McBeath (1974), Ross (1977) and Suttermeister (1976) have the tendency to have more concentration of efforts on the human side in order to improve productivity. Their approaches are more identified with the managerial process and the behavioral

IDENTIFYING AND RESOLVING PROBLEMS		
Problem Area	Techniques to help identify the problem	Techniques to help resolve the problem
In-process inventory	Activity sampling	Fixed path handling Move ticket control Fixed storage location Finite scheduling Capacity determination Group technology
Information timeliness & accountability at point of use	Activity sampling Control charts	Process analysis of input and output data external to the computer Form & report design Routine operating system audits
In-process queues	Work sampling Control charts	In-process inventory control Timely, accurate, and usable information Control charts
Job, material, tool, machine delays due to one or the other, e.g., Lack of adequate coordination	Sampling ANOVA	MRP (Materials requirements planning)
Maintenance	Sampling	Methods study Time standards Spares program Simulation
Damaged parts, scrap, & rework	Sampling Design of experiments ANOVA	Handling Storage Tooling Low cost automation
Expediting	Systems analysis	Information timeliness & accuracy MRP Planning, scheduling, and dispatching algorithms Material flow systems design
Short run set-up cost	Sampling	Group technology N/C sequencing
Assembly delays	Sampling	Group technology Modularization Cellular manufacturing Methods analysis Low cost automation
Distribution	Cost & time delay analysis	Simulation Linear programming Network analysis Dock design Order gathering
Conservation of energy	Survey sampling	Storage area design Handling systems Equipment replacement studies Energy use audits
Stores or finished goods	Sampling	Systems & procedures Information systems Inventory aging Modularization Group technology
Material handling	Activity sampling	Centralized dispatching Fixed path equipment Semi-automation Code reading systems
Clerical	Work measurement Sampling Methods analysis	Forms design Coding Semi-automation Data gathering Data processing Job cost reporting

211 0001 76 11

Figure II.2. Cost reduction areas and suggested solutions.  
From Reed (1976).

process. Their suggestions for an improvement are: a better communication among the personnel, increasing motivation, a better delegation of power, etc. By the same token, the study by Katzell (1975) is mainly concerned with job satisfaction and motivation.

### III. RATINGS OF OUTCOMES

"The storm debate Atrides hears with joy  
 For heaven foretold the contest, when he trod  
 The marble threshold of the Delphic god,  
 Curious to learn the counsels of sky  
 Ere yet he loos'd the rage of war on Troy"

"The Iliad" by Homer.  
 Translated by Alexander Pope.

#### Introduction

An analysis of some of the material covered in the second page of the questionnaire will be presented in this chapter.

In that part of the questionnaire, the respondents were asked to rate four proposed goals in accordance with the following scale.

Productivity decreases or is unchanged		May produce a small improvement		Certain to make a small improvement		May raise productivity significantly		Certain to yield large improvement	
1	2	3	4	5	6	7	8	9	10

The proposed goals were a cluster of several objectives that organizations frequently attempt to fulfill to improve productivity. They are:

IMPROVED EFFICIENCY: Lower total operating costs, savings in labor and machine time, less waste of material, fewer damages, less remake, etc.

IMPROVED EFFECTIVENESS: Growth in total revenues and/or profits, better decision making and communications, better utilization of resources, etc.

HIGHER PERFORMANCE: Improve quality of output, increased flexibility, fewer breakdowns and accidents, etc.

GREATER ORGANIZATIONAL VITALITY: More initiative and involvement, more worker stability, greater cooperation and job satisfaction, etc.

It should be noted that the respondents were asked to rate the goals considering the organization's interests rather than being more concerned about their own goals, as was the case in the survey by Sirota and Greenwood (1971).

The purpose of the rating was to realize the importance given to the proposed goals and if some factors, such as the type and size of the organization (number of employees), influenced the ratings. To accomplish these purposes, confidence intervals of the mean ratings were calculated and analyses of variance performed.

## Results

An analysis of variance was performed for the ratings of each of the proposed goals. The factors that were considered were previously presented in Chapter I.

The two factor variables and the blocking variable were considered to be fixed effects. The model tested

was a generalized randomized block design [Netter and Wasserman (1974)].

$$Y_{ijkm} = \mu \dots + \tau_i + \gamma_j + \pi_k + (\tau\gamma)_{ij} + (\tau\pi)_{ik} + (\gamma\pi)_{jk} + (\tau\gamma\pi)_{ijk} + \epsilon_{jikm}$$

$\mu \dots$  is a constant.

$\tau_i$ ,  $\gamma_j$  and  $\pi_k$  are constant subject to the restrictions.

$(\tau\gamma)_{ij}$ ,  $(\tau\pi)_{ik}$ ,  $(\gamma\pi)_{jk}$ ,  $(\tau\gamma\pi)_{ijk}$  are constants subject to the restrictions that the sums over any subscript are zero.

$\epsilon_{ijk}$  represents the random error term which is assumed to be independent normally distributed, with mean 0 and variance

$$i = 1, \dots, n; j = 1, \dots, a; k = 1, \dots, b; m = 1, \dots, i_{jk}$$

The analyses of variance were obtained using the statistical computer package SPSS, Nie et al. (1975).

Table III.1 shows the results of such analyses in a condensed form.

The 95% confidence intervals of the mean ratings are presented in Table III.2 in accordance with the two levels for the type of organization (Appendix section A.1). The mean values were calculated using the statistical computer package SPSS, Nie et al. (1975).

Some analyses of variance were performed for each type of organization in order to test if there existed differences in the ratings given to the four goals. The model used was an additive repeated measurements design where the



four goals were the treatments and the respondents were the blocks, Netter et al. (1974, p. 747). The results of these analyses are presented in Tables III.3 and III.4.

In the case of the non-profit organizations, there were no differences in the ratings of the goals at the  $\alpha = 0.05$  and  $\alpha = 0.10$  level (Appendix section A.2). However, the F test was significant at the  $\alpha = 0.10$  level for the profit organizations. Hence, a Tukey test of multi-comparison was performed (Appendix section A.3). The results of that test indicated that the goal "Efficiency" received a slightly higher rating than the other goals. The rating of the tactic "Effectiveness" was also slightly higher than the goal "Vitality".

TABLE III.1. CRITICAL VALUES FOR THE F TEST

Source of variation	DF	Efficiency		Effectiveness		Performance		Vitality	
		F	SF	F	SF	F	SF	F	SF
S	1	1.01	0.317	0.23	0.632	0.27	0.603	0.49	0.483
T	1	19.21	0.001*	1.14	0.287	1.00	0.320	0.31	0.581
P	3	1.34	0.266	0.38	0.767	1.08	0.362	0.86	0.463
S x T	1	0.19	0.667	0.67	0.415	0.27	0.607	0.17	0.683
S x P	3	0.49	0.690	0.06	0.982	0.32	0.814	1.30	0.279
T x P	3	0.45	0.714	0.53	0.664	0.06	0.980	1.17	0.322
S x T x P	3	0.19	0.901	0.32	0.809	0.40	0.754	1.25	0.297
ERROR	112	MSE = 4.29		MSE = 4.53		MSE = 3.60		MSE = 4.88	

S = Size of the organization

T = Type of the organization

P = Organization position of the respondent

F = Calculated value for the F

SF = Significance of F test

S x T, S x P, T x P, S x T x P = Interaction of the factors

MSE = Error Mean Square

DF = Degrees of freedom

\*Significant at the  $\alpha = 0.05$  level

TABLE III.2. CONFIDENCE INTERVAL FOR THE MEAN RATINGS OF THE GOALS

FACTOR LEVEL	N	EFFICIENCY	EFFECTIVENESS	PERFORMANCE	VITALITY
Non-Profit	39	5.92 ± 0.65	6.28 ± 0.67	5.89 ± 0.59	6.18 ± 0.69
Profit	89	7.71 ± 0.43	6.59 ± 0.44	6.27 ± 0.39	5.92 ± 0.46

N = Sample Size

$\alpha = 0.05$

TABLE III.3. ANALYSIS OF VARIANCE OF THE GOAL RATINGS BY  
THE NON-PROFIT ORGANIZATIONS

Source of Variation	DF	SS	MS	F
Goals	3	4.22	1.41	0.4132
Respondents	38	337.49	8.881	2.6045
Error	114	338.51	3.41	
Total	155	680.22		

DF = Degrees of Freedom

SS = Sum of Squares

F = F Value

MS = Mean Squares

TABLE III.4. ANALYSIS OF VARIANCE OF THE GOAL RATING BY  
THE PROFIT ORGANIZATIONS

Source of Variation	DF	SS	MS	F
Goals	3	160.02	53.34	2.42
Respondents	88	5,419.06	20.53	0.93
Error	264	5,824.73	22.06	
Total	355	11,403.81		

DF = Degrees of Freedom

SS = Sum of Squares

MS = Mean Square

F = F Value

Comments

## A) About factors which influenced the ratings

The results in Table III.1 indicated that only in the case of the goals identified as "Efficiency" was the factor "Type of industry" to be influential on the ratings. For the other goals, there was an agreement among the level of the factors in their ratings. This means that the mean rating given to "Efficiency" differs with the type of industry.

## B) About the ratings

The Tukey test showed that, at the  $\alpha = 0.10$  level, the rating given to "Efficiency" by the profit organizations (around eight i.e. May raise productivity significantly) was the highest. The rating given to "Effectiveness" was slightly higher (6,5) than the one for vitality (6).

## C) About the application of the results

The information accumulated concerning the ratings given to the different goals (the subject of this chapter) and tactics (the subject of the next chapter) can be used as an information system where the data input would be the type and the size of the organization, and the output would be the 95% confidence intervals of the mean ratings. If more information is desired, the frequency of the

responses could be presented also as an output (Figure III.1).

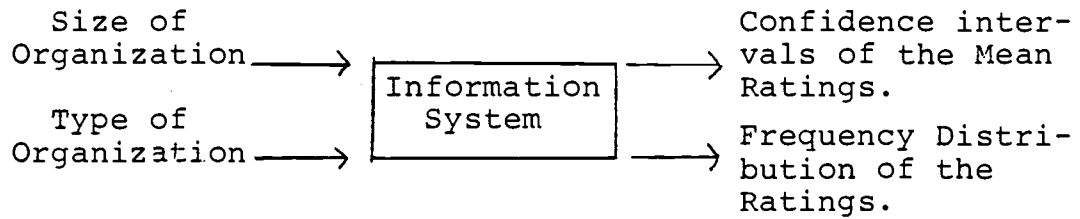


Figure III.1. Information System

The information provided by the system, based on opinions of organizations with similar characteristics (i.e. type and size), could be useful to managers, industrial engineers, etc. who are trying to implement a productivity program. The information provided by the system could be used as an initial guideline of what could be the convenient emphasis given to the goals and, also, which tactics would be more suitable to implement.

The results presented in Table III.2 can be used as the output of one of the aforementioned information systems. In this case, only the type of organization is used as the input data since it was the factor which showed to have influence in the ratings. The results can be interpreted as follows:

#### TYPE OF ORGANIZATION

Non-profit oriented	Gives the same importance to the achievement of the four goals.
---------------------	---

Profit oriented

Gives a slight priority to the achievement of efficiency, a little less to the achievement of effectiveness, and slightly less to the achievement of performance and vitality.



#### IV. RANKING OF TACTICS

##### Introduction

This chapter is also concerned with the analysis of some of the material of the second page of the questionnaire. The part of that section of the questionnaire that is covered in this chapter is the ranking of six proposed tactics in accordance with their promise to improve productivity. The proposed tactics were the following:

Machines: Replace manual labor by machines, get faster or more reliable equipment (automate).

Management: Better coordination and budgeting, more inspiring leadership (motivate).

Processes: Improve scheduling and material flow, more accurate faster data flow (computerize).

Work Design: Modify job content, improve work methods, retrain workers (enrich jobs).

Environment: Make safer or more pleasant working conditions, reorganize structure (innovate).

Programs: Raise pay, revise policies, try goal-setting (MBO)<sup>3</sup> programs (all participate).

The main objective of the ranking was to determine the preferences of the tactics and to measure whether some

---

<sup>3</sup>Management by Objectives

of the factors, such as type and size of the organization, influenced the ranking of the tactics.

On page two of the questionnaire, the respondents were also asked to rate the expected effects of the tactics on each goal in accordance with the following scale:

- + Change will have a positive effect on the outcome; likely successful.
- Possible negative effect on outcome.
- 0 Change should have no effect or there is equal likelihood of either a positive or negative effect on the outcome.

The results of these ratings are also presented in this chapter. On page one of the questionnaire, the respondents were asked to answer the following question:

"To what extent has your organization emphasized productivity measurement and improvement programs, and to what extent have you been personally involved (mark with an x on the scale below the organizational emphasis, and with a ✓ the extent of your personal involvement).

		Approximate Measurements				Extensive Measurements			
		Made but not used			Made and uti- lized	Made but not wide- ly ap- plied			Made and applied vigorous- ly
Not used	Just men- tioned	3	4	5	6	7	8	9	10
0	1	2							

## Results

Some analyses of variance were performed on the ratings of each of the tactics. The factors that were considered were described previously (see Chapter 2, page 21).

The model tested was also a generalized randomized block design (previously described in Chapter 2, page 21). However, in this case  $Y_{ijkm}$  represented the rank given to the tactics. The same model assumptions are valid in this case.

The analyses of variance were obtained using the statistical computer package SPSS, Nie et al. (1975). Table IV.1 shows the results of such analyses in a condensed form.

The 95% confidence intervals for the mean ranking are presented in Table IV.2 in accordance with the type of organization (see Appendix Section A.4).

To realize the order of preference of the tactics, a non-parametric test known as the Friedman Two Way Analysis of Variance was performed ad hoc., Daniel (1978, p. 224). The elements of the blocking variable were each one of the respondents (Appendix Section A.5).

The null hypothesis was:

$H_0$ : The population within a block are identical.

The alternative hypothesis was:

$H_a$ :  $T_1 \neq T_2 \neq T_3 \neq T_4 \neq T_5 \neq T_6$

where  $T_i$  is the mean ranking

TABLE IV.1. CRITICAL VALUES FOR THE F TEST.

TABLE IV.2. CONFIDENCE INTERVALS FOR THE MEAN RANKING OF THE TACTICS.

Type of Organi- zation	N	Machines	Management	Processes	Work-Design	Environment	Programs
Profit	90	2.75 ± 0.30	2.89 ± 0.25	2.96 ± 0.23	3.12 ± 0.23	4.66 ± 0.25	4.47 ± 0.28
Non- Profit	40	4.47 ± 0.46	1.85 ± 0.38	3.42 ± 0.35	3.22 ± 0.12	4.67 ± 0.37	3.17 ± 0.42

N = Number of Respondents

$T_1$ Machines	$T_3$ Processes	$T_5$ Environment
$T_2$ Management	$T_4$ Work Design	$T_6$ Programs

The test was performed for each type of organization. For both levels (Profit, Non-profit) the null hypothesis was rejected. Therefore, to make pairwise comparisons, a non-parametric multicomparison test was performed, Daniel (1978, p. 331) (Appendix Section A.6). The results obtained with this test were the following:

Non-profit:  $T_2 < T_6 < T_4 = T_3 = T_1 = T_5$

Profit:  $T_1 = T_2 = T_3 = T_4 < T_6 = T_5$

For the non-profit organizations,  $T_3$  was not statistically different from  $T_1$  at the  $\alpha = 0.10$  and  $\alpha = 0.05$  level, but  $T_4$  was statistically different from  $T_5$  even at the  $\alpha = 0.05$  level. Therefore, since they were close to being significantly different, they could be considered as another group producing the following result:

Non-profit:  $T_2 < T_6 < T_4 = T_3 < T_1 = T_5$

The results of how the respondents related the effect of the tactics to the achievement of the goals is presented in Table IV.3. The rating was in accordance with the scale presented in Chapter 3, page 21.

In order to analyze the responses to the question concerning the involvement of the respondents and their organizations in the productivity improvement programs and measurements (Section III-1), a paired difference test was utilized ad hoc., Mendenhall (1978, p. 228). This test was selected since the respondents gave both the

personal and the organizational grading of involvement (Appendix section A.7). The null hypothesis was:

$$H_0: u_d = 0 \quad \text{That is equivalent to } H_0: u_1 = u_2$$

where  $u_1$  = mean rating of the organization

$u_2$  = mean rating of the respondents

The null hypothesis was not rejected. The mean values of the ratings were

$$u_1 = 6.375$$

$$u_2 = 6.50$$

TABLE IV.3. TACTICS EFFECT ON THE ACHIEVEMENT OF GOALS

TACTICS	EF- FECT	O U T C O M E S *							
		EFFICIENCY		EFFECTIVENESS		PERFORMANCE		VITALITY	
		P	NP	P	NP	P	NP	P	NP
Machines	1	91	66	74	41	49	55	20	11
	0	6	25	19	52	41	34	47	50
	-1	3	9	7	7	1	11	33	39
Management	1	63	57	80	91	54	64	84	39
	0	34	41	19	9	45	36	15	5
	-1	3	2	1	0	1	0	1	0
Processes	1	84	82	80	68	63	66	31	29
	0	15	14	19	30	36	32	59	57
	-1	1	4	1	4	1	2	10	14
Work Design	1	78	68	66	59	71	64	74	64
	0	19	25	32	36	26	34	20	34
	-1	3	7	2	5	3	2	6	2
Environment	1	54	27	30	30	42	43	55	45
	0	35	57	50	66	50	55	32	48
	-1	16	6	20	4	8	2	3	7
Programs	1	38	34	49	57	38	54	62	86
	0	50	55	41	41	57	41	32	14
	-1	12	11	10	2	5	5	6	0

P = Profit Organizations  
 NP = Non-Profit Organizations  
 1 = Positive effect on outcome

0 = No effect on outcome  
 -1 = Negative effect on outcome  
 \* = Results are in percentage



Comments

## A) About the Factors Affecting Ranking

The results of the analyses of variance (Table IV.1) indicated that the factor designated "Type of Organization" was significant ( $\alpha = 0.05$ ) in the ranking of the following tactics: "Machines", "Management", and "Programs". The aforementioned factor was also influential in the ranking of the tactic "Processes" at a higher level ( $\alpha = 0.10$ ).

The factor "Size of the Organization" was not shown to be influential in any case ( $\alpha = 0.05$  or  $\alpha = 0.10$ ); although the significance of the F test was just a little higher than  $\alpha = 0.10$  for the tactics "Processes" and "Work Design".

The effect of the blocking variable "Business Position of the Respondent" was significant in three of the tactics at the  $\alpha = 0.05$  level and for another at the  $\alpha = 0.10$  level. This can be interpreted [Steel and Torri (1960)] as an indication that the precision of the analysis has been increased through the use of this design relative to the design without blocking.

The tactics denominated "Work Design" and "Environment" did not get influenced in the ranking by the factor "Type of Organization" i.e. there was general agreement about the ranking given to these tactics among the respondents.

B) About the Ranking of the Tactics

The preferential differences between the two categories of organizations were with respect to the tactics "Machines" and "Programs".

The non-profit organizations ranked the tactic "Programs" quite highly (second place), while the profit organizations ranked it nearly last (fifth place). Au contraire, the non-profit organizations ranked the tactic "Machines" in the fourth place, whereas the profit organizations ranked this tactic first.

The high ratings of the tactics "Management" and "Programs" by the non-profit organizations coincided with the opinion of R. Oswald who stated the following:

"Productivity improvements in the public sector are peculiarly labor-oriented rather than technology induced. As a result, greater emphasis must be placed upon labor-management cooperation to achieve productivity gains." [Industrial Relations Research Association (1975, p. 100)]

The role of the industrial engineer is closely involved with productivity. R. Reed (1976) established this point when he stated:

"Industrial Engineers, through their professional society, AIIE, have accepted this responsibility by designating themselves, the productivity people..."

J. H. Kehlbeck (1978) also commented in this regard: "What is each industrial engineer's responsibility? Certainly it is to implement productivity improvement."

Consequently, the results of the order of preference of tactics could be useful in the planning of Industrial Engineering academic programs. It should also be noticed that the tactic "Management" (i.e. better coordination and budgeting, more inspiring leadership) was rated highest by both types of organizations. Hence, it may be advisable to grant more emphasis in this area of the academic curriculum. Conversely, the low ratings for the tactic "Environment" suggest that less importance might be given in this area.

#### C) About the Interaction of Tactics and Goals

Some comments related to the interaction of tactics and goals are presented next:

For the profit organizations, the tactic that had the highest expectations for a negative effect on the achievement of a goal was "Machines" on the goal "Organizational Vitality" (33% of the respondents). For the non-profit organizations, "Machines" on the goal "Organizational Vitality" also had the highest expectation (39% of respondents).

The tactic with the highest expectation for a positive effect on the achievement of a goal was "Machines" on the goal "Efficiency" for the profit organizations, and "Management" on the goal "Effectiveness" for the non-profit organizations.

These results agree with the ranking of the tactics. However, taking in consideration the previously mentioned facts, we should indicate that in the opinion of the profit organizations' respondents, there was a high expectation of a positive increase in "Efficiency" (91%). Nevertheless, there was also a considerable expectation (33% of the respondents) of causing a negative effect in the "Organizational Vitality".

Similar information can be obtained for both types of organizations (i.e. profit and non-profit) for all tactics and outcomes, if the results of Table IV.3 are analyzed in a similar manner.

The results of Table IV.2 in conjunction with those of Table IV.3 (concerning the ranking of tactics) can be used as the output of an information system similar to the one described previously in section III-3-C.

#### D) About the Involvement of the Respondents in Productivity Improvement Programs

The analysis of the responses to the question on the first page of the questionnaire (Section III-1) is presented next. The hypothesis that there was an equal interest among the respondents and their organizations referrent to their concern on productivity measurement and improvement programs was not rejected. The organizations' and the respondents' ratings were "made and utilized" and "made but not widely applied", respectively.

## V. AUXILIARY PRODUCTIVITY RATIOS FOR INVESTMENT PROPOSALS, CONTROLLING OPERATIONS, AND ATTAINING SOCIAL OBJECTIVES

### Introduction

In the present chapter, an analysis of the responses to the third page of the questionnaire is presented.

The purpose of this section was to inquire into the preference of the respondents in the use of productivity ratios in three promising areas of application. The areas of application were the following:

Evaluation of capital investment proposals: ratios to supplement the "net income/amount invested" criterion to rate specific gains expected from investment.

Control of operations: ratios to supplement processes efficiency that can provide early warning of future operational difficulties.

Achievement of social objectives: Supplements to the "benefit/cost" criterion that define and rate how well a project satisfies conditions deemed desirable for the welfare of society.

Five productivity ratios were proposed and it was asked to relate them with respect to their value for the potential use in the aforementioned areas. The proposed ratios were:

$$\text{Social Ratio} = \frac{\text{Social objectives (\# or \$)}}{\text{Sales or Budget (\# or \$)}}$$

$$\text{Employment Ratio} = \frac{\text{Value added (\$)}}{\text{People Employed}}$$

$$\text{Energy Ratio} = \frac{\text{Units Produced (\#)}}{\text{Energy Used (kw-hr)}}$$

$$\text{Work Ratio} = \frac{\text{Employee hours worked (hr)}}{\text{Employee hours paid (hr)}}$$

$$\text{Material Ratio} = \frac{\text{Material in product}}{\text{Total material supplied}}$$

$$\text{or } \frac{\text{Recycled material used}}{\text{Total material supplied}}$$

\*For a more thorough description of the ratios see the sample questionnaire in Chapter I.

The rating scale is presented next:

Decep- tive indi- cator of value		Appro- priate consider- ation		Measures factors of in- terest		Important indicator of achieve- ment		Vital measure of critically	
1	2	3	4	5	6	7	8	9	10

\* A zero value was assigned if the ratio was not valid for an application in the respondents' organizations.

Also, in this part of the questionnaire the respondents were asked to suggest ratios that could have been appropriated for the respondents' organizations and to rate them in accordance with the previously mentioned scale.

## Analysis of the Ratios Proposed in the Questionnaire

### A) Presentation of Results

The descriptive statistics (sample means and standard deviations) of the ratings given to the proposed ratios concerning their desirability to be used in the three previously mentioned areas of application (see section V.1) are presented in Table V.1.

TABLE V.1. MEAN ( $\bar{x}$ ) AND SAMPLE STANDARD DEVIATION ( $s$ )  
FOR THE RATING GIVEN TO THE PROPOSED TACTICS.

RATIO	N	INVESTMENT	CONTROL	SOCIAL
Employment	134	$\bar{x} = 5.11$ $s = 3.17$	$\bar{x} = 6.03$ $s = 2.87$	$\bar{x} = 3.15$ $s = 2.70$
Energy	133	$\bar{x} = 4.76$ $s = 3.18$	$\bar{x} = 4.98$ $s = 3.18$	$\bar{x} = 3.8$ $s = 3.30$
Work	133	$\bar{x} = 4.7$ $s = 3.07$	$\bar{x} = 7.43$ $s = 2.47$	$\bar{x} = 3.6$ $s = 2.59$
Material	133	$\bar{x} = 4.52$ $s = 3.47$	$\bar{x} = 5.53$ $s = 3.64$	$\bar{x} = 2.83$ $s = 2.84$
Social	130	$\bar{x} = 2.92$ $s = 2.48$	$\bar{x} = 3.41$ $s = 2.71$	$\bar{x} = 6.14$ $s = 2.91$

N = Number of respondents

The 95% confidence intervals were calculated assuming that the sample population followed a normal distribution (Mendenhall, p. 218). The confidence intervals are presented in Table V.2 (Appendix A.8).

TABLE V.2. CONFIDENCE INTERVALS FOR THE RATINGS GIVEN TO FIVE PROPOSED RATIOS ( $\alpha = 0.05$ ).

RATIO	INVESTMENT	CONTROL	SOCIAL
Employment	5.11 $\pm$ 0.54	6.03 $\pm$ 0.48	3.15 $\pm$ 0.46
Energy	4.76 $\pm$ 0.54	4.98 $\pm$ 0.52	3.80 $\pm$ 0.56
Work	4.70 $\pm$ 0.52	7.43 $\pm$ 0.42	3.60 $\pm$ 0.44
Material	4.52 $\pm$ 0.59	5.53 $\pm$ 0.62	2.83 $\pm$ 0.48
Social	2.92 $\pm$ 0.43	3.41 $\pm$ 0.46	6.14 $\pm$ 0.50

## B) Analysis of Results

The employment ratio was considered applicable as a measure of interest in the areas of control of operations and in the evaluation of capital investment proposals. Its possible role as a measure of achievement of social objectives was considered poor. Six percent of the respondents considered the employment ratio as not applicable to their organization.

Although with a little less emphasis than the employment ratio, the energy ratio was considered applicable as a measure of interest for the control of operations and in the evaluation of capital investment proposals. Its application as a measure of achievement of social objectives was considered appropriate. Eleven percent of the respondents did not consider the energy ratio applicable for their organizations.

The main area of application for the work ratio was considered the control of operations. In the mentioned



area it was rated as an important indicator of achievement. In the area of evaluation of capital investment proposals it was considered as a measure of factors of interest. The application of this ratio to the measurement of social objectives was deemed as an appropriate consideration. Two percent of the respondents did not consider this ratio applicable.

Material ratio: The principal area of application of the material ratio was also in the control of operations and was rated as a measure of factors of interest. Its use in the area of evaluation of capital investment proposals was deemed as an appropriate consideration. Its value as a measure of achievement of social objectives was considered poor. Eighteen percent did not consider this ratio applicable.

As could have been expected, the main use suggested for the social ratio was as an indicator of social objectives. It was considered to measure factors of interest. Its use in the control of operations was deemed appropriate and its application as a measure in the area of evaluation of capital investment proposals was considered deceptive. Seven percent of the respondents did not consider this ratio applicable in their organizations.

### C) Overall Analysis

An overall view of the ratings given to the ratios concerning their usefulness in the different areas of

application seems to indicate that for all but the social ratio, the area which received the highest rating was the control of operations. The area with the second largest ratings was the evaluation of capital investment proposals and in third place the measure of achievements of social objectives.

The ratio that was considered less applicable in general, was the material ratio (18%) and was followed by the energy ratio (11%).

#### Analysis of the Ratios Suggested by the Respondents

##### A) Presentation of Results

The suggested ratios by the respondents were of a great variety. Some of them were very specific; for example, diameter inches of welding/man hour.

The statistics of the ratings given to the different suggested ratios are presented in Table V.3. For the calculations of the 95% confidence intervals it was assumed that the ratings' distribution followed a normal distribution (Appendix section A-9).

TABLE V.3. MEAN, STANDARD DEVIATION, AND CONFIDENCE INTERVALS OF THE RATINGS GIVEN TO THE RATIOS PROPOSED BY THE RESPONDENTS.

	INVESTMENTS	CONTROL	SOCIAL
Mean Ratings	6.87	7.93	4.32
Standard Deviation	0.3188	0.2207	0.3097
Confidence Interval	(7.394; 6.46)	(8.45; 7.40)	(4.84; 3.796)

The mean ratings indicated a pattern similar in the area of preference for the applications of the productivity ratios suggested in the questionnaire. The area of application with the highest rating was the control of operations. The second desirable area of application was the evaluation of investment proposals and in the last place the application in the evaluation of achievements of social objectives.

The suggested ratios were classified in accordance with the following categories:

1. Ratios showing a relation of performance to some standard, e.g., Earned hours/Actual hours.
  - a. Ratios showing an output/input relation. The outputs in this category were related mainly with what could most commonly be considered as the output of the system, e.g., Utility increases/investment; Net profit/Cost of execution.
  - 2b. Ratios showing also an output/input relationship, but the output was related only in an indirect

way to the system output, e.g., Maintenance man-hours/production man-hours; Minority employees/total employees.

The percentage of the different ratios in the three different categories are:

Category 1	21%
Category 2	52%
Category 3	27%

#### B) Analysis of Results

It can be observed that 21% of the proposed ratios by the respondents presented an output/standard relation instead of the output/input relation that was suggested in the questionnaire.

One explanation for this tendency could be the fact that the concepts of productivity do not embrace merely an output-input relationship but several others as is shown in the study by R. Katzell et al. (1975). This fact stems from an unclear definition for a productivity index. An example of this incertitude is presented in the book by Mali (1978). At the beginning of his book (page 7), Mali defines the productivity index as the relation between output and input and also as the relation between effectiveness and efficiency, but later in the same work (page 85), he defines a productivity index as a relation of productivity in the current year to the productivity

in a base year. This last definition of productivity index agrees with the one given by M. Mundel (1976).

P. Mali also suggests five categories of ratios to represent the productivity indexes. The five categories are presented next:

- 1) Overall indexes: Final output/resource inputs.
- 2) Objective ratios: Achievement of individual managers/objectives that were planned.
- 3) Cost ratios: Performance output/costs.
- 4) Work standards: Work units achieved/expected time standards.
- 5) Time standard: Performance output/time needed.

These categories could be reduced to two. Mali's categories four and two present an output/standard relation which can be identified with the suggested category one (the suggested categories were defined in the previous section). Mali's categories one, three and five can be identified with the suggested categories 2a and 2b because they represent merely an output/input relation.

These discrepancies in proposed ratio are as a consequence inexact about what a productivity index is: Is it the quotient of the current output/input ratio to an output/input ratio in a base year? Is it merely an output/input ratio? Is it the ratio of actual performance to a certain standard?

What can be done to avoid such confusion is to define five different types of productivity indexes. The proposed types are:

1. Rough productivity index = Current output/Current input
2. Base productivity index = Output in base year/ input in base year
3. Transformed productivity index = Rough productivity index/Base productivity index
4. Goal productivity index: The desired output-input relation
5. Comparison productivity index = It could be expressed as a difference or as a ratio of the desired productivity index with the transformed productivity index.

The previous definitions of productivity indexes can be more clearly presented by means of a block diagram of a closed loop (feed back) control system (Figure 1). A description of such systems can be found elsewhere [K. Ogata (1970), J. Cadzow (1973)].

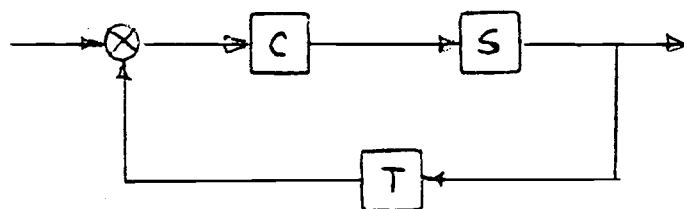


Figure V.1. Feed-Back Control System.

C Controller  
 S System  
 T Transducer

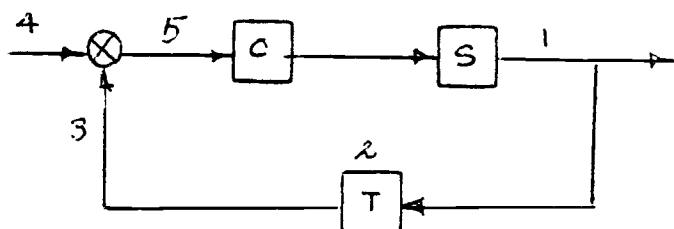


Figure V.2. Feed-Back Control System applied to productivity measurement.

- |                     |                    |
|---------------------|--------------------|
| 1) Rough P.I.       | 4) Goal P.I.       |
| 2) Base P.I.        | 5) Comparison P.I. |
| 3) Transformed P.I. |                    |

Traditionally in this system the main concern is to control the output. The current importance given to productivity suggests that the principal interest could be to try to control the output/input ratio instead. Why should we use output/input ratios instead of merely output and input quantities in a separated way? Although C. A. Westwick (1976) mentions that "The information is more useful if it is in the form of a ratio rather than an absolute figure", he did not indicate why he considered it more useful. The main reason for this preference could be that in this form an implicit measure of efficiency is carried in the information.

The approach using output-input ratios are addressed with the same identification numbers as before (Figure V.2). It should be remarked that the comparison productivity index in this case took the form of a difference and not a ratio. The goal productivity index represents what in control engineering jargon is known as set point.

References of Possible Methods to Use in the Evaluation of Capital Investment Proposals Using Productivity Ratios

It can be observed in Tables V.2 and V.4 that the mean ratings given to the ratios proposed in the questionnaire and the ones suggested by the respondents with reference to their application in the evaluation of capital investment proposals is by selecting some of these ratios as objectives and to apply one of the several techniques that are used to make decisions when there are multiple objectives. Some of these techniques are presented in the book by R. L. Keeney and L. Raiffa (1976) and in the book by the same authors and R. Bell (1977).

An article which is related to productivity and with the application of one of these techniques (Multiplicative multiattribute function) is by W. T. Stewart (1978). His main concern was the measurement of productivity, not the evaluation of capital investment proposals. In the aforementioned article he uses for the selection of objectives a procedure known as the nominal group technique, which is more thoroughly covered in the book by Delbecq et al. (1975).

One relatively simple technique used to deal with proposals with multiple objectives is the Churchman-Ackoff method [C. W. Churchmann et al. (1957)]. An application of this technique in the evaluation of capital investment proposals can be found in the books by J. Canada (1971) and J. L. Riggs (1976).



## Summary

In this chapter the main areas of application for the five suggested ratios were inferred from the respondents' ratings. It was also observed that the main area of application of the ratios were in the control of operations followed by the evaluation of capital investment proposals. It was also apparent that the concept of a productivity index is not well defined. In order to clarify this concept five productivity indexes were proposed. The representation of these indexes in a feedback system block diagram was presented.

References to some techniques that can be used to apply productivity ratios in the area of evaluation of capital investment proposals were presented.

## VI. SHARING OF PRODUCTIVITY GAINS

### Introduction

The analysis of page four in the questionnaire will be covered in this chapter. In that part of the questionnaire was presented the following scenario to the respondents:

Scenario: Your organization has a productivity pattern, corrected to a base year index, shown in the table below. Assume that net profit increased at a commensurate rate with total productivity gains each year. (Also assume the national inflation rate is zero.)

	<u>1974</u>	change	<u>1975</u>	change	<u>1976</u>
Net OP (1)	100	15%	115	13%	130
Labor IP (2)	50	0	50	14%	57
Capital IP (3)	40	25%	50	4%	52
Labor PR (1) + (2)	2.0	15%	2.3	0	2.3
Capital PR (1) + (2)	2.5	-9%	2.3	9%	2.5
Total PR (1) + (2+3)	1.11	4%	1.15	4%	1.19

OP = Output  
IP = Input  
PR = Productivity

The graphical displays of these values are presented in Figures VI.1 to VI.7.

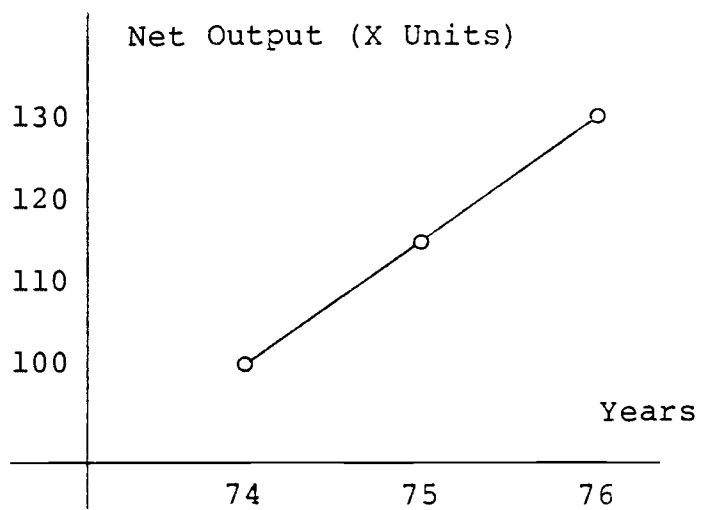


Figure VI.1. Net Output versus Time.

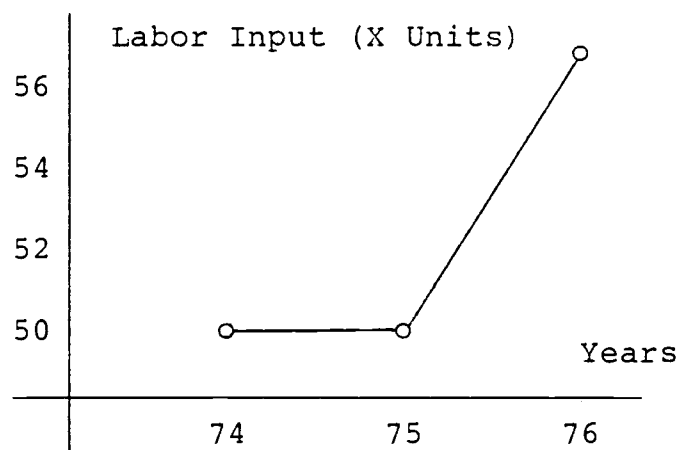


Figure VI.2. Labor Input versus Time.

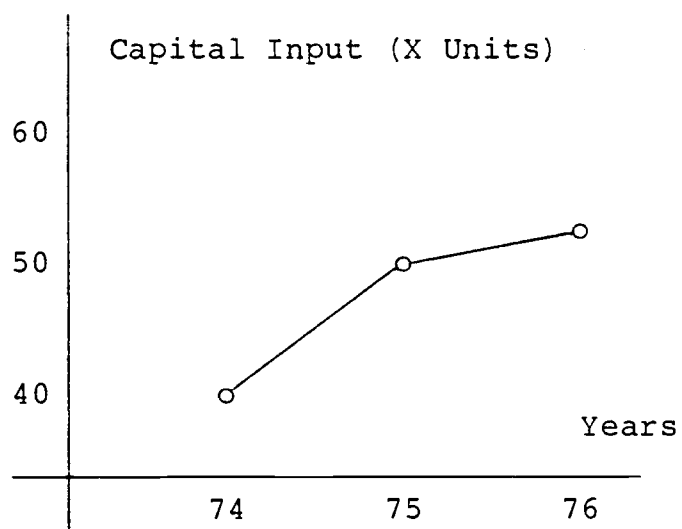


Figure VI.3. Capital Input versus Time.

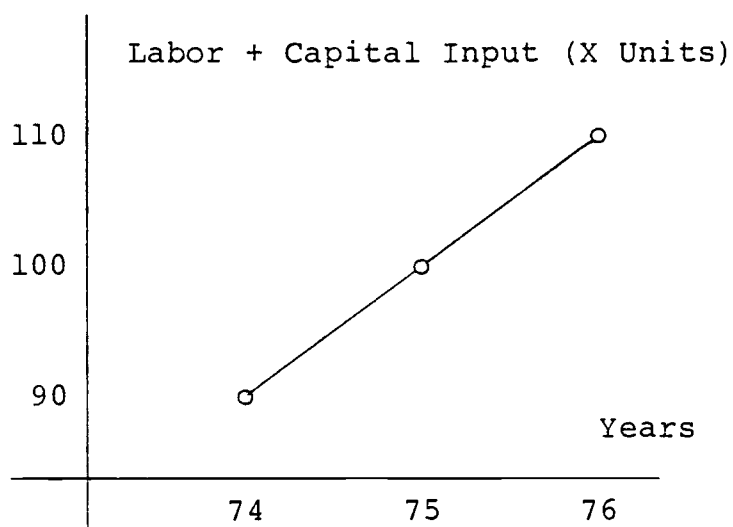


Figure VI.4. (Capital + Labor) Input versus Time.

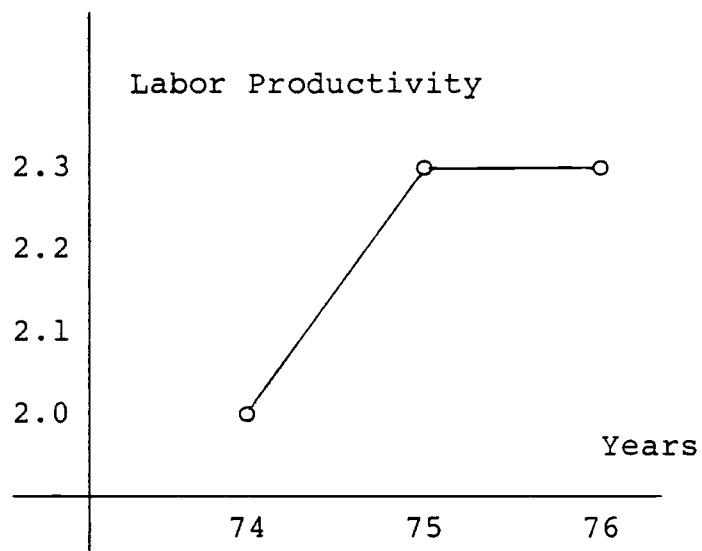


Figure VI.5. Labor Productivity versus Time.

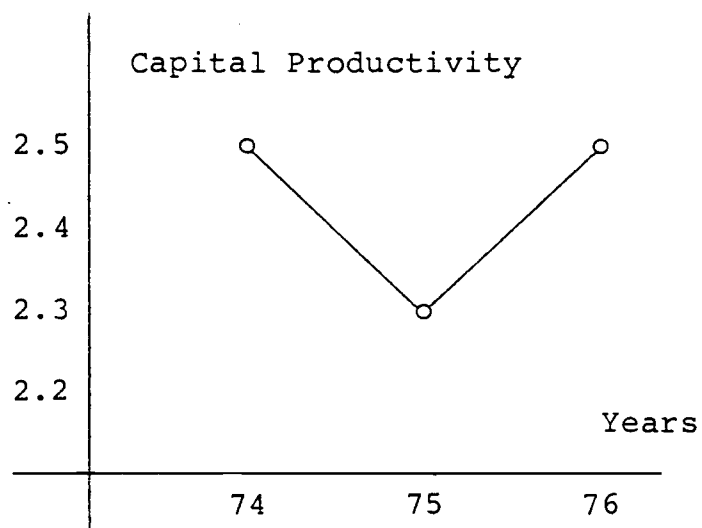


Figure VI.6. Capital Productivity versus Time.

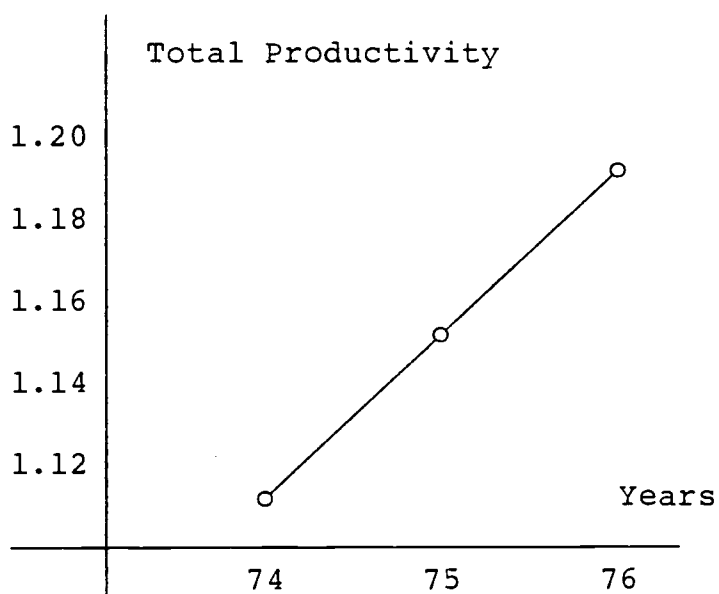


Figure VI.7. Total Productivity versus Time.

Three questions concerned with the scenario were asked. The analysis of the responses is the subject of the following sections.

#### Analysis of the Responses to the First Question

##### A) Description

The first question with reference to the scenario presented in section VI.1 was the following:

Is the increase in total productivity from 1974 to 1975, at no increase in labor input, sufficient reason to grant a wage increase to workers? Yes\_\_\_\_ No\_\_\_\_.

If yes, about how large an increase is reasonable?

\_\_\_\_%      Comments\_\_\_\_\_

## B) Results

The percentage of the affirmative and negative answers were as follows:

Yes                    61%

No                     39%

The 95% confidence interval of the proportion of affirmative answers, was the following [Daniel (1978, p. 52)] (Appendix section A.10):

$$0.53 < \text{Proportion} < 0.69$$

To investigate, if more than half of the respondents answered in the affirmative, a test of proportions [Daniel (1978, p. 46)] was performed ad hoc. (Appendix section A.11). The following hypothesis was tested.

$$H_0: \text{Proportion} \leq 0.50$$

$$H_1: \text{Proportion} > 0.50$$

The null hypothesis was rejected. Therefore, it was concluded that the proportion seems to be greater than 0.50.

The statistics of the answers given by the respondents which gave an indication of how much wage increase should be granted were the following:

48% granted more than 4% increase

52% granted less than, or equal to, 4% increase

A test of proportions, Daniel (1978, p. 46) was performed to investigate if more than half of the

respondents granted a wage increase not greater than 4%. The null hypothesis (i.e. the proportion was not greater than half) was not rejected (Appendix section A.12).

The statistics of the percentages granted were the following (Appendix section A.13):

Average = 5.164

Std. Dev. = 0.407

95% Confidence Interval =  $5.07 < x < 5.26$

#### C) Comments

The statistics indicated that there did not exist a clear preference in the responses concerning the concession of a wage increase since the percentages of affirmative and negative answers were very similar. Nevertheless, there seems to be a slight preference for the positive answers (i.e. the increase in total productivity is a good reason for a wage increase), since the hypothesis that the proportion of positive answers was not greater than fifty percent was rejected.

The results of the survey and the opinion of L. Greenberg, Industrial Relations Association (1975, p. 12), concerning the percentage of wage increases that should be granted are compared next. Greenberg based his criteria on output per man-hour (labor productivity) as a measure of productivity. His point of view about how much wage increase should be allowed was the following:



"If productivity rises, say ten percent, and output increases commensurately, then each factor of production-labor-management, capital--can receive a ten percent increase. If output does not rise commensurately (this can happen in a firm or industry but has not happened in the long-run in total private economy) then total compensation of input factors and rates of return to those factors will depend on the difference between the output increase and the productivity increase, the size of the hourly compensation increase and the cost of new capital investment."

Following Greenberg's procedure, an increase of 15% should have been granted since the labor productivity and the output increase commensurately. However, only two of the respondents granted 15% of increase (this represented 2.6% of the respondents who specified a percentage of increase). Therefore, it seems that the respondents did not agree with Greenberg's procedure. Nevertheless, if ad arbitrium it is assumed that the respondents who granted a wage increase not greater than 4% based their criterion in accordance to the total productivity and it is also supposed that those who granted more than a 4% wage increase based their criterion in accordance with labor productivity; then we can conclude that there existed a difference of opinion concerning which productivity measurement (labor or total productivity) should be the criterion to grant a wage increase, since the null hypothesis (i.e. no more than half of the respondents granted a wage increase not greater than 4%) was not rejected.

The most frequent comments made by the respondents were the following:

1. There was not enough information.
2. The increase in productivity was mainly due to capital investment.

The facts about whether the respondents did or did not grant a wage increase, and whether the respondents did or did not specify the percentage of increase, in conjunction with the comments of the respondents to question one engendered the following combination of responses.

- a) Do not grant --- No percentage specified ---  
Comment: Not enough reason. The increase in total productivity is not enough reason; other factors should be considered.
- b) Do not grant --- No percentage specified ---  
Comment: Capital is the reason. The increase in total productivity is not enough reason.  
The main cause of the increase in productivity was the increase in capital.
- c) Yes --- No percentage specified --- Comment:  
Not enough reason. An increase in total productivity is enough reason but there is not enough information about how much should be charged.
- d) Yes --- Grant X --- Comment: Capital is the reason. An increase in total productivity is enough reason to grant a wage increase but the main factor for the increase in productivity was the increase in capital.

e) Yes --- Grant X --- Not enough information.

An increase in total productivity is enough reason to grant a wage increase as should be x% but there is not enough information.

It should be noted that category (d) presented a contradiction since the respondents granted a specific wage increase notwithstanding they claimed that there was not enough information.

### Analysis of the Second Question

#### A) Introduction

In this section, an analysis of the responses to the second question is presented. The second question to the scenario previously presented (Section VI.1) was the following:

"If the decrease in capital productivity resulted from a mandatory capital investment to conform to a new law restricting pollution, should this benefit be recognized differently in the productivity measure?"

Yes\_\_\_\_\_ No\_\_\_\_\_

If yes, how? \_\_\_\_\_

#### B) Results

The statistics of the respondents were the following:

Yes	45%
No	55%

The 95% confidence interval for the proportion of negative answers is the following (Appendix section A.14):

$$0.467 < \text{Proportion} < 0.633$$

To test if the same proportion of respondents answered with a negative or a positive answer the following hypothesis was tested using a test of proportions ad hoc., Daniel (1978, p. 46) (Appendix section A.15).

$$H_0 = \text{Proportion} = 0.5$$

$$H_a = \text{Proportion} \neq 0.5$$

#### C) Comments

The null hypothesis that proposed half of the respondents answered in the negative could not be rejected, therefore this fact seems to indicate that there existed a difference of opinion about this issue. Nevertheless, the statistics seem to indicate there existed a slightly greater percentage of persons who did not think that the mandatory capital expenditure to conform a new law restricting pollution should be considered different in the productivity measurements.

The most frequent comments about how mandatory expenditures should be considered in productivity measurements were grouped as follows:

1. Excluding the capital from calculations.
2. Considering it as a long term investment or depression cost.

3. To measure productivity with and without capital expenditure.
4. To consider it by means of an auxiliary ratio.
5. To make a footnote of this abnormal situation.

Two main tendencies could be observed in the comments by the respondents: Those who excluded the compulsory capital expenditure from the productivity measurements (Group 1, 2 and 5) and the others which suggested to include it in a different way (Group 3 and 4).

### Analysis of the Third Question

#### A) Introduction

The analysis of the third question concerning the scenario previously presented is shown in this section. The third question was the following:

Who should benefit from the 4% gain in 1976? What percentage of the total profit for that year should be distributed to each of the following parties, based on...

...an unbiased analysis of data	...what your organization would likely do	...your personal opinion
___% to consumers	___% to consumers	___% to consumers
___% to workers	___% to workers	___% to workers
___% to owners	___% to owners	___% to owners
___% retained in organization	___% retained in organization	___% retained in organization

## B) Results

There were two main objectives of the third question. The first one was to determine whether there were a difference of opinion among the following criteria: The respondents' criterion, the organization opinion and what should have been done if a strict analysis of data were pursued. To accomplish the first objective, an analysis of variance was performed [Netter et al. (1974)]. The model used was the following:

$$Y_{ijkl} = \mu + S_i + P_k + S \times C_{ij} + S \times P_{ik} + C \times P_{jk} + E_{ijkl}$$

S = Subject

C = Criteria

P = Party

Y = Percentage granted

The variable "Subject" represented the different respondents and was a random factor; "Criteria" represented the three different criteria, and "Party" represented the different groups to whom the profits were granted. The two last factors were fixed.

The table for the analysis of variance is presented next:

TABLE VI.1. ANOVA TABLE

Factor	Degrees of Freedom	Mean Square
Subject	114	10.05
Criteria	2	26.49
Subject x Criteria	228	9.97
Party	3	62,880.70
Subject x Party	342	1,147.88
Criteria x Party	6	1,632.74
Error	684	338.60
Total	1374	

The F ratio for the interaction term of "Criteria" with "Party" was the following:  $F_{(6, 684)} = 4.82$ . The critical values at the 5% level from the table presented in Netter et al. (1974) were the following:

$$F_{(6, 120)} = 2.18 \quad F_{(6, \infty)} = 2.1$$

Hence it was concluded that the F test was significant. In addition a Tukey test [Netter et al. (1974, p. 594)] was performed in order to get a multicomparison of the mean values. The test showed that the mean percentage allowed to the consumers was different at the 10% level between the criteria of the organization and the personal opinion of the respondents. There was also a difference in the percentage granted to the consumers at the 10% level between the organization's criteria and the criteria based in an unbiased analysis of data.

TABLE VI.4. MEAN (X) AND SAMPLE STANDARD DEVIATION (S) OF THE PERCENTAGE GRANTED TO THE DIFFERENT PARTIES BY THE THREE CRITERIA.

CRITERIA PARTIES	N	UNBIASED ANAL- YSIS OF DATA	ORGANIZATIONS' OPINION	RESPONDENTS' OPINION
Consumers	115	X = 13.12 S = 16.34	X = 7.56 S = 13.46	X = 12.93 S = 15.16
Workers	115	X = 18.05 S = 21.13	X = 18.05 S = 19.98	X = 21.76 S = 17.43
Owners	115	X = 28.18 S = 21.14	X = 25.68 S = 25.62	X = 24.46 S = 24.67
Retained in Organization	115	X = 40.95 S = 26.95	X = 48.62 S = 31.51	X = 39.32 S = 23.16

N = Number of respondents.



TABLE VI.5. CONFIDENCE INTERVALS ( $\alpha = 0.05$ ) OF THE PERCENTAGES GRANTED TO THE DIFFERENT PARTIES BY THE THREE CRITERIA.

CRITERIA		UNBIASED ANAL- YSIS OF DATA	ORGANIZATIONS ' OPINION	RESPONDENTS ' OPINION
PARTIES	N			
Consumers	115	13.12 $\pm$ 2.99	7.56 $\pm$ 2.46	12.96 $\pm$ 2.78
Workers	115	18.05 $\pm$ 3.89	18.05 $\pm$ 3.67	21.76 $\pm$ 3.20
Owners	115	28.18 $\pm$ 3.86	25.68 $\pm$ 4.68	24.46 $\pm$ 4.53
Retained by Organization	115	40.95 $\pm$ 4.92	48.62 $\pm$ 5.76	39.32 $\pm$ 4.25

N = Number of respondents.

### C) Comments

The order in accordance with the magnitude of the percentage of the productivity earnings given to the different groups was the same for the three criteria. The biggest percentage was allowed to be retained in the organization, followed by the percentage given to the owners, the percentage to workers and the percentage to consumers.

There was a difference in criterion about the percentage that should be retained in the organization. For the organizations' criteria the amount allowed was around 50%, whereas for the other two criteria (i.e. an unbiased analysis of data and the respondents' personal opinion) were around 40 percent. Although the Tukey test did not show that the percentage granted to consumers were statistically different among the three criteria, the percentage granted by the organizations' criteria seems to be smaller (7.5%) than the other two criteria (13%).

It should also be remarked that the biggest percentage of productivity earnings granted to the workers was the one granted by the respondents' personal opinion (28%).

In summary, the form of distribution of the productivity earnings seems to be similar for the respondents' opinion and an unbiased analysis of data, but there existed a difference with what the organization would do and the two former criteria. This also could have been interpreted like the personal opinion was more closely based with an

unbiased analysis of data, whereas the organizations' criteria was in a certain way more arbitrary. The main difference among the organizations' and the personal opinion of the respondents was concerning the percentage to be retained by the organization. Although it could be expected that this difference would be reflected in a variation of opinion with respect to the percentage granted to the workers, this difference was rather reflected in the percentage granted to consumers (7.5% and 13%).

## VII. GENERAL CONCLUSIONS

"So the last shall be first,  
and the first last,..."

Matthew 20:16

The conclusions of this work can be summarized as follows:

A) The ranking given to the proposed tactics and the ratings of the proposed goals varied with the type of organization. The size of the organization did not prove to be influential either in the ranking of the tactics or the ratings of the goals.

The non-profit organizations tended to use tactics which included more human participation, whereas the profit organizations preferred tactics which were more related to technical factors.

The non-profit organizations had an equal preference for the achievement of the four proposed goals ("Efficiency", "Effectiveness", "Performance", "Vitality"). The profit organizations had slightly more preference for the achievement of "Efficiency".

The effect of the applications of the proposed tactics to the achievement of the proposed goals was presented in Table IV.3. The effect of the tactic "Machines" for the profit organizations was considerable. The results indicated that although there was a high expectation to

increase "Efficiency" there was also a considerable expectation of decreasing the organizations' "Vitality".

The results pinpointed in the former paragraphs could be used by managers who are preparing a productivity improvement program. The results could be useful to managers as an indication of: a) The emphasis to give to the achievement of each goal; b) the most appropriate tactics to use; c) the effects of the tactics on the achievement of the goals.

Further research could be directed toward a more detailed classification of the organizations. This objective could be accomplished by increasing the size of the respondents sample. The variable "Business Position" proved to be effective as a blocking variable. Therefore for each type of organization it is recommended that the respondents be included from the entire business hierarchy.

B) The results indicated that there was an equal interest between the respondents and their organizations with respect to their concern on productivity measurement and improvement.

C) The main applications of the five suggested ratios (Section V.1) were in the control of operations and the evaluation of capital interest proposals.

The respondents' comments suggested that there was not a clear concept of productivity indexes. In order to clarify this concept, five new productivity indices were proposed.

Since the application of productivity ratios in the evaluation of capital investment proposal was promising, further research could be done with respect to methods of including productivity ratios in these evaluations. A study relating productivity concepts to control theory could also prove useful.

D) The opinion that a wage increase should be granted when an increase in productivity occurred showed slight preference in the questionnaire. There existed a difference of opinion concerning which productivity measurement (labor or total productivity) should be the criterion to grant a wage increase.

There existed a different point of view concerning the consideration of mandatory capital investments in productivity measurements. Almost half of the respondents suggested to consider those investments in a different form while the others opined the contrary.

There was an opinion difference among the three criteria (i.e. the respondents' criterion, the organizations' criterion, and the criterion based on a strict analysis of data) concerning the sharing of productivity gains. The main discrepancy was concerning the percentage to be retained by the organizations. The organizations' criterion allowed a percentage around 50% whereas the other two criteria were around 40%. The respondents granted the 10% difference mainly to consumers and workers. This tendency

could have been the consequence that the respondents could have considered their participation also as workers and consumers.

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## APPENDIX

## APPENDIX

A.1. - The confidence intervals presented in Table III.2 were calculated as follows:

$$X \pm \sqrt{\frac{MSE}{n}} * Z_{\alpha/2}$$

X = Mean rating

MSE = Error Mean Square

n = Number of responses

Z = Value of the normal distribution at the appropriate significance level

The MSE values are those reported in Table III.1. They were used as an estimation of the variance. The Z values can be found in a table for the Normal Distribution elsewhere. An example of the calculations is presented next for the non-profit organizations for an  $\alpha = 0.05$ .

$$\text{Efficiency} \quad 5.92 + \sqrt{4.292/39} * 1.96$$

A.2. - The theoretical F values, [Neter et al. (1974, pp. 808-813)] for the analyses of variance presented in Tables III.4 and III.5 are presented next:

<u>For Table III.4</u>			<u>For Table III.5</u>		
	$\alpha = 0.10$	$\alpha = 0.05$		$\alpha = 0.10$	$\alpha = 0.05$
F(3, 30)	2.28	2.92	F(3, 60)	2.18	2.76
F(3, 60)	2.18	2.76	F(3, 120)	2.13	2.68

A.3. - From Section III.2, the following formulas were used to perform the Tukey test.

$$S(D) = \sqrt{2(MSE)/n} = \sqrt{2(3.408)/89} = 0.277$$

$$T = 1/\sqrt{2} * q(1 - \alpha; r, n_t - r) = 1/\sqrt{2} * (0.90; 4.264) = 2.29$$

$$n_t = r*n = 4 * 89 = 276$$

where:

MSE = Error Mean Square (Table III.4)

n = replications

r = treatments

$q(1 - \alpha; r, n_t - r)$  = Studentized range distribution

$$D - T * S(D) \leq \mu_j - \mu_{j'}, \leq D + T * S(D)$$

$$D = \bar{Y}_{.j} - \bar{Y}_{.j'}$$

D is an estimator of the mean differences.  $\mu_j$  and  $\mu_{j'}$  represents the mean ratings for goals j and j'. (J = 1 "Efficiency", 2 "Effectiveness", 3 "Performance", 4 "Vi-tality").

The pairwise comparisons are presented next:

$$0.49 < \mu_1 - \mu_2 < 1.75^*$$

$$0.81 < \mu_1 - \mu_3 < 2.07^*$$

$$1.16 < \mu_1 - \mu_4 < 2.42^*$$

$$-0.31 < \mu_2 - \mu_3 < 0.95$$

$$0.04 < \mu_2 - \mu_4 < 1.30^*$$

$$-0.28 < \mu_3 - \mu_4 < 0.98$$

The asterisk indicates that the difference was significant at the  $\alpha = 0.10$  level.

A.4. - The confidence intervals from section IV.2 presented in Table IV.2 were calculated using formula (1) previously presented in Section A.1. The MSE values used in the calculations were those reported in Table IV.1. An example of the calculations is presented next:

Tactic "Machines" for the profit organizations.

For  $\alpha = 0.05$

$$2.47 \pm \sqrt{\frac{4.292}{139}} * 1.96$$

A.5. - From section IV.2.

The test statistics for the Friedman two way analysis of variance is the following:

$$x_r^2 = \frac{12}{bk(k+1)} \sum_{j=1}^k R_j^2 - 3b(k+1)$$

where  $R_1, \dots, R_k$  are the treatments rank sums.  $k$  represents the number of treatments (tactics in this case).

The test statistic for the non-profit organizations was:

$$x^2 = \frac{12}{40*6*7} [(179)^2 + (74)^2 + (137)^2 + (129)^2 + (187)^2 + (127)^2] = 45.8929$$

$$x_5^{2*} = 11.070 \quad \alpha = 0.05 \quad \text{degrees of freedom} = 5$$

Reject  $H_0$

The test statistic for the profit organization was:

$$x^2 = \frac{12}{90 \cdot 6 \cdot 7} [(246)^2 + (260)^2 + (269)^2 + (281)^2 + (419)^2 + (402)^2] = 67.460$$

$$x_5^{2*} = 11.07 \quad \alpha = 0.05 \quad \text{degrees of freedom} = 5$$

Reject  $H_0$

A.6. - From Section IV.2, a multicomparison test between the tactics was performed using the following criterion

$$\text{If } |R_j - R_{j'}| \geq z_\alpha * \sqrt{b \cdot k(k+1)/6}$$

$$\text{Then } R_j = R_{j'}$$

Where  $R_j$  and  $R_{j'}$  are the  $j^{\text{th}}$  and the  $j'^{\text{th}}$  treatment (tactic) rank totals, and  $z$  is a value from a table of normal curve areas corresponding to  $\alpha/k(k-1) = 0.05/6(5) = 0.0017$ .

The criteria for both types of organizations [i.e.

$z_\alpha^* \sqrt{b \cdot k(k+1)/6}$ ] were the following:

Non-profit organizations:

$$2.93 \sqrt{\frac{40(6)7}{6}} = 49.029$$

$$T2 - T6 \quad |74 - 127| = 53^*$$

$$T6 - T4 \quad |127 - 187| = 60^*$$

$$T4 - T3 \quad |129 - 137| = 8$$

$$T3 - T1 \quad |137 - 179| = 42$$

$$T1 - T5 \quad |179 - 187| = 8$$

$$T3 - T5 \quad |137 - 187| \quad = 50^*$$

$$T4 - T5 \quad |129 - 187| \quad + 58^*$$

\*Significant at the  $\alpha = 0.05$  level

Profit organizations:

$$2.93 \sqrt{\frac{90(6)(7)}{6}} = 73.5425$$

$$T1 - T2 \quad |246 - 260| = 14$$

$$T2 - T3 \quad |260 - 269| = 9$$

$$T3 - T4 \quad |269 - 281| = 12$$

$$T6 - T4 \quad |402 - 281| = 121^*$$

$$T6 - T5 \quad |402 - 419| = 17$$

\*Significant at the  $\alpha = 0.05$  level

#### A.7. (From Section IV.2)

The test statistic for the paired difference test was the following:

$$T = \frac{\bar{d}}{S_d/\sqrt{n}} = \frac{0.125}{2.0385/\sqrt{136}} = 0.7151$$

where  $\bar{d}$  = Mean value of the differences of two ratings.

$S_d$  = Standard deviation of the differences of the two ratings.

The statistic was compared with the value reported in a t-distribution table for a  $\alpha = 0.05$  level ( $t = 1.96$ ).



## A.8. (From Section V.2 - A)

The confidence intervals reported in Table V.2 were calculated using the following equation:

$$\frac{X \pm t_{\alpha/2} * s}{\sqrt{n}} \approx \frac{X \pm Z_{\alpha/2} * s}{\sqrt{n}}$$

where X = mean rating

S = Sample variance of the rating

n = respondents

Z = Value from the normal curve that represents the appropriate significance level

X and s were obtained by using the statistical computer package SIPS, Guthrie et al. (1974).

## A.9. (From Section V.3-B)

The confidence intervals reported in Table A.9 were calculated in a similar form as it was described previously in section A.8.

## A.10. (From Section V.2-B)

The proportion's confidence interval was calculated using the following formula:

$$p \pm z_{\alpha/2} * \sqrt{p(1-p)/n}$$

where p is the proportion of the sample

z is the value from a table of areas of the normal curve

n is total number of respondents

For  $\alpha = 0.05$

$$0.61 \pm 1.96 \sqrt{\frac{0.61(0.39)}{138}}$$

A.11. (From Section VI.2-B)

To test the hypothesis the following test statistics was used:

$$s = n \cdot p_o + z_{\alpha} \sqrt{n \cdot p_o (1 - p_o)}$$

where:  $s$  = number of successes .

$n$  = respondents

$z$  = the value from a table of areas of the normal distribution

Then for a  $\alpha = 0.05$

$$s = 138 * 0.50 + 1.645 \sqrt{138 (0.50) * 0.50} = 78.662$$

Since the number of positive answers was 84 then the null hypothesis was rejected.

A.12. (From Section VI.2-3)

The hypothesis was tested using the same procedure described in section A.11.

$$\begin{aligned} s &= 75 (0.50) + 1.645 \sqrt{75(0.5) * (0.5)} \\ &= 44.623 \end{aligned}$$

Since the respondents who granted a wage increase no greater than 4% were 39 the hypothesis could not be rejected.

## A.13. (From VI.2-B)

The confidence interval was calculated in the form described in section A.8.

$$5.164 \pm 1.96 (0.407) / \sqrt{75}$$

## A.14. (From Section VI.3-B)

The estimation of the confidence interval for the proportion was calculated in the form described in section A.10.

$$0.55 \pm 1.96 \sqrt{0.55(0.45)/138}$$

## A.15. (From Section VI.3-B)

The test statistic was the same as the one used in section A.11 but using  $Z_{\alpha/2}$  instead of  $Z$

$$\begin{aligned} s &= 138 (0.50) \pm 1.96 \sqrt{138(0.50)0.50} \\ &= 80.51 \quad \text{for } \alpha = 0.05 \\ &51.4876 \end{aligned}$$

Since the number of repondents who gave a negative answer were 69 the hypothesis was not rejected.

## A.16. (From Section VI.3-B)

The Tukey tests which were performed using the formulas previously described in section A.3. The following modifications of the parameters were needed:

$$n_t - r = (r-1)(c-1)(p-1) = 114(2)(3) = 684$$

$r$  = respondents

$c$  = criteria

$p$  = parties

$$D = \mu_{ij} - \mu_{ij'}$$

$\mu_{ij}$  represents the mean percentage granted to party  $i$  by criterion  $j$  ( $i = 1$  consumers, 2 workers, 3 owners, 4 retained in organization;  $j = 1$  data analysis, 2 organization, 3 respondents).

$$S(D) = \sqrt{(2/115) * 338.54} = 2.4267$$

For  $\alpha = 0.05$

$$T = \frac{1}{\sqrt{2}} q(0.95, 12, 684) = \frac{1}{\sqrt{2}} (4.62) = 3.2668$$

$$S(D) * T = 7.9276$$

For  $\alpha = 0.10$

$$T = \frac{1}{\sqrt{2}} q(0.90, 12, 684) = \frac{1}{\sqrt{2}} (4.28) = 3.0264$$

$$S(D) * T = 7.3442$$

The results of the test are presented in Tables A.1 and A.2.

A.17. - The confidence intervals reported in Table VI.5 were calculated using the same procedure of section A.8. The sample variances needed for the calculations were those reported in Table VI.4.

TABLE A.1. TUKEY TEST RESULTS ( $\alpha = 0.05$ )

i	$D = \mu_{i_1} - \mu_{i_2}$	$D = \mu_{i_1} - \mu_{i_3}$	$D = \mu_{i_2} - \mu_{i_3}$
1	-2.36<D<13.49	-7.74<D< 8.12	-13.30<D< 2.55
2	-7.93<D< 7.93	-11.64<D< 4.21	-11.64<D< 4.21
3	-5.42<D<10.4	-4.24<D<11.65	-6.71<D< 9.14
4	-15.60<D< 0.26	-6.30<D< 9.55	1.37<D<17.22*

$\mu_{ij}$  = Mean percentage granted to party i by criterion j

i = 1 Consumers, 2 Workers, 3 Owners, 4 Retained in organization

j = 1 Data analysis, 2 Organization, 3 Respondents

\* Significant at the  $\alpha = 0.05$  level

TABLE A.2. TUKEY TEST RESULTS ( $\alpha = 0.05$ )

i	$D = \mu_{i_1} - \mu_{i_2}$	$D = \mu_{i_1} - \mu_{i_3}$	$D = \mu_{i_2} - \mu_{i_3}$
1	-1.78<D<12.91	-7.153<D< 7.53	-12.72<D< 1.97
2	-7.34<D< 7.34	-11.06 <D< 3.63	-11.06<D< 3.63
3	-4.84<D< 9.85	-3.72 <D<11.066	-6.13<D< 8.56
4	-15.01<D< 0.32*	-5.72 <D< 8.97	1.95<D<16.64*

$\mu_{ij}$  = Mean percentage granted to party i by criterion j

i = 1 Consumers, 2 Workers, 3 Owners, 4 Retained in organization

j = 1 Data Analysis, 2 Organization, 3 Respondents

\* Significant at the  $\alpha = 0.10$  level

Department of  
INDUSTRIAL ENGINEERING  
Corvallis, Oregon 97331  
United States of America  
Telephone (503) 754-4645

Oregon  
State  
University

May 1977

Dear Sir:

You are being asked to participate in a worldwide survey about productivity. Its purpose is to determine the current methods employed in productivity analysis and the uses made of the productivity measures. The survey is designed to obtain representative views from different areas of management, classes of organization, and types of culture. Results of the survey will be reported at the International Productivity Congress to be held next September in Australia. Your reply is important!

There are just four pages in the survey. Please answer the questions completely and thoughtfully, especially those that rely on subjective judgment. A stamped, addressed envelope is enclosed for your reply. If you have further inquiries or comments, direct them to Dr. James L. Riggs at the letterhead address.

Your prompt reply will be greatly appreciated, and we will be pleased to send you a summary of the survey results if you check the box below. Thank you.

☐ Send survey results to ☐ address above ☐ other address \_\_\_\_\_

#### DATA ABOUT RESPONDENT

- The type of organization in which you work is most closely described as  
 15 ☐ National government ☐ Manufacturing/Mining Industry } 25  
 30 ☐ State/local government ☐ Agriculture/Timber/Fishing }  
 30 ☐ Health/Education/Service ☐ Retail/Commercial/Transportation 15
- Number of people employed in the organization with which you are now associated (if it is a government agency or a conglomerate industry, report the size of the unit, division or branch for which productivity data would be reported) is  
☐ Under 100 ☐ 101 to 1000 ☐ 1001 to 10,000 ☐ over 10,000  
 Comments 61 82
- Category that most closely describes your current position is  
 5 ☐ self-employed 47 ☐ middle-level manager ☐ staff specialist 39  
 30 ☐ top management 7 ☐ lower-level manager ☐ line operator 0  
 8 ☐ independent professional ☐ other 7
- Circle the number of years of formal education you have  
 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 +  
 grade school high school college post graduate
- To what extent has your organization emphasized productivity measurement and improvement programs, and to what extent have you been personally involved (Mark with an x on the scale below the organizational emphasis, and with a y the extent of your personal involvement.)

Not used	Just mentioned	Approximate Measurements				Extensive Measurements				
		made but not used	made and utilized			made but not widely applied	made and ap- plied vigorously			
0	1	2	3	4	5	6	7	8	9	10
						x	✓			
Comments		6.37 6.50								

Figure A.1. Page One of the Questionnaire.

# SELECTION OF OPERATIONAL CHANGES TO IMPROVE PRODUCTIVITY

**Perspective:** Productivity improvements are usually the result of intentional operational changes. Depending on the type and state of current operations, certain changes are more likely to result in improvement than others.

**Scenario:** Your organization is about to initiate productivity-improvement plans. Several target activities and potential outcomes are identified in the matrix below. You have been asked to rank or rate the targets according to their promise for improving productivity in the organization in which you now work. Follow the directions below.

Comments: \_\_\_\_\_

## POSSIBLE OUTCOMES

<b>GREATER ORGANIZATIONAL VITALITY:</b> More initiative and involvement, more worker stability, greater cooperation and job satisfaction, etc.
<b>HIGHER PERFORMANCE:</b> Improve quality of output, increased flexibility, fewer breakdowns and accidents, etc.
<b>IMPROVED EFFICIENCY:</b> Growth in total revenues and/or profits, better decision making and communications, better utilization of resources, etc.
<b>IMPROVED EFFICIENCY:</b> Lower total operating costs, savings in labor and machine time, less waste of material, fewer damages, less remake, etc.

RANKING OF CHANGE TARGETS: 1 through 6

CHANGE TARGET	1	2	3	4	5	6
<b>MACHINES:</b> Replace manual labor by machines, get faster or more reliable equipment (automate).	2.75	4.41				
<b>MANAGEMENT:</b> Better coordination and budgeting, more inspiring leadership (motivate).	2.89	1.56				
<b>PROCESSES:</b> Improve scheduling and material flow, more accurate-faster data flow (computerize).	2.46	3.42				
<b>WORK DESIGN:</b> Modify job content, improve work methods, train workers (enrich jobs).	3.12	3.22				
<b>ENVIRONMENT:</b> Make safer or more pleasant working conditions, reorganize structure (innovate).	4.66	4.61				
<b>PROGRAMS:</b> Raise pay, revise policies, try goal-setting (MBO) programs (all participate).	4.41	3.17				
OUTCOME RATINGS on 1 through 10 scale - P* 7.71 6.59 6.27 5.92 NP* 5.42 5.28 5.89 5.18						

Directions for Completing above matrix: (Make an entry in every cell of the matrix.)

**Target Ranking** - Rank change targets in a 1 to 6 order of their probable success in improving productivity in your present organization. Base rankings on what has worked for you or what you believe would work. 1 is the best and 6 is the worst.

**Target or Outcome Relationship** - Indicate the probable effect on each outcome of the implementation of each change. In each circle insert one of the following symbols.

- (+) change will have a positive effect on the outcome; likely successful
- (-) possible negative effect on outcome
- (0) change should have no effect or there is equal likelihood of either a positive or negative effect on the outcome.

**Outcome Ratings** - Rate the value of each outcome in producing a measurable improvement in productivity. Select the rating for each from 1 through 10 according to the scale below.

Productivity decreases or is unchanged	May produce a small improvement	Certain to make a small improvement	May raise productivity significantly	Certain to yield large improvement					
1	2	3	4	5	6	7	8	9	10

\* Profit Organizations.

\*\* Non-Profit Organizations

Figure A.2. Page Two of the Questionnaire.

**AUXILIARY PRODUCTIVITY RATIOS FOR EVALUATING INVESTMENT PROPOSALS  
CONTROLLING OPERATIONS, AND ATTAINING SOCIAL OBJECTIVES**

**Perspective:** Productivity has traditionally measured the output of goods with respect to an input of production, usually workers hours. The purpose of the comparison is to detect changes in ratio levels and relate them to their causes. Productivity measurements also establish bases to roughly compare operations in various sectors of the national economy and in equivalent operations in other countries.

Both the types of productivity measurements and their uses can be extended. Auxiliary productivity ratios, such as "Safety Productivity" which could relate the cost of injuries to hours worked, can supplement existing criteria for decision making. Three areas of application appear promising:

1. Evaluation of capital investment proposals - ratios to supplement the "net-income/amount-invested" criterion to rate specific gains expected from an investment.
2. Control of operations - ratios to supplement process efficiency measures that can provide early warnings of future operational difficulties.
3. Achievement of social objectives - supplements to the "benefit/cost" criterion that define and rate how well a project satisfies conditions deemed desirable for the welfare of society.

**Scenario:** You are developing supplementary productivity/ratios to use in your current area of work. The aim in generating new ratios is to improve investment decisions (I), operational control (C), and general welfare satisfaction (S). Five suggested ratios are given and these are to be rated with respect to their value for each of the potential uses (I, C, and S) in your organization. Also, define and rate other productivity ratios that you feel would be appropriate. For example, a ratio appropriate to a delivery service would be "amount delivered/fuel consumed," and it could be rated as very important in deciding which vehicle to invest in, less important for rating the performance of vehicles in operation, and quite important as a measure of a national drive to cut gasoline consumption.

**Directions:** Rate each productivity ratio as to its value in each use (I, C, and S) in your type of work. Develop and rate additional ratios that you feel would be useful. Make the 1 to 10 ratings according to the scale below (Enter 0 if the ratio is not valid for an application in your organization).  $\bar{x}$  = Mean Rating.  $s$  = Sample Variance.

Deceptive indicator of value		Appropriate Consideration		Measures factors or interest		Important indicator of achievement		Vital measure of criticality	
1	2	3	4	5	6	7	8	9	10
Productivity Ratio		Description		Application Areas					
Employment ratio	Value added	(S) People employed (#)		Selling price of units, minus materials and components to produce the units, compared to equivalent number of full-time employees of the organization.					
Energy ratio		Units Produced (#) Energy used (kw-hr)		Comparable amounts of output (equivalent value units) per energy input measured in equivalent standardized units.					
Work Ratio		Employee hours worked (hr) Employee hours paid (hr)		Person-hours of productive time spent on assigned work compared to total hours for which wages were paid.					
Material ratio	Material in Product	Total Material Supplied		Amount of a certain type of material that is actually in the final product, or amount that is recycled from prior use, compared to the total amount of that material consumed in producing the product.					
	Recycled Material Used								
Social ratio		Social Objectives (# or S) Sales or Budget (# or S)		Units that measure a socially desirable condition, such as convertible currency earned or minority workers employed, compared to the amount of activity as measured by the output or operating budget of the unit.					

Figure A.3. Page Three of the Questionnaire.



Productivity Ratio	Description	(I)	(C)	(S)
(Other Productivity Ratio)				
<u>Utility Increase</u> <u>Investment</u>				
(Another Productivity Ratio)				
<u>Earned Hours</u> <u>Actual Hours</u>				

## PRODUCTIVITY ANALYSIS

Perspective: It is recognized that productivity ratios do not necessarily reflect the efficiency of operations, do not provide reliable comparisons over a span of years, and do not always reveal the effect of individual input or output components. Nevertheless, the ratios still influence managerial decisions.

Scenario: Your organization has a productivity pattern, corrected to a base-year index, shown in the table below. Assume that net profit increased at a commensurate rate with total productivity gains each year. (Also assume the national inflation rate is zero.)

	1974	change	1975	change	1976
Net output (1)	100	15%	115	13%	130
Labor input (2)	50	0	50	14%	57
Capital input (3)	40	25%	50	4%	52
Labor productivity (1) ÷ (2)	2.0	15%	2.3	0	2.3
Capital productivity (1) ÷ (3)	2.5	-9%	2.3	9%	2.5%
Total productivity (1) ÷ (2 + 3)	1.11	4%	1.15	4%	1.19

1. Is the increase in total productivity from 1974 to 1975, at no increase in labor input, sufficient reason to grant a wage increase to workers? ☒ Yes ☐ No 34%  
If yes, about how large an increase is reasonable? 5.16%  
Comments \_\_\_\_\_

2. If the decrease in capital productivity resulted from a mandatory capital investment to conform to a new law restricting pollution, should this social benefit be recognized differently in the productivity measure? ☒ Yes ☐ No 51%  
If yes, how? \_\_\_\_\_

3. Who should benefit from the 4% gain in 1976? What percentage of the total profit for that year should be distributed to each of the following parties, based on...

... an unbiased analysis of data	... what your organization would likely do	... your personal opinion
<u>13.2</u> % to consumers	<u>7.56</u> % to consumers	<u>12.43</u> % to consumers
<u>19.05</u> % to workers	<u>18.05</u> % to workers	<u>21.76</u> % to workers
<u>26.13</u> % to owners	<u>23.63</u> % to owners	<u>24.46</u> % to owners
<u>40.95</u> % retained in organization	<u>43.62</u> % retained in organization	<u>34.32</u> % retained in organization
100%	100%	100%

Comments \_\_\_\_\_

Figure A.4. Page Four of the Questionnaire.