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# Metrics and Techniques To Measure Microcomputer Productivity

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
Gaithersburg, MD 20899

December 28, 1984
Final Report

Prepared for:
**Office of the Assistant Secretary of Defense (Comptroller)**
**Washington, D.C. 20301**

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**U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary***
**NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director***

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# METRICS AND TECHNIQUES TO MEASURE MICROCOMPUTER PRODUCTIVITY

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## EXECUTIVE SUMMARY

There is strong evidence that microcomputers can be used to improve the productivity of users in an office environment. The literature is replete with studies citing productivity improvements resulting from the use of microcomputers. Many of these studies not only attest to the productivity improvements, but go further by attempting to describe the magnitude of the improvements. This report includes an annotated bibliography which contains numerous examples of such studies.

We also have evidence that the use of microcomputers can improve productivity, based on direct input we have received from interaction with organizations that use this technology. These organizations tell us that, through the use of microcomputers, they can routinely accomplish tasks that were not practical to attempt using either manual methods or traditional computer-based approaches. Many of the tasks that were performed previously can now be accomplished faster and with higher quality than would be possible without microcomputers.

Our own experience in using microcomputers to support office related functions within the Institute For Computer Sciences And Technology provides specific evidence of productivity improvement through the use of microcomputers. This experience mirrors the experiences of other organizations with respect to the scope and impact of the improvements that result from the use of microcomputers.

This report examines measures used to describe the magnitude of productivity improvements that result from the use of microcomputers in an office environment. The focus of our work has been to identify and analyze existing measures of productivity rather than attempt to develop new measures. Our primary information source was articles published in the open literature. In addition, we conducted a limited survey of organizations which use microcomputers in an office environment. The report specifically addresses the following:

- How productivity can be measured
- What measures are being used
- Recommendations regarding measuring productivity

### Measuring Productivity

We found that studies citing productivity improvements resulting from the use of microcomputers in an office environment are based, in large part, upon the perceptions of managers and workers in those organizations. These perceptions, however correct, are not generally based on traditional measurements supported by quantitative analysis, well defined metrics, and repeatability of results under controlled conditions.

One of the important issues here is the extent to which the results of such studies can be applied outside the specific environment in which the studies were conducted. Based on our investigations, using the results of studies citing productivity improvements in one environment, as a basis for predicting productivity in a different environment, should be approached with caution. The methods used to obtain improvements in productivity are for the most part highly dependent on subjective measures of quality and other factors that are domain specific.

It is clear, however, that organizations are making substantial investments in microcomputers without the benefit of systematic productivity studies. For these organizations, the potential productivity improvement is frequently perceived to be so large and so obvious that a formal study is deemed unnecessary.

Productivity Measures

We found that there are basically three classes of productivity measures:

- those that are both measurable and quantifiable, such as cost and time savings.
- those that are measurable but not quantifiable, such as increased quality.
- those that are neither measurable nor quantifiable, such as new insights and learning.

We also found that organizations are not deterred by the fact that productivity measures do not conform to academic notions of rigor or accuracy. While many of these organizations have introduced microcomputers without the benefit of a prior productivity measurement study or program, evidence of their cost effectiveness and impact on the organization has come from both managers and end-users. The management of these organizations is convinced that improvements in products, services, efficiency, morale, and numerous other areas occurred as a result of using microcomputers. What appears to be important is that the perceptions and intuitions underlying the measures reflect the judgement of individuals knowledgeable about the organization and the environment in which microcomputers are being used.

Recommendations

The report describes our recommended methodology for obtaining productivity measurements. The key factors to be considered prior to initiating a productivity measurement program, however, are the feasibility, constraints, and anticipated cost benefits of such a program. If, after a careful evaluation of

organization goals, objectives, and requirements, a productivity measurement program is determined to be neither feasible nor cost effective, all further planning for such a program should cease.

If the decision is to proceed with a productivity measurement program, the next step should be to define the objectives of the measurement program; and then establish the baseline for assessing subsequent changes in productivity. Deciding exactly what is to be measured and the particular level within the organization at which measurements are to be taken are perhaps the most difficult, yet the most important decision in establishing the baseline. Since the effects of using microcomputers may be more pronounced immediately after their introduction, measurements of changes in productivity should made over an extended period of time.

Thus, our recommended methodology includes:

- Defining the goals of productivity measurement to include the entire organization and using global measures
- Establishing a baseline prior to the introduction of microcomputers
- Measuring changes in productivity over a sufficiently long period of time

Once the baseline has been established, the factors and attributes presented in Tables 1, 2, and 3 should be considered. Although organizational requirements differ, the quantitative factors identified in Table 1 are fairly universal, and can generally be mapped to the methodology described above. The more the individual knows about the activity being assessed, the more likely the attributes contained in Tables 2 and 3 will figure in the assessment. The method we recommend is a synthesis of the methods we found in the literature and, as such, depends to a large degree on measures of quality and other value-added factors. The effectiveness of this method depends on observations by knowledgeable individuals to assess the changes in productivity.

While the primary focus of this report is on microcomputers, we believe that the phenomenon underlying these productivity improvements have their roots in personal computing rather than in the personal computer. The microcomputer, i.e. the personal computer, is simply the primary means presently being used to accomplish personal computing more effectively. Some of the characteristics of the microcomputer include: a high bandwidth between system memory and display, an orientation for non-computer professionals, and emphasis on individual and personal use. Personal computing, on the other hand, is a means by which significantly more control over computing requirements

and services is placed in the hands of the end-user. A byproduct of this added control is that the end-user has greater access to information, data, and computing resources resulting in more cost-effective services.

The clear message is that while meaningful measures of productivity improvement are possible, these measures are based upon subjective factors that must be tailored to the specific environment in which the measurements are taken.

# 1.0 INTRODUCTION

The National Bureau of Standards (NBS) Institute for Computer Sciences and Technology (ICST) has been tasked to develop a series of reports addressing specific aspects of productivity improvement through the use of information technology. This report addresses analysis of metrics and techniques which can be used to measure productivity gains resulting from the use of microcomputers by the functional workforce in DoD. An Annotated Bibliography of information sources on productivity measurements is included (APPENDIX II).

This report identifies current productivity measurement techniques, analyzes them, and presents an assessment of each.

## 1.1 Background

The role of information processing has changed with the introduction of the microcomputer into the workplace. The microcomputer has become a "tool" that often enables the user to directly control information processing needs without the assistance of the professional ADP staff. The relative low cost of microcomputers, their adaptability to various applications, and the availability of software which is useful to non-computer professionals has resulted in the proliferation and use of microcomputers in the office environment.

While there is general agreement that microcomputers do increase office productivity, there is little hard, quantifiable data to actually support this claim. Many companies have published reports of substantial improvements to productivity, but few have attempted to actually measure the changes, and fewer still have achieved any reliable measurements. By and large, the published reports have drawn the conclusion of productivity gains based on the perception of the managers and workers in the affected office environments.

The use of microcomputers by professional and clerical staffs overlap but are functionally different. The clerical staff primarily utilizes word processing which can be measured at the individual level (e.g. number of words in within a specific period). It appears, however, that the primary benefits to the professional staff are not in speeding up the information flow, but in improving the depth of analysis and understanding of the available information. Therefore, professional staff productivity should be measured in terms of the information handled and processed. Through spread sheet analysis and accounting and financial systems, the professional can better understand the significance of the

information and thus, can make more informed decisions which result in improved performance of the entire organization.

This report addresses the measurement of the effect on productivity in an end user, office environment as a result of the introduction of microcomputer-based technology. It analyzes and assesses the various measurement techniques presented and makes recommendations on how to measure productivity gains in the functional workforce. Measuring productivity changes in an office environment primarily involves the assessment of the impact of new technology on qualitative factors which cannot be measured directly. Thus, the inability to assign a numeric value to a factor such as "efficiency" limits the measurement and makes it highly subjective. In general, if the product or service is completed faster; if the quality and performance is improved; if there are noticeable, desirable differences in the process: then, there are productivity gains for the organization.

Productivity is often equated with efficiency (reducing unit costs, improving output per hour, reducing errors, etc.) or quantity of work performed. Quality of output may, in fact, be far more important than quantity when measuring and assessing traditional white collar worker performance since accurate communication of information is the primary function of such workers. The usefulness and effectiveness of this output is determined by such qualitative characteristics as "efficiency", "completeness", and "effectiveness". Although these attributes are discernible to those involved, they are not directly measurable and thus, an assessment of changes in productivity is much more difficult to make.

Productivity measurement can be facilitated if the input properties and the output properties are clearly defined. This is more difficult to do in a white collar environment since most managerial and professional work does not have well-defined, measurable inputs or well-defined outputs. Thus, the usefulness of any productivity measurement is dependent upon the accuracy of the perceptions of the qualitative factors which are used.

## 1.2 Productivity Difficult To Measure

The introduction and use of microcomputers have increased the productivity of users, but measuring these increases has not been easy. Much of the difficulty is due to the fact that techniques for measuring productivity are neither well known nor well defined. Further, the benefits do not always appear as single, discernible entities, rather they are often small gains across many tasks. As a result, few organizations have

initiated productivity measurements citing the lack of money, time, knowledge, or an inclination to perform a comprehensive, scientific study. The situation is further complicated by the lack of information needed to measure productivity.

One of the perennial problems is the difficulty in measuring the productivity of value added activities. Inevitably when a manual system is automated, many new functions and products are generated, usually without additional resources and at negligible cost. These intangible byproducts of automation, which did not exist previously, can enhance a managers decision making ability. Another problem in measuring productivity gains is the omission of some of the cost of converting from manual to automated methods, and a comparison of these costs against the benefits. Some of the costs typically omitted are site preparation, training, and ongoing software maintenance. Quantifying professional or managerial productivity has proven to be difficult, particularly for such activities as: preparation for and attending meetings, reading and writing reports, responding to telephone calls, etc.

Prior to implementing a productivity measurement program, there are a number of factors to be considered. While the methodology presented in Table 5 is recommended for measuring changes in productivity, it may not be feasible depending on organizational constraints. These constraints include:

- the unavailability of measurement data/information. It is difficult to measure changes in productivity in the absence of baseline data. If the information needed to conduct such a study is incomplete or unavailable it may be better to rely on the judgement of the users of the microcomputers.

- the lack of well defined productivity measurement techniques. Measures of productivity that are appropriate for the different levels and functions in the organization must be well defined.

- the cost, time, and effort to effectively measure productivity.

- the lack of a means to capture much of what is done in an office environment.

-the size of the organization or project, and the type of applications. If the environment is small, the cost of such a study could outweigh the benefits.

- the lack of (active) participation in the productivity

measurement program by all impacted by the introduction of microcomputer.

Once the decision has been made to measure changes in productivity, it is often desirable to implement a productivity improvement program to maximize productivity gains resulting from microcomputer use. Some approaches for improving productivity from the perspectives of both the end-user and management are discussed in the Appendix I.

Quite simply, organizations are as concerned with what a productivity program is going to cost as with what it is going to return. Knowing how to spend funds where the most benefit can be realized, however, is sometimes difficult. Before productivity can be effectively measured, there must be a thorough understanding of what is being done, the activities performed, for whom, and why. While the old maxim, "you can't improve what you can't measure" is not entirely true, it is important to develop a strategy for defining what to measure, when to measure, and how to use the measurement data.

As the activities performed in the functional workplace become more complex and technical in nature, and ready access to reliable information becomes more critical, it is essential to make better use of each individual's time. The effectiveness of any productivity measure is how accurately it reflects what is taking place with respect to the ability of the individual, and ultimately the organization, to perform tasks easier, faster, and better.

## 2.0 MEASURING CHANGES IN PRODUCTIVITY

Techniques for measuring changes in productivity rely on two types of measurements: quantitative and qualitative. Quantitative techniques generally measure quantities of work over some unit of time such as "pieces per hour", "person-hours per completed product", or "defects per unit of time". These types of measurements are fairly easy to quantify and are typical of measurements made when investigating productivity changes in a production, blue-collar environment. Qualitative techniques are those which address less tangible attributes such as "quality", "effectiveness", and "efficiency". Measurement of such attributes is very difficult because it is highly subjective.

Assessing productivity and changes resulting from the introduction of microcomputers primarily requires the measuring or estimating of qualitative attributes rather than quantitative factors. While it is not possible to obtain highly definitive qualitative measurements, it is possible to assess the relative changes in productivity through a careful and consistent assessment of selected qualitative attributes before and after the introduction of the new technology.

Measuring changes in productivity can be done at the global (organization), local (functional unit), or individual level. Measurement of quantitative factors can be successfully performed at the lowest individual levels since exact counts can be obtained for specific factors (number of letters typed, hours worked, number of forms processed, etc.). Assessment of qualitative attributes, however, is more reliable at a higher level within an organization since the individual variances and inconsistencies will tend to balance out.

Based on the literature search which was conducted as part of this task, there is a great deal of interest in productivity measurement in general and the effects of microcomputers on productivity in particular. The Annotated Bibliography (APPENDIX II) includes references to over sixty (60) articles, reports, and books which have been published recently on assessing and measuring changes in productivity. Many organizations have initiated efforts to determine the effects of microcomputers on individual and organizational productivity. However, there is a dearth of information on any actual quantifiable changes. These reports consistently discuss the difficulties in performing such measurement and usually conclude that there has been improvement in productivity on a global level as a result of the introduction of microcomputers.

Some of the techniques discussed later in this section have

been proposed to provide quantifiable measurements. Organizations have been reluctant, however, to embark on the effort required to make such measurements citing the cost, lack of time, lack of information, and lack of proof that these techniques will actually provide useable results. Thus, the consensus is that microcomputers have improved productivity, but there is little documentation to support that conclusion.

## 2.1 What Should Be Measured

Productivity measurement, particularly of qualitative items, can be a costly endeavor. In a small organization with limited resources, it may be unreasonable to undertake a comprehensive study either to determine productivity gains or to determine how to achieve them. Regardless of the size of the organization, it may be determined after a careful evaluation of organization goals, objectives, and requirements that the difficulty of implementing a productivity measurement program just would not be cost effective. Another instance in which a program to measure changes in productivity may be unnecessary is when it is <u>obvious</u> that the use of microcomputers has resulted in improved productivity.

The attributes and factors to be measured must be selected and carefully defined. Since each organization is unique, the attributes and factors selected for measurement will differ. After the technology has been introduced, sufficient time should transpire before conducting the second productivity measurement. This is important because there may be a short-term decline in productivity which occurs while the users are learning to use the new technology properly. The baseline and new productivity levels should then be carefully evaluated and an assessment made on the relative productivity changes which have been realized.

### 2.1.1 Factors that complicate measurement

Several factors frequently complicate the measurements:

1. Value-added activities may not be adequately measured. When a manual system is automated, many new functions and products may be generated without requiring additional resources or cost. These activities, while difficult to measure, should be taken into consideration.

2. A number of cost factors are frequently omitted when measuring productivity gains. Included are those costs associated with the conversion from manual to

automated procedures such as: site preparation, training, and maintenance of both the hardware and the software systems.

3. The introduction of new technology frequently results in substantial changes to the office environment. Personnel become responsible for different or additional parts of the process, duties shift, and some work may be eliminated while new work is created. Thus, attempts to measure individual productivity changes is often a case of comparing apples and oranges. For this reason, the assessment should be made at the organizational level rather than the individual level.

### 2.1.2 Factors and attributes for measuring productivity

The following three tables list some of the more commonly used factors and attributes used in evaluating productivity. Table 1 identifies tangible, quantitative factors which can be measured directly. Table 2 and Table 3 identify less tangible, more subjective, qualitative attributes which should be assessed in attempting to evaluate the productivity of an organization. Section three provides a discussion of several case studies which make use of many of the factors and attributes identified in the tables below.

The productivity improvements most frequently mentioned as a result of using microcomputers are increased workload, new or more work accomplished in a shorter time, and cost saving. Improved accuracy, efficiency, quality, attitude and morale are also cited as benefits of microcomputer use. Not all of factors and attributes identified may be appropriate to a specific situation and others which are not found in these tables may be critical in specific environments.

TABLE 1

Factors That Can Be Measured and Quantified
To Determine Productivity Gains

- workload
- schedules
- cost/budget
- end products
- training cost
- size of staff
- methods/techniques
- response/turnaround time
- time to perform a specific task
- number of new requests/alternatives examined
- outputs before and after using microcomputers
- amount of data handled, sorted, and calculated

TABLE 2

Attributes Which Can Be Measured But Not Easily Quantified To Assess Productivity Gains

- accuracy
- efficiency
- reliability
- completeness
- user acceptance
- data accessibility
- value added capabilities
- improved analysis (budget, trends, etc.)
- timeliness of reports/tickler files/information

TABLE 3

Attributes Which Are Not Easily Measured Nor Quantifiable To Determine Productivity Gains

- control
- flexibility
- communication
- attitude and morale
- quality of decisions
- new insights and learning
- better understanding of business
- effectiveness (of team work, etc.)
- quality of presentations (graphic displays, etc)

### 2.1.3 Criteria to measure desired outcomes

The ultimate objective of introducing microcomputers is to increase the productivity of an organization. This may be accomplished by reducing costs, avoiding increases in costs, increasing value added activities/products, increasing employee satisfaction or becoming more competitive. Our findings indicate that the identification of desired outcomes and the selection of appropriate measurement criteria are essential to the success of any productivity measurement program. The desired outcome, more than any other factor, influences the choice of criteria for measuring the outcome and determining if goals have been achieved. The following table identifies some possible criteria for different objectives and goals.

TABLE 4
Criteria To Measure Desired Outcomes For OA Projects

| Desired Outcome | Possible Criteria |
|---|---|
| To increase organizational productivity | Total output in number of units produced as a function of labor, investment, etc. measured in dollars |
| To reduce or avoid costs | Cost of labor, materials, and overhead |
| To increase value added with products/services | Contribution to profits from improved products/services |
| To increase managerial productivity | Time required to complete tasks and level of individual, unit, and organization productivity |
| To increase timeliness of information | Average and variance of time to prepare/distribute information |
| To increase quality of information | Quality, accuracy, and completeness of information used to generate products |
| To provide more job satisfaction | Turnover or absenteeism |

## 2.2 Measurement Techniques

Measurable improvements in productivity generally can be attributed to a combination of human resource and technological factors. Therefore, any effort to determine changes in productivity as a result of the introduction of microcomputers should consider both the work environment (equipment and tools) and the employee effectiveness (training, education, attitude). Tables 8 and 9 of APPENDIX I provide guidance for improving productivity with an emphasis on the work environment and employee effectiveness.

There are few effective measurement techniques available for measuring productivity in the office environment. The qualitative measurements which are most useful in assessing changes in the office productivity are most difficult to obtain. The quantitative measuring techniques can be characterized as a comparison of INPUT/OUTPUT before and after microcomputers are used. Although the INPUT is generally well defined, the difficult aspect in performing this type of measurement in the functional workplace is quantifying the OUTPUT.

The most commonly used techniques for measuring changes in productivity are Questionnaires and Empirical Analysis. The primary difference between these two approaches is that the latter relies more on intuitive knowledge and information gained through experience and less on a systematic, structured methodology. Both of these techniques make use of before and after information concerning the qualitative and quantitative aspects of the process and the products; both are relatively easy to employ; both can be administered formally or informally; and both can be used for almost any size and type of environment/organization.

Examples of the techniques listed in Table 5 are discussed in the case studies and the annotated bibliography (APPENDIX II). Specific references also may be found at the end of sections 2.2.1 and

2.2.2.

### 2.2.1 Questionnaire

The questionnaire/survey method of assessing changes in productivity resulting from the introduction of microcomputers appears to be one of the most useful. One of the advantages provided by the technique is that it can readily be adapted to measure global, as well as localized changes in productivity. The questionnaire can be used to gather information about: characteristics and functions of

the organization; projected requirements and desired features; work process, equipment, and products; and profile data on individual performance. It can also be used to isolate problem areas, determine employee attitudes, and solicit suggestions.

Another advantage provided by the questionnaire/survey method is that it can be used to obtain information from multiple levels of the organization. This approach makes it possible to obtain information about perceived qualitative, as well as quantitative changes in productivity. This is essential since the perceptions of the changes may differ. In fact, everyone who either uses microcomputers, or is impacted by changes in the environment as a result of their use, should be surveyed. Properly employed, it is one of the most effective techniques for obtaining, comparing, evaluating, and measuring changes in productivity within the organization.

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TABLE 5
Productivity Measurement Techniques

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| Questionnaire/survey | Empirical Analysis |
|---|---|
| - Before and after measurement | - Before and after measurement |
| - Assessment of need | - Intuitive |
| - Quantitative metrics | - Quantitative metrics |
| - Qualitative measures | - Qualitative measures |
| - Methodology/formula | |

---

Note:
The establishment of a baseline level of productivity prior to the introduction of the new technology is essential to the success of a "before and after" assessment.

The case studies and the bibliography entries referenced below contain examples of the various approaches used in conjunction with the questionnaire technique.

Case studies - see sections 3.1, 3.2, 3.4, 3.5

Bibliography - [VANE83], [BOEH83], [GAO82], [GSA83], [STEE83], [SENA83]

### 2.2.2 Empirical analysis

Empirical analysis is employed to measure productivity before and after the introduction of microcomputers in the workplace. Empirical analysis relies primarily on experience and observations about a particular area or environment, and does not generally make use of systematic methods or methodologies. It may be performed by weighing and measuring the applicable, quantitative or tangible factors such as those identified in Table 1. The weights are generally assigned to the variables to be measured based on the value and function of that variable within the specific environment. Qualitative factors may also be taken into consideration. Using empirical analysis, a baseline is established against which all changes are measured.

The case studies and the bibliography entries referenced below contain examples of the various approaches used in conjunction with the empirical analysis technique.

Case studies - see sections 3.3 - 3.8

Bibliography - [GSA83], [STEE83], and [SENA83].

### 2.2.3 Summary and recommendations on measurement techniques

When using either the questionnaire or the empirical analysis technique to measure productivity, it is important to focus on the extent of productivity changes at the global level, as opposed to the short term or incremental increases at the local level. The introduction of any new technology involves a learning period during which there may actually be a decline in productivity. Consequently, sufficient time must be allowed after microcomputers are introduced into the organization to permit a stable state of operation to be established before the productivity impact is assessed. The usefulness of these techniques is dependent upon the accuracy and completeness of the information collected, and the skill and knowledge of the surveyor or evaluator.

Table 6 contains a set of recommended steps which should be followed in measuring productivity changes in an office environment.

## 2.3 Methodology For Measuring Productivity

There are a number of approaches for determining a methodology for measuring productivity changes. One approach is to evaluate attempts by other organizations to measure productivity, while another is to determine the estimated cost of such a program, and then compare this cost with the expected gains in productivity. Whether or not either of these methods are employed, it is essential to determine the goals or desired outcomes of a productivity measurement program for the specific office environment. See Table 4 for some desired outcome measurement criteria.

### 2.3.1 Preparing to measure change

The first step in preparing to measure changes in productivity after defining the goals is to determine the feasibility of such a program. This requires that those involved have a thorough understanding of what is meant by productivity, of the activities to be measured, and of the areas likely to benefit most from the application of productivity measures. Since productivity has different meanings in different environments, it is essential to establish a definition that is suitable for the environment that is to be measured.

Each environment is unique and the attributes and factors useful in one may not be appropriate for another. This is especially true in the case of qualitative, subjective attributes such as reliability, accessibility, and efficiency. Therefore, it is necessary to define not only a set of factors and attributes (productivity indicators), but a method for quantifying the qualitative attributes. It is also essential that changes in productivity be measured at the global or organizational level, as well as the local or individual level to ensure the least amount of bias. If there is little or no assurance that a program to measure changes in productivity can be justified from a budgetary standpoint, the costs are likely to outweigh the gains. Finally, if it is determined that the implementation of such a program is not feasible, then planning should cease.

### 2.3.2 Performing measurements

Once the decision has been made to proceed, it is essential to establish and measure the baselined activities before and after microcomputers are introduced. After a sufficient time has elapsed, there should be a careful assessment and evaluation of any changes in productivity. This process should be repeated over a period of time at unscheduled intervals at sufficiently high levels within the organization to preclude constraints and otherwise, unrepresentative conclusions. Table 6 describes a methodology for both preparing for and performing productivity measurements.

TABLE 6
Steps In Measuring Changes In Productivity

A Planning and Preparing To Measure Change

1. Determine the feasibility of measuring productivity changes in the specific environment.

2. Develop a definition of productivity for the specific organizational environment.

3. Identify the attributes to be used in measuring productivity and define a method of quantifying the subjective qualitative attributes.

4. Develop and implement productivity measures at the global or organizational level rather than at an individual level to ensure a reliable assessment.

B Performing Measurements

1. Perform a measurement to establish the baseline productivity level.

2. Introduce the new technology.

3. Permit a sufficient period of time to elapse to allow any short term decreases in productivity to be eliminated.

4. Re-measure the productivity levels.

5. Carefully evaluate the results to ensure that the results are interpreted within the context of the organizational environment. The evaluation should be performed at the highest, global level possible to avoid local aberrations and biases.

## 3.0 CASE STUDIES

In addition to conducting a literature search, we surveyed a number of organizations to determine their experiences in measuring productivity. We found that:

1. Virtually every organization reported substantial gains in productivity.

2. Most organizations and studies which reported gains in productivity from the use of microcomputers based that claim on a perceived improvement and the subjective judgment of management.

3. Actual, quantitative measurement studies were either not conducted or did not yield quantifiable results.

After reviewing more than two hundred sources (including journals, reports, texts, and individuals), sixty-two were selected for inclusion in the Annotated Bibliography (APPENDIX II). Of those sixty-two, eight were chosen for this section of the report to illustrate how the various organizations make use of quantitative (Table 1) and qualitative (Tables 2 and 3) information to assess productivity changes. Table 7 provides a matrix which identifies the factors and attributes referenced in the following case studies. Thus, this section presents the findings of a number of the survey studies and represents the "best" published reports.

While these 8 case studies provide some insight on the different approaches used to determine changes in productivity, they demonstrate the difficulty in identifying and measuring subjective attributes. Each of the case studies reference increased workload, new or more work accomplished in shorter time, and cost saving as a result of using microcomputers. In many environments, microcomputers are credited with increasing productivity if schedules are met in a timely manner, if the workload is handled without additional staff, and if the products are acceptable and of high quality without the benefit of any "formal" measurements. The following table lists factors or indicators identified in the selected case studies:

TABLE 7
CASE STUDY MATRIX

| Firm | Table 1 Factors Measured | Table 2/3 Attributes Assessed |
|---|---|---|
| 3.1 NSRDC | workload<br>staff<br>time<br>etc. | timeliness<br>efficiency<br>quality |
| 3.2 GAO | workload<br>manpower<br>cost<br>number hours<br>data handled | analysis<br>efficiency |
| 3.3 GSA | manpower<br>cost<br>workload<br>etc. | qualitative benefits<br>timeliness, etc. |
| 3.4 USS | costs<br>workload<br>etc. | users/mgrs. best judge<br>of how much productivity<br>is achieved (no detail) |
| 3.5 Bethlehem Steel | | improved morale<br>timeliness<br>communication<br>reliability<br>(errors reduced)<br>quality of life<br>teamwork |
| Polaroid | costs<br>workload<br>work equip. | |
| 3.6 Banking | cost | |
| 3.7 Data Processing and Research | workload<br>time | value added processing |
| 3.8 Brokerage Firm | cost | user acceptance |

As indicated, very little quantitative data is available and most of the conclusions of improved productivity are based on intuitive belief, not on firm, scientific measurement.

## 3.1 Naval Ship Research And Development Center

> "The Scientific/Engineering Workstation Experiment: Plans and Progress", David W. Taylor Naval Ship Research and Development Center (Questionnaire and Empirical Analysis)

As part of the Technical Office Automation and Communication (TOFACS) project, the David W. Taylor Naval Ship Research and Development Center has undertaken a study of the effects of individual scientific/engineering workstations (SEWs) on the productivity of scientists and engineers [VANE83]. A prototype network of SEWs was developed to assess the changes in productivity which could result from the introduction of SEWs. Initial results of this research indicate that workstations are viable tools which aid productivity in a scientific and engineering environment.

The technique used in this study was to have the subjects being studied perform the evaluation and assessment of their before and after productivity levels. See APPENDIX II for a brief description of the methodology employed. A rather complex formula was used which basically involved applying values to attributes before and after the introduction of the workstations, and then calculating the change in the ratio of the Output to Input totals. Quantitative data was gathered by having the technical staff assess the changes in how long it took to complete a typical task with and without the scientific and engineering workstation. Most of the other data was more subjective (qualitative) in nature and less easy to quantify. The use of the subjects to evaluate their changes in productivity resulted in more consistent assessments on an individual basis, but may have also introduced biases which could affect the findings. In general, this method appeared to work satisfactorily in this R&D laboratory environment and the general methodology could be applicable to other similar measurement attempts.

## 3.2 General Accounting Office

> "Electronic Workstation Project Report to Information Policy Committee", GAO (Questionnaire)

The GAO initiated an electronic workstation project to determine if the installation of workstations "could be cost effective at GAO in performing various auditor functions." The auditing (workload) functions are described and

activities are divided into categories for the purpose of measurement. Benefits and problems are discussed. A matrix of automatable and non-automatable activities was defined and provided the basis for determining how best to utilize the workstations.

This report discusses the study and the methods employed and concludes that an approximate 25% increase in the capacity to perform audit functions was realized as a result of the introduction of the electronic workstations. The basic measurement unit utilized was the number of staff hours actually needed versus the estimated number of hours which would have been required if the electronic workstation had not been introduced. The report contains little information on the actual collection and analysis of data.

## 3.3 General Services Administration

"Final Report on the GSA End User Computer Pilot Project" (Empirical Analysis)

The General Services Administration conducted a pilot project to study the effects of the introduction of microcomputers within GSA. The project involved 500 GSA employees using 53 microcomputers and consisted of the automation of 175 applications. The report provides information on the experiences during the project and identifies the actions completed or initiated to facilitate end user computing. The report summarizes both the qualitative and quantitative benefits encountered by the end users. Most improvements were a result of automating manual operations. Specific examples of productivity gains are given in terms of cost savings, manhours, and increased workloads/tasks.

In discussing the findings, the report notes that in some cases productivity increases were measured "in terms of staff hours, or dollars", but in other cases were not quantifiable because "the microcomputers satisfied requirements that were previously postponed due to staffing shortages." Direct changes in productivity were measured in terms of changes in staff hours or dollars whenever possible. However, most of the conclusions drawn in this report are based on qualitative estimates of perceived improvement to the process. Nevertheless, there is a very strong indication that "the use of microcomputers can pay for themselves in less than one year" and can "help provide better, more timely products and more in-depth analysis."

## 3.4 United States Senate

"The Pilot Test of Office Automation Equipment in the Offices of United States Senators" (Questionnaire, Empirical Analysis, and Before/After Measurement)

This pilot study focused on office automation in the U.S. Senate offices. The method used to measure productivity gains was a before and after analysis of the functional requirements and the day-to-day office workload. Participants were asked to complete forms which identified the areas that could be improved most by automation. They were also asked to rank each of the areas in terms of importance to the performance of their responsibilities. Guidelines were developed to ensure that everyone recorded the same types of information in assessing changes as a result of automation. The key aspect of the productivity measurement program was the requirement that productivity goals and cost justification be established for each workstation to be installed.

The test demonstrated that the staff could quickly learn to use the equipment and put it to productive use. The report does not present any detailed information on measuring productivity changes but does state that "In the final analysis the actual users and office managers are the best judges of how much improvement has been achieved."

## 3.5 American Productivity Center

"White Collar Productivity: The National Challenge and Case Studies", The American Productivity Center, sponsored by Steelcase Inc. (Questionnaire and Empirical Analysis)

Steelcase Inc. commissioned the American Productivity Center, a nationally recognized expert on productivity issues, to conduct a study on productivity in the workplace. During this six month study, the Productivity Center sent survey questionnaires to 600 U.S. firms and received 140 responses. The study is based on those responses and includes twenty-five case studies selected on the basis of the techniques used to assess and measure productivity gains resulting from the introduction of office automation. While this study does not identify any unique measurement techniques, it does suggest that almost any productivity improvement program, no matter how unstructured, can result in increased productivity.

Word processing was found to be the most effective factor in improving office productivity. Other factors consistently cited were team building and the work environment. The

productivity measurement programs of two of the most representative case studies are described and evaluated below:

1 - Bethelehem Steel (Methodology/Intuitive)

Bethelehem Steel initiated a Productivity through Office Systems (PROS) effort to improve productivity of the 400 person sales force and their support personnel. The thrust of PROS, which was aimed at the secretarial force, involved the introduction of both an office automation system and a "Quality of Work Life"(QWL) methodology. The QWL methodology program encourages greater employee participation, and provides for training in all aspects of an office that contribute to the "quality of life" in the office. As part of this effort, monthly PROS meetings were held to address team building, problem solving, and other issues which can strengthen employee capabilities. No formal techniques or measurements were undertaken either before or after the office automation system was installed. There is a strong perception, however, that there were substantial gains in productivity which could be attributed to both office automation and to the QWL methodology program. The reported subjective estimates of the productivity improvements were:

| | |
|---|---|
| -increased output | 20% |
| -more timely delivery | 80% |
| -credibility of offices | 20% |
| -morale improved | 20% |
| -task difficulty reduced | 20% |
| -communication improved | 50% |
| -space more effectively used | 25% |
| -response time reduced | 80% |
| -errors reduced | 5% |
| -quality of service enhanced | 50% |

2 - Polaroid (Needs Assessment)

Polaroid, spurred by a reduction of 4000 employees between 1978 and 1982, established an Office Technology Council to determine how to "better manage and utilize emerging office technologies, reduce cost and enhance the effectiveness and productivity of personnel". As a first task, the Council developed and implemented a seven-step "Needs Assessment Methodology" to justify the acquisition of new technology. An examination was made of the personnel, workload, and tools needed within the organization to accomplish its mission; data was gathered and evaluated; and a summary of the qualitative benefits

expected from the application of electronic technology was made. Polaroid considers this type of assessment helpful in identifying methods for improving productivity prior to the introduction of new technology. The seven steps of the methodology are:

1. Orientation (Overall mission, functions, needs, equipment, costs)
2. Professional activity profile
3. Administrative profile
4. Administrative reporting
5. Detailed workload
6. Word processing benefits summary
7. Financial Analysis worksheet

### 3.6 Banking (Empirical Analysis)

A large northeastern bank is currently using seventy-five (75) microcomputers for such varied applications as: budget and financial analysis, gas and oil studies, balance sheet reporting, and custom tailored accounts. Although a formal study has not been conducted, this firm believes that significant gains in productivity have been achieved and that microcomputers have proven to be very cost effective.

### 3.7 Data Processing and Research (Empirical Analysis)

A large data processing firm provides service for the fifty (50) top banks in the country. Some of the applications handled by the firm include: a significant amount of file transfer - from micro to mainframe; extensive word processing; budget analysis; and value added processing. A much greater workload (volume of transactions) are now being handled in a shorter period of time due to the use of microcomputers. No formal study has been conducted, but it is accepted by the firm that the use of microcomputers has resulted in increased productivity.

### 3.8 Brokerage Firm (Empirical Analysis)

A large New York brokerage firm makes extensive use of microcomputers to handle customer accounts around the country. While no formal studies have been undertaken, customers have indicated that the use of microcomputers generally results in productivity gains and that the replication of successful microcomputer applications would increase both productivity and cost effectiveness. Overall,

this firm has been successful in the introduction of microcomputers. However, concerns were expressed that there may not always be sufficient control and coordination of this process.

## 3.9 Summary

As stated in the introduction to this section, two distinct conclusions can be drawn from the available information on the measurement of the effect on productivity from the introduction of microcomputer-based technology into the office environment.

1. Nearly everyone claims to have obtained significant improvements in productivity.

2. Virtually no one has successfully measured and quantified those changes.

There is strong, anecdotal, circumstantial evidence that most of the claims of increased productivity are correct. There is, however, little reason to accept the specific percentages which are cited. Apparently, the strong perception of improved productivity has been sufficient to justify the further acquisition of microcomputers in many organizations.

# 4.0 SUMMARY AND CONCLUSIONS

While no definitive techniques for measuring productivity changes in an functional workplace were identified, this study did find overwhelming support for the idea that the introduction of microcomputers to the functional workforce will result in significant improvements in productivity. The "measurement" techniques employed have usually been highly subjective and sensitive to biasing factors which can make the cited statistics highly suspect. The most that can be concluded is that microcomputers appear to increase productivity and that this perception is very widely held.

A few organizations have identified a set of measures unique to their environments. Some of these, as in the case of NSRDC, may be conceptually transferred to other environments. However, with the exception of traditional method of measuring inputs and outputs (before and after), there are virtually no universally accepted productivity measures for use in an office environment.

## 4.1 Summary

Our findings indicate that there are several key factors which should be clearly understood when attempting to evaluate and measure productivity within an organization. These findings are summarized below:

1 - Few Effective Measures

The measurement of changes in productivity in a production environment is a well-understood process; however, the measurement of such changes in an office environment is much more difficult to quantify. While various methods have been proposed for measuring changes in productivity resulting from the introduction of microcomputers, very few are effective.

The useful measures are those which primarily address qualitative aspects of the environment and the work produced. These measures are highly subjective and thus, must also be evaluated in light of the methods and techniques used to produce the measurements.

[BOOZ83], [CLUC83], [GAO83], [GSA83], [PLAS83], [SENA83].

2 - Qualitative Measures Should Be Global

Too often, an attempt is made to measure productivity at the atomic or detailed level. The introduction of microcomputers may affect how and what individuals in an organization do to varying degrees. Indeed, the actual work (throughput) of some individuals may appear to decrease. While this would seem to contraindicate the use of microcomputers in this case, an examination at a higher, macro level, may show that there has been a resultant overall improvement in productivity.

The key to a successful productivity improvement program is to define what is expected in terms of productivity gains, specifically, what and how to measure, and then proceed. The best measurements of productivity changes in an office environment are qualitative. These measures are the most accurate when employed at an organizational level. It should be clearly understood that the goal of any productivity program is to improve the overall productivity of the organization. Thus, the measurements should be made at the global level and indications of increases or decreases in productivity at individual levels should be evaluated within the context of the productivity changes of the entire organization. [VANE83].

3 - Measurements Must Be Made Against An Established Baseline

Results of measurement techniques can be highly suspect since the items being measured or counted are often subject to various conflicting interpretations. Regardless of the method or technique used, it is essential to measure changes in productivity against an established baseline. The questionnaire method appears to be the most useful in obtaining, comparing, evaluating, and measuring relative changes in productivity against a baseline. This method provides for gathering information on qualitative, as well as quantitative changes in productivity. [STEE83].

4 - Allow Sufficient Time Before Measuring Productivity Changes

The introduction of any new technology involves a learning period during which there may actually be a

decline in productivity. On the other hand, the excitement of being involved in an "experiment", such as the introduction of microcomputers in an organization, may also lead to an increase in productivity. The effect, however, may be more pronounced immediately after the introduction of microcomputers than later. Consequently, sufficient time must be allowed after microcomputers are introduced into the organization to permit a stable state of operation to be established before the productivity impact is assessed. [STEE83].

5 - Measurements Should Be Carefully Evaluated

Improper or undisciplined use of microcomputers can be counterproductive due to the wrong work being done or to new work being created which is not needed. Thus, the measurement of the effects of microcomputer use should be carefully evaluated. Care should be taken to evaluate the impact on the entire organization, not just the directly affected individual. In addition, measurements must be made over a long enough time period to balance any short term drops or rises in productivity. [STEE83], [BROW83].

Microcomputer use within the organization decentralizes the computing resources and enables users (ADP professionals as well as those without previous ADP experience) to be in direct control of their information processing activities. The user has a wide range of information on which to base decisions and can make those decisions quickly and accurately. Consequently, the user can perform his job more efficiently and effectively. While microcomputers are frequently used as stand alone, general purpose tools, they are rapidly becoming a means of accessing the large scale systems and other microcomputers. The link between the microcomputer and mainframe provides the user with broader range of capabilities and greater potential for productivity gains. The result is the work being done faster, the quality of reports and other documents is improved, and work is performed which was previously not possible. [BOOZ83], [CLUC83], [GAO83], [GOLD83], [GSA83], [PLAS83].

## 4.2 Conclusions

The primary purpose for measuring changes in productivity resulting from the use of microcomputers is to provide evidence of their cost-effectiveness and impact on the organization. This can be accomplished in a number of ways

ranging from a cursory examination of activities and products before and after the introduction of microcomputers, to a plan which encompasses the recommended methodology outlined in Table 6. (see pages 2 and 18). We strongly recommend the use of this methodology to determine first, whether to initiate a measurement program; and secondly, how to go about performing the measurements.

A significant number of Federal Government and private sector organizations have introduced microcomputers and subsequently, have been able to identify gains in overall productivity. Although many of these organizations introduced microcomputers without the benefit of a prior productivity measurement study or program, evidence of their cost effectiveness and impact on the organization has come from both managers and end-users. The management of these organizations is convinced that improvements in products, services, efficiency, morale, and numerous other areas occurred as a result of using microcomputers.

Prior to initiating a study or program to measure changes in productivity, some consideration should be given to the feasibility and cost benefits of such a program. (see step 1 of Table 6). If it is determined that a productivity measurement program is not feasible, or if there is little or no assurance that such a program could be justified from a budgetary standpoint, then it may be better to rely on the judgement of the managers and users of the microcomputers.

Therefore, while a study or program to measure changes in productivity as a result of using microcomputers may be a worthwhile endeavor, it is not necessary or appropriate for every environment.

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# APPENDIX I

# IMPROVING PRODUCTIVITY

## Supporting The User

The productivity of a microcomputer user can be increased through the use of special software tools and with organizational guidance and assistance. An organization should promote the computer literacy and education of all levels of management and users in order to encourage knowledgeable decisions about the selection, operation, and management of the microcomputer systems within the organization. Implementation of educational and training activities will help the end-user to understand the capabilities of the microcomputer and its use, and to make good procedural and procurement decisions.

For the end-user, the computer is a tool which will only be used as long as it provides positive assistance in performing supported functions. To supplement training, support structures need to be developed to provide guidance, assistance, and disseminate information to organizational personnel. Included in this, is the development of a support staff, user groups, information centers, and/or local consultants (user-experts) to provide additional advise and solve problems not anticipated by formal training or specific methodologies.

The ergonomics of the office, equipment, and software play a crucial role in improving the end-user's productivity. In the past, office ergonomic studies have concentrated on the effects of space allocation, lighting, desk and chair height, etc. Similarly, with the introduction of the computer, emphasis was initially place on the construction and placement of the computer terminal, keyboard, disk drives, and screen color, etc. However, increasing attention is being directed to the development of "user-friendly" software. Integrated systems provide consistent names and formats for commands and processes. New systems have been designed to function in a manner in which users are accustomed (e.g. spreadsheets) rather than forcing them to adopt new techniques and thought processes in order to utilize the system. In some systems, operations and data are represented pictorially. Other features such as a "mouse" and touch sensitive screens are also being made available.

Table 8 presents an overview of steps which can be taken within an organization to improve the productivity of the individuals and the overall productivity of an organization.

TABLE 8

Improving Productivity

- Provide extensive training in the use of available microcomputers and available software.
- Establish inter-computer communication capabilities. Make features such as electronic mail available and train the users.
- Establish easy to use procedures for the transfer of data between microcomputers and between microcomputers and the central mainframe computer.
- Establish conventions for common data structures to enable the use of data bases with different application systems.
- Provide and train users in the use of graphics packages. Clear, well-designed charts and figures are highly effective means of communicating large amounts of information.
- Assist the microcomputer users with a centralized support facility which provides user assistance and guidance.
- Whenever possible, make sure that the microcomputers which are acquired are physically and logically compatible with one another. This is necessary to provide inter-computer communication, data transfer, application system execution on different machines, etc.
- Provide the end-users with appropriate software packages, train them in their use, and encourage the use of the packages.

## Management Considerations

Once the meaning of productivity is understood, the next step is to ensure that the environment is conducive to the performance of high quality work, and that the responsibilities for a high level of productivity are well defined. Individuals should have a clear understanding of their job responsibilities and should be held accountable for results. They must be made to feel that they make a difference. If productivity is a major organizational concern, then the individuals within the organization must also be a major concern. This implies that there must be a feeling engendered among the workers that they are: valued, trusted, challenged, making a contribution, and involved in decisions affecting them.

Increases in productivity and profitability, however, cannot be achieved simply with acquisition of new and better technology. Such acquisitions should be accompanied by a management commitment to implement a cost-justified, strategic, system integration approach which addresses the human or social aspects of automation on both the individual and the organization. Too often, productivity has little or no meaning for the individual since it is viewed as an attempt by management to impose more procedures and controls, and ultimately, more work with little additional remuneration. There is likely to be little incentive to use new tools and techniques or to improve performance, if a feeling exists that productivity measures are only being taken to increase the organization's image or profits at the expense of the worker.

Improvements in productivity require upper management to play an active role in the productivity improvement program and also requires that the affected individuals realize benefits from the changes. The introduction and use of microcomputer and related hardware and software must be accompanied by proper and adequate training and regard for the individual's working environment.

In order to achieve significant productivity gains, there must be an integrated, cost-justified, program designed to achieve improvements in predefined areas which would benefit most by the improved productivity. The areas most frequently cited as being in need of improvement are: management, incentives for individuals, work environments, tools, training, software quality and software maintenance. Therefore, the initiation of a comprehensive productivity improvement program can be both a costly and long term effort which requires careful planning, coordination, and the cooperation of all concerned.

It is essential to plan for some recognizable gain within the first two years, substantially more within the next two or three, and depending upon the extent and cost of the effort to achieve an increase in productivity, there should be still more gain within the next five years. A well planned productivity program should have a substantial payoff within three to ten years.

Implementing a productivity program, however, is not without some risks. If it is not well planned, there is likely to be excessive optimism and overestimation of potential productivity gains. If the efforts are not well coordinated, there may be only spotty success, resulting in little overall benefit to the organization. If it is viewed negatively, the workers may decide to thwart its implementation, causing it to fail. And finally, unless there is cooperation between each level of management, professionals, clericals, end users, and others for whom the program is intended, there is little likelihood for success.

Table 9 outlines the basic steps which should be taken to establish a Productivity Improvement Program within an organization. Adherence to this program will help ensure definite gains in productivity as a result of the introduction of microcomputers into an office environment.

TABLE 9

Establishing A Productivity Improvement Program

1. Determine how the tasks/jobs are currently done.
2. Determine where performance can be improved.
3. Define the level of productivity gain expected.
4. Perform a cost-benefit analysis to determine if this is a feasible expectation.
5. Understand that introducing automation requires significant up front costs.
6. Take future inflation into account.
7. Determine the amount to be committed to achieve productivity gains.
8. Determine for whom equipment will be used. In white collar domains, there are clearly two sets of users: professional and clerical.
9. Determine for which applications equipment will be used.
10. Determine what kind of equipment will be used.
11. Evaluate large, difficult to maintain programs for possible replacement with off the shelf packages.
12. Evaluate activities that require substantial resources, i.e., OR, simulation, job scheduling, for possible replacement by more efficient ones.
13. Run a pilot to substantiate the expected improvements.
14. If the pilot is successful, go forward with the whole program.

# APPENDIX II

This annotated bibliography provides information germane to the question of measurement of productivity gains achieved in the workplace through the use of microcomputers. The magazines, books, journals, and reports selected are considered primary sources for articles on microcomputers and provides a consolidated reference to materials on metrics, techniques and tools used to measure productivity. Summaries of interviews with managers of several large firms which use microcomputers are also included. An alphabetized cross-index of all reference citations is included at the end of this report.

## CATEGORIES

1. Resources/Interviews

   This section presents a summary of several of the discussions held with managers of large firms which use microcomputers.

2. Productivity - Metrics, Measures, Techniques

   These articles identify and describe various methodologies for measuring the productivity of microcomputer use.

3. Productivity Factors

   A wide range of factors (e.g. ergonomics, training, corporate strategies, etc.) that can influence the productivity of the microcomputer user are discussed in these articles.

4. End-User Productivity Tools

   Software tools that can be used on microcomputers to increase the productivity of the user are described.

5. Productivity - Micro/Mainframe

   These articles address the benefits to productivity that can be derived from linking microcomputers to mainframe computers.

6. Supports General Perceptions

   These articles describe how microcomputers are and can be used to increase the productivity of the user.

7. Related or Limited Use

   This section references articles which present information indirectly related to this effort, and are therefore provided as supplementary references.

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## 1. Resources/Interviews

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The following organizations were interviewed because of their success or experience using microcomputers. Each was asked the following questions:

1. Does your organization use microcomputers in the headquarters and field or branch offices?

2. Have you found there have been productivity gains as a result of using microcomputers? If so, did you use either formal or informal measures or techniques to determine those gains?

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[INTERVIEW-1]

This firm is a nationally recognized expert devoted to the improvement of productivity and quality of work life issues. Among the major areas of concentration are: productivity and quality of work life management, white collar productivity, and productivity measurement. The major activities of this firm include publications, presentations, educational and training materials, seminars and workshops, library resources and research, and individualized consulting services.

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[INTERVIEW-2]

A representative of a large northeastern bank stated that his organization was using 75 microcomputers for such varied applications as: budget and financial analysis, gas and oil studies, balance sheet reporting, and custom tailored accounts. Although a formal study had not been conducted, he stated that significant gains in productivity had been achieved and the use of microcomputers had proven to be very cost effective.

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[INTERVIEW-3]

The director of management systems for a large Federal agency stated that an initial evaluation of organization activities and procedures indicated that a pilot office automation study should be undertaken. The decision was made to provide all of the field offices with $30,000 worth of microcomputers. Procedures were also established to measure the microcomputer use and productivity gains.

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[INTERVIEW-4]

An organization which performs research in a number of areas and provides planning information, analysis, and recommendations to managers and executives in the information processing industries, recently conducted a study on productivity in the work place. The study suggests there is increased productivity as a result of using microcomputers.

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[INTERVIEW-5]

We spoke with a manager in a large data processing and research firm which provides service for the fifty (50) top banks in the country. Some of the applications handled by this firm include: a significant amount of file transfer - from micro to mainframe, extensive word processing, budget analysis, and value added processing. He stated that a much greater volume of transactions was being handled in a faster period of time as a result of the introduction of microcomputers. He further stated that while no formal study had been conducted, the use of microcomputers had resulted in increased productivity.

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[INTERVIEW-6]

A representative of a large manufacturing firm stated that his firm had not conducted any studies on measuring productivity gains as a result of microcomputer use. He did send a brief report of a microcomputer conference which discusses the increasing introduction of microcomputers in the workplace and addresses some of the DOD concerns in this area.

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[INTERVIEW-7]

A manager in a large New York city brokerage firm stated that while no formal studies have been undertaken, discussions among his clients have indicated that the use of microcomputers generally resulted in productivity gains, and that the replication of successful microcomputer applications would increase both productivity and cost effectiveness. He stated, however, that too often firms take the approach of "Lets do it and see what happens." He believes that management problems are developing; that a "second stage action to handle the desired coordination - such as an advisory board" is needed; and that we need to look at who is using the microcomputers and how.

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## 2. Productivity - metrics, measures, techniques

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[BOCZ83] Boczany, William J., "Justifying Office Automation", Journal of Systems Management, July 1983 pp 15-19.

This article discusses a means of quantifying the cost/benefits of office automation before implementation. An outline of a six step process to be used in justifying OA acquisition and a summary justification example is given. A major element of this process is the determination of a "productivity improvement factor" which is simply defined as the change in the amount of time needed to perform a set of tasks. In other words, the change to the INPUT/OUTPUT ratio.

The report states that "by its nature, justification implies measurement...that is adding up the inputs and the outputs." It further states that there are currently no successful methods for "determining what the distinct products of the office are, let alone a way to measure the variability of output of these products over time."

The report recommends measuring things that are quantifiable and that using a microcomputer is directly transferable into dollars per-hours used. It also provides a six-step process to be used in justifying the purchase of office automation equipment.

1. Determine appropriate improvement factor to be used (example cited).

2. Perform pre-implementation cost-benefit analysis to determine gross savings (example cited).

3. Discount savings determined in step 2 to obtain net savings (example cited).

4. Determine the amount that management is willing to spend for an improvement in quantity (example cited).

5. Determine the amount that is justified for equipment expenditures.

6. Prepare proposal and justification.

[BOEH83] Boehm, Barry W., "The TRW Software Productivity System", September 1983.

TRW conducted a software productivity study during 1980 to analyze requirements for a TRW-oriented software support environment, to evaluate the technology base available for such an environment, and the likely trends in that base. As a part of this effort, TRW developed the Software Productivity System (SPS), a Unix based software support environment. They also performed an economic analysis to determine whether the significant level of investment for productivity aids was justified. The study included an internal assessment, an external assessment, a quantitative analysis, and a set of recommended actions.

The report does not address microcomputers specifically, and does not provide detailed descriptions of measurement techniques which were employed. Most of the conclusions and the resulting SPS were based on interviews with managers and staff. There was a general consensus that the four primary avenues for improving productivity are: work environment and compensation, education, training, and software tools.

[BROW83] Brown, Bruce R., "Productivity Measurement in Software Engineering", prepared by Social Security Administration (SSA), Office of System Integration, Software Technology and Engineering Center Staff, June 1983.

The Social Security Administration recently performed a study to determine the usefulness of productivity measures and metrics. The primary purpose was to identify and analyze methods for establishing baseline productivity measurement of programmer performance. This study provides a number of the metrics and measurements currently employed, as well as an assessment of their applicability. The report concludes that the science of productivity measurement metrics have made enormous advances since the development of the concept of lines-of code (LOC) as the only means of measuring programmer productivity, and that the trend is toward more functional measures and the use of a wide spectrum of measures.

[CLUC83] Clucas, Richard, "Are Your Computers Paying Off?", Personal Computing, December 1983, pp 118-122,231,232.

The introduction and use of microcomputers has increased the productivity of the users, but measuring these increases has not been easy. The examination of several corporate studies indicates the difficulty in measuring productivity and that most measures used are not quantitative. Several methodologies were provided, one of which suggested that white-collar productivity be evaluated in terms of quality, timeliness, and effectiveness, and measured by before and after comparisons of output. No actual measurement techniques are presented, however.

The report includes the statement: "Most computer industry analysts agree that personal computers provide significant gains in productivity, but few offer simple formulas for determining whether systems are in fact paying for themselves in increased efficiency and productivity. And once you begin to examine personal computing among managers, executives, and professionals (the so-called 'knowledge workers'), productivity becomes more difficult to analyze."

[GAO82] "Workstation Project Report To Information Policy Committee", Directed by Kenneth Pollock, Associate Director of Information Management Systems, General Accounting Office, Internal Study, 1982.

The GAO initiated an electronic workstation project to determine if the installation of workstations "could be cost effective at GAO in performing various auditor functions." The auditing functions are described and activities are divided into categories for the purpose of measurement. Benefits and problems are discussed. A matrix of automatable and non-automatable activities was defined and provided the basis for determining how best to utilize the workstations.

This report discusses the study and the methods employed and concludes that an approximate 25% increase in the capacity to perform audit functions was realized as a result of the introduction of the electronic workstations. The basic measurement unit utilized was the number of staff hours actually needed versus the estimated number of hours which would have been required if the electronic workstation had not been introduced. Little information is provided, however, on the actual collection of the data.

The techniques employed by GAO to improve office productivity include:

1 - gathering profile data for all assignments,

2 - determining areas for possible improvement and projected increased productivity, and

3 - comparison of the performance of staff before and after automation.

[GSA83] "Final Report on the GSA End User Computer Pilot Project", Prepared by The General Service Administration's End User Computer Support Staff (KGS-1), September 28, 1983.

The final report of a GSA pilot project to make microcomputer systems available within GSA. The project involved 500 GSA employees using 53 microcomputers and consisted of the automation of 175 applications. The report provides information on the experiences during the project and identifies the actions completed or initiated to facilitate end user computing. The report summarizes both the qualitative and quantitative benefits achieved by the end users. Most improvements were a result of automating manual operations. Specific examples of productivity gains are given in terms of cost savings, manhours, and increased workloads/tasks.

In discussing the findings, the report notes that in some cases productivity increases were measured "in terms of staff hours, or dollars", but in other cases were not quantifiable because "the microcomputers satisfied requirements that were previously postponed due to staffing shortages." However, most of the conclusions drawn in this report are based on qualitative estimates of perceived improvement to the process. Nevertheless, there is a very strong indication that "the use of microcomputers can pay for themselves in less than one year" and can "help provide better, more timely products and more in-depth analysis."

The following steps are recommended for improving microcomputer implementation:

1 - Establish policy guidelines for the procurement and use of microcomputers.

2 - Establish and maintain procedures to advise microcomputer users what other users have accomplished.

3 - Continue to train, educate, and inform all levels of employees of the changes that will affect their work environment as a result of new technology.

[IDC84] "Strategies for Microcomputers and Office Systems, Cost Justification of Office Systems", Prepared by IDC Corporate Headquarters for Continuous Information Service Clients, IDC No. 2533, Framingham, Ma. 01701, July 1984.

According to IDC, there are three fundamental issues which contribute to the demand for cost justification solutions. First, many organizations are poised to initiate or expand pilot projects, however, they are increasingly being required to justify proposed expenditures. Secondly, the available cost justification methodologies have proven to be inadequate. Finally, any cost justification solutions must encompass issues that go far beyond the development of the methodology to include every aspect of office system planning and implementation. A detailed discussion of the benefits of specific types of office automation projects is provided. Criteria for measuring the effectiveness of office automation based on the desired outcome are also presented. IDC, however, considers "selecting the right process to automate" to be the most important criteria.

A number of case studies and examples are used to illustrate techniques for identifying worthwhile office automation projects. The report also provides a detailed bibliography and references to nine different sources of information on office automation which includes publications, user, research, and professional organizations, courses, etc. IDC recommends that the cost of information processing or office automation be analyzed by function, by technology, and by organizational units. Thus, the conclusions drawn by the IDC report are consistent in many respects with those of the Task 2 report.

[KEEN80b] Keen, Peter G.W., "Value Analysis: Justifying Decision Support Systems", Sloan School of Management, Massachusetts Institute of Technology, October 1980.

Decision Support Systems (DSS) are designed to help improve the effectiveness and productivity of managers and professionals. The benefits provided by DSS are often qualitative and difficult to quantify. This report includes a discussion of qualitative assessments which should be made when evaluating managerial productivity. It examines how DSS are justified and how a value can be assigned to effectiveness, learning and/or creativity. Value Analysis, a methodology for planning and evaluating DSS proposals is recommended and discussed in detail. Alternative approaches to evaluation: cost/benefit analysis, scoring techniques and feasibility studies are also included. No formal methodology or method of quantifying the assessment is presented.

[PLAS83] Plasket, Richard and Wilneff, Paula, "Productivity and DP Management: Losing Control?", Journal of Systems Management, October 1983, pp 30-33.

In order to improve productivity, several basic management problems must be overcome. Productivity is defined to be OUTPUT divided by INPUT and a methodology for increasing productivity (and reducing management problems) is presented. The solution requires the DP manager to consider vital productivity areas such as organization plans, strategies, and people. Included are tables of productivity inputs and outputs, and implications. While many of these inputs and outputs are qualitative, some are directly measurable. It is recommended that as many as possible should be taken into consideration when attempting to measure productivity in the office environment.

[PRES82] Pressman, Roger S., Software Engineering, A Practitioner's Approach, McGraw-Hill Book Company, New York, New York., 1982, pp. 66-69, 164, 173, 329.

Software productivity is an elusive quantity to measure because software is not manufactured in the classical sense. We are therefore left with a dilemma. The discussion on productivity and measurement raises such issues as the need for measuring planning, analysis, design, and testing during development. The five key factors that influence productivity are provided. Other factors and variables that correlate significantly with programming productivity are presented.

[SENA83] "The Pilot Test of Office Automation Equipment in the Offices of United States Senators", Committee on Rules and Administration United States Senate, S-Prt 98-120, November 1983.

This pilot study focused on office automation in the U.S. Senate offices. The method used to measure productivity gains was a before and after analysis of the functional requirements and the day-to-day office procedures. Participants were asked to complete forms which identified the areas that could be improved most by automation. They were also asked to rank each of the areas in terms of importance to the performance of their responsibilities. Guidelines were developed to ensure that everyone recorded the same types of information in assessing changes as a result of automation. The key aspect of the productivity measurement program was the requirement that productivity goals and cost justification be established for each workstation to be installed.

The test demonstrated that the staff could quickly learn to use the equipment and put it to productive use. The report does not present any detailed information on measuring productivity changes but does state that "In the final analysis the actual users and office managers are the best judges of how much improvement has been achieved."

[STEE83] "White-Collar Productivity: The National Challenge and Case Studies", sponsored by Steelcase Inc., Grand Rapids, Michigan, 1982.

This report is based on the results of a productivity survey of 140 firms. It details how American companies are pursuing the problem of measuring white-collar productivity and shows that some have scored impressive gains. Particular focus is given to: what programs have been undertaken, how firms approached the challenge, and what outcomes have been achieved. Included are twenty-five case studies detailing the company and its productivity gains due to office automation. The overall conclusion of the study - that significant productivity gains were realized - is divided into sub-conclusions and examined in detail.

[VANE83] Van Eseltine, R.T., "The Scientific/Engineering Workstation Experiment: Plans and Progress", Proceedings of the 22nd Annual Technical Symposium of the Washington, DC, Chapter of the ACM, Co-sponsored by the National Bureau of Standards, June 1983, pp C3.1-C3.13.

As part of the Technical Office Automation and Communication (TOFACS) project, the David W. Taylor Naval Ship Research and Development Center has undertaken a study of the effects of individual scientific/engineering workstations (SEWs) on the productivity of scientists and engineers. A prototype network of SEWs was developed to assess the changes in productivity which could result from the introduction of SEWs. This research indicates that workstations are viable tools which aid productivity in a scientific and engineering environment.

The methodology employed during this study was to first develop a formula for determining relative productivity. (Relative productivity here to the ratio of the productivity after a change to the productivity before the change.) Before and after baseline measurements of specific areas including the projected products for those areas were obtained for comparison. Then, a

questionnaire was developed to gather information on computer usage, user responsibilities, computer capabilities, characteristics of terminals, projected computer requirements, and desired features. Next, a project profile of the productivity of the scientists and engineers employed at the Center was developed. The project profile, based on information collected using an interview guide, focuses on such criteria as project quality, timeliness, and efficiency. Finally, a system and software configuration analysis was performed.

The technique used for measuring changes in productivity was a form of calculating the changes to the inputs and outputs ratio. Primary data was gathered by having the technical staff assess the changes in how long it took to complete a typical task with and without the scientific and engineering workstation. This method appeared to work satisfactorily in this R&D laboratory environment, and the general principles could be applicable to other measurement attempts.

## 3. Productivity Factors

[BASI78] Basili, V., and Zelkowitz, M., "Analyzing Medium Scale Software Development", Proceedings of the 3rd International Conference on Software Engineering, IEEE, 1978, 00. pp 116.

This article identifies factors that can influence productivity and divides them into the following five categories:

a) people factors - organization size and expertise;

b) problem factors - complexity and number of changes in constraints and requirements;

c) process factors - analysis and design techniques, language, and procedures used;

d) product factors - reliability and performance of computer-based system; and

e) resource factors - availability of tools, hardware, and software resources.

[COMP83] "Corporate Moves With Micros", Computerworld, Office Automation Issue, Volume 17, Number 41A, October 12, 1983, pp 13-15.

This article discusses the need to develop a corporate strategy for microcomputer use. It discusses the associated problems and provides a checklist for developing guidelines for microcomputer use.

[FEEZ83] Feezor, Betty, "Microcomputers: A Delicate Balance", Computerworld, Office Automation Issue, Volume 17, Number 32A, August 17, 1983, pp 9-10.

A wide range of good and bad features of which microcomputers users should be aware are identified. The article states that microcomputers alone may not always give the productivity increases users are looking for. In general, the effectiveness of large scale use of microcomputers is dependent on a well-planned implementation, compatible equipment and software, and vendors who can provide the necessary guidance and

technical support with respect to standards and mainframe access. The article suggests that microcomputers can dramatically increase management productivity.

[FRIE82] Fried, Lousi, "Nine Principles for Ergonomic Software", Datamation, November 1983, pp 163-166.

There is a high probability that ergonomic design of software will result in increased productivity. Based on observations of SRI International clients, nine fundamental principles of ergonomic software and examples of their application are presented. Emphasis is placed on enhancing the worker's ability to manipulate and process the software.

[GAO82] "Strong Central Management of Office Automation Will Boost Productivity", Comptroller General, General Accounting Office report AFMD 82-54, September 1982.

Office automation has the potential to improve the productivity of Federal employees. However, the lack of strong, central management and effective guidance has resulted in the development of office automation systems that are not cost effective. GAO believes that to reap the benefits without wasting resources, agencies should establish strong, central management of office automation systems.

[GAO83b] "Federal Productivity Suffers Because Word Processing Is Not Well Managed", General Accounting Office, FGMSD-79-17, Report to Congress of the United States, April 6, 1979.

Word processing systems are said to offer the potential for a more efficient and productive office place - provided the people, equipment, and procedures are managed properly. Some recommendations are provided to assist Federal agencies in demonstrating that productivity has increased and that word processing systems are cost effective.

[GOLD83] Goldfield, Randy J., "Achieving Greater White-Collar Productivity in the New Office", BYTE, May 1983, pp 154-172.

Increases in productivity and profitability can not be achieved simply with the acquisition of new and better technology. Management must implement a cost justified, integrated, strategic approach to office automation. This article discusses the key issues and benefits of such an approach,

including the affect of automated tools on white collar productivity. The article concludes with a methodology for successfully achieving increased productivity through office automation.

[HABE83] Haber, Lynn "Ergonomics Seen Key To Better Productivity", Computerworld, Volume 18, Number 4, January 23, 1984, pp 29-30.

It is not enough to just put a microcomputer on a desk. Mechanical engineering must go hand-in-hand with human engineering - ergonomics - if the office is to be effective. There are strong indications that with improved ergonomic workstations, worker productivity increases. According to the recent IFMA conference, firms are recognizing that people are their greatest resource and that improving the work environment is cost effective.

[LAMB84] Lambert, G.N., "A comparative study of system response time on program developer productivity, IBM Systems Journal, Vol 23, No. 1, 1984, pp 36-43.

A controlled study was conducted to determine whether added computer resources could decrease system response time and increase programmer productivity for particular conditions in a program development environment. The primary purpose of the study was to justify to higher management the case for improved data processing resources, based on savings in the number of developer personnel and faster delivery of applications. Based on a 92 percent sample, the study found that programmer productivity increased sixty-two percent with sub-second system response time, and that individual group project offices, rather than large open rooms, lead to greater efficiency. In addition to the productivity gains, the study project reduced overtime to almost zero and installation of the finished product was finished ahead of schedule.

[MARC83] Marcus, M. Lynne, "The New Office: More Than You Bargained For", Computerworld, Office Automation Issue, February 23, 1983, Volume 17, Number 8A, pp 37-44.

What's good for the organization is not necessarily good for the employee. The article discusses the impact of office automation on both the individual and the organization. Explored are the benefits of office automation and the problems or negative impacts that can result. Productivity is examined in terms of social aspects (e.g. how tasks are distributed among people) as well as work task impacts (e.g. efficiency).

[MART82] Martin, James, Application Development Without Programmers, Prentice-Hall, Inc., New Jersey, 1982, pp 161-177.

Chapter three addresses factors that contribute to increased white-collar productivity. The premise is that technology is not enough, it is people who improve productivity - their attitudes, their attention to time and efficiency, and their motivation. The author suggests that an increase in productivity will come about after management realizes that the design and flow of work in the paperless office should be quite different from the flow of work designed for paper. End user applications are discussed.

[POWE83] Powers, Dick, "Conquering Microphobia", Computerworld, Office Automation Issue, Volume 17, Number 32A, August 17, 1983, pp 49-50.

In many organizations, the introduction of microcomputers is causing increased anxiety. This type of frustration is not an unusual symptom in the early period of microcomputer use. The premise is that dramatic increases in productivity are possible if managers take the time to learn how to use the microcomputer and the associated software properly. Some of the management productivity gains cited are in such areas as: mainframe accessibility, multi-tasking, capacity to integrate different applications and electronic mail.

[RUBI83] Rubin, Charles, "Computing In High Places", Personal Computing, November 1983, pp 77-85.

Personal computers are appearing in the upper levels of management and are changing the structure (responsibilities) of the organization. The use of a personal computer can increase an individual's productivity, but it can decrease the workload (and productivity) of other staffers. This article explores the impact a personal computer can have on corporate workstyles. Included are scenarios of "responsibility shuffling" caused by users doing work previously done by subordinates or co-workers.

[RYAN83] Ryan, Hugh, "End-User Game Plan", Datamation, December 1983, pp 241-244.

End user computing provides real benefits, but in order to succeed, users need training, the right equipment, and good coaching. To create a successful and productive end user environment, factors such as relevant user training, coaches,

data delivery systems, and fourth generation software tools are necessary. This article explores these factors as part of an end user computing strategy.

[SCHA83] Scharer, Laura, "User Training: Less is More", Datamation, July 1983, pp 175-182.

Productivity can be improved by providing the user with adequate training tools. Elements of successful user training include the use of cheat sheets, training demonstrations, and a user-expert. Introducing these various training elements can provide various cost saving opportunities, increase the effectiveness of the training, and improve the productivity of the analyst.

[TEGE83] Teger, Sandra L., "Factors Impacting the Evolution of Office Automation", Proceedings of the IEEE, Volume 71, Number 4, April 1983, pp 503-511.

Corporate motivation to implement OA is related to their basic goal of improving profitability. This goal is characterized in terms of: cost displacement - systems aimed at reducing the cost per unit of output; and value added - systems which improve the effectiveness (rather than efficiency) of the organization and/or enable it to perform additional functions. The paper examines some of the market factors which will be central to the evolution of office automation. Specific attention is given to a description of problems of current processes and generic solutions of time spent in interpersonal communications (voice, meetings, documentation).

[THAD84] Thadhani, A.J., "Factors Affecting Programmer Productivity During Application Development", IBM Systems Journal, Vol. 23, Number 1, 1984, pp. 19-35.

The effects of good computer services on programmer and project productivity during application development are examined. Programmers' terminal activity and the nature of terminal work are analyzed. The discussion includes the effects of short response times, programmers' skills, and program complexity on productivity.

[THAR83] Tharrington, James M., "How Microcomputers Can Aid In Applications", Computerworld, November 14, 1983, pp 80.

This report discusses how some firms through creative and aggressive utilization of microcomputers are achieving improvements in productivity. Three examples are cited.

## 4. End-User Productivity Tools

[COCH83] Cochran, Henry, "Fourth-Generation Languages", Computerworld, Office Automation Issue, June 15, 1983, Volume 17, Number 24A, pp 47-52.

Fourth-Generation Languages are tools that bring self-sufficiency to end users and guide them in becoming responsible for the development and maintenance of their own tasks. The article examines these tools and how their use can help increase the productivity of the user. Examples of various uses within different computing environments (including office automation and personal computers) is given.

[COMP83b] "DP Managers Say DSS Needed To Tie Together Corporate Micros", Computerworld, Volume 17, Number 42, October 12, 1983, pp 32.

An abstracted talk from Info 83, this article discusses the need to employ a Decision Support System (DSS) to tie microcomputers together to protect against the proliferation of dozens of independent systems. The implication is that a DSS can aid productivity. An example is cited which describes how a DSS can help to measure productivity.

[GILL83b] Gillin, Paul, "One Unified Strategy", Computerworld, Office Automation Issue, Volume 17, Number 42, October 17, 1983, pp 22.

This article abstracts a talk given at Info 83 on implementing DSS on both microcomputers and mainframes. As the trend towards linking microcomputers to mainframes continues, companies should implement a DSS strategy that encompasses both hardwares. Several of the benefits and problems are discussed along with three potential implementation strategies.

[HORW83] Horwitt, Elisabeth, "Creating Your Own Solutions", Business Computer Systems, June 1983, pp 130-141.

The use of applications software generators offers businesses a way to develop programs tailored to individual needs. These tools enable a non-programmer to create timely and cost efficient programs. A general description of application

software generators, examples of their use, and a list of criteria to consider when shopping for an applications software generator are provided.

[KEEN80] Keen, Peter G.W., "Decision Support Systems and Managerial Productivity Analysis", Sloan School of Management, Massachusetts Institute of Technology, September 1980.

This paper describes the use of Decision Support Systems (DSS) to improve managerial productivity. DSS can provide the base for a generalized approach to productivity analysis, by looking at the task from the inside. DSS is discussed from this perspective. The paper discusses several studies and provides evidence of productivity benefits to the users. The author's analysis of productivity gains from DSS systems is included.

The report contains the following statement in regard to assessing productivity: "Too often, productivity is equated with efficiency, reducing cost, improving output per hour or eliminating errors. At the extreme, this approach suggests that we can improve the productivity of a strategic planning group by increasing the number of plans it generates per month. Managerial work, however, does not produce well-defined outputs from well-defined inputs. The quality of the plan is more important than volume. Performance is measured in terms of effectiveness as well as efficiency. Decision making is a process of problem-solving, not a tidy set of standard operating procedures."

[LOCH83] Lochovshy, Fred, "Improving Office Productivity: A Technology Perspective", Proceedings of the IEEE, Volume 71, Number 4, April 1983, pp 512-518.

The emerging office technology provides great potential to improve office productivity. This paper explores ways that office workers can use computer-based tools to easily access and process data, to better understand and computerize their work, and to assist in managing their time and performance of tasks more effectively. It provides a definition for productivity and stresses the need for better and more integrated end user facilities.

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## 5. Productivity/micro-mainframe

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[EDP83] "The Mainframe/Micro Data Exchange Facility", EDP Analyzer, Volume 21, Number 11, November, 1983, pp 13-14.

One of the major uses of microcomputers is expected to be retrieval of data from corporate mainframes for analysis and display on the microcomputers. This article explores alternative facilities which might be needed for this function. Increased accessability to mainframe computers which house the most current and accurate information is just another factor in increasing productivity.

[FERR83] Ferris, David, "The Micro-Mainframe Connection", Datamation, November 83, pp 127-138.

The increasing need for end users to communicate between microcomputers and mainframes is explored. The premise is that after becoming accustomed to spreadsheets, WPs, databases, and simple graphics, end users will think of reasons for wanting to communicate with the outside world. Micro/mainframe linkage will make it possible to handle some applications more effectively, thereby aiding productivity. Some of these applications are discussed.

[GILL83] Gillin, Paul, "The Micro-Mainframe Links", Computerworld, Office Automation Issue, Volume 17, Number 52/Volume 18, Number 1, December 26, 1983/January 2, 1984, pp 23-27.

There is an increasing user demand for micro/mainframe linkage. As a result DP managers are looking desperately for ways to tie microcomputers into the corporate mainframes. Some of the applications and benefits are discussed.

[LUTZ83] Lutz, Merritt M., "The Micro/Mainframe Link", Computerworld, Office Automation Issue, Volume 17, Number 32A, August 17, 1983, pp 65-69.

This article discusses the EDP revolution during the past 20 years. It describes both the potential and the problems associated with the widespread use of microcomputers.

[ZACK83] Zack, Robert, and Guthrie, Steven, "The Micro-to-Mainframe Link", Computerworld, Office Automation Issue, Volume 17, Number 48A, November 30, 1983, pp 11-15.

The ability to transfer information between microcomputers and mainframe databases holds the potential for full utilization of corporate microcomputer resources. Some of the benefits and applications, including uploading and downloading, are discussed. The article suggests that the greatest shortcoming of the stand-alone microcomputers is the need to access current and correct information, generally contained in the mainframe database.

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## 6. Supports general perceptions

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[ABRA83] Abrams, Marshal D., "Using the Desktop Computer for Project management", Proceedings of the 22nd Annual Technical Symposium of the Washington, DC, Chapter of the ACM, Co-sponsored by the National Bureau of Standards, June 1983.

This article discusses how a manager can use personal computers to access, share, satisfy his/her style or concerns, and present information needed for project management. Some examples are provided on how managers can use the microcomputers to improve productivity by accessing and sharing information.

[BROW83a] Brown, Gary D., and Sefton, Donald H., "The Micros vs The Applications Logjam", Datamation, January 1984, 96-104.

The typical DP department has a three year backlog of development and maintenance work. Although microcomputers can help to reduce this backlog, an assessment of what it does well and what it does poorly is needed. In general, backlogs exist because there are more tasks than there are people to execute them. The ease of use, low cost and increased speed must be weighed against the difficulty in processing and printing large files. Productivity gains are likely if microcomputers become an important part of a company's computing resource, and if they are used for those tasks that can be done well by end users. Advantages and disadvantages are discussed.

[COMP83c] "Workstation Rules Out Paperwork for Court", Computerworld, Volume 17, Number 46, November 14, 1983, pp 50.

According to this article, the use of workstations has resulted in improved accuracy, increased efficiency and erased backlogs in the Fairfax County Court system. Even though staff size increased by 22%, 46% more work was handled. In some areas, estimates of increased productivity ranged as high as 50%. Although no formal measures or metrics were employed, the use of the workstations has proven to be cost effective.

[COMP83d] "Most Senior Accountants Found Using Micros", Computerworld, Volume 17, Number 46, November 14, 1983, pp 26.

This article cites examples of increased productivity as a result of microcomputer use. It identifies the cost of an organization's staff as the largest element in the MIS budget. Microcomputers are seen as a tool that can be used to reduce this cost.

[DATA83] "Micros at Big Firms: A Survey", conducted by Data Decisions, Datamation, November 1983, pp 161-174.

One thousand corporate firms and institutions were surveyed to determine why and how microcomputers are being used and the impact of their use. The survey provides an in-depth assessment of microcomputers in the workplace. The most significant benefit cited, was improved productivity. DP managers expect productivity gains to be realized by alleviating some of the dp applications backlog and because of increased computer literacy of end users. Some of the benefits provided by microcomputers are identified.

[EDP83b] "Future Effects of The End User Computing", EDP Analyzer, Vol 21, No 11, Nov. 1983, pp 1-12.

Microcomputing in the not-distant future probably will overwhelm the informations systems department unless adequate preparations are made. The article explores the growing use of microcomputers through a discussion of applications and incentives for use. The need for planning for end user growth is stressed. Examples are provided of how some firms are using microcomputers.

[FLEM84] Fleming, Maureen and Jeffrey Silverstein, "Microcomputers and Productivity: an analysis of microcomputer hardware and software usage in business", Knowledge Industry Publications, White Plains, New York, 1984.

This report presents the findings of a survey of subscribers to the Microcomputer Software Letter. The report states that more than 80% of the respondents "estimated that their machines (microcomputers) made them at least 50% more productive. Nearly 60% felt that microcomputers at least doubled their productivity." Only 54% indicated that they saved any money as a result, but there is an overwhelming support for the use of microcomputers as a productivity tool.

[LYON82] Lyons, Gordon, "Microcomputers and the Writing of Programs", Proceedings of Trends and Applications, sponsored by IEEE Computer Society and the National Bureau of Standards, May 1982, pp 65-68.

Microcomputers are a resource that can promote new ways of doing things in the field of programming. A brief examination is made of a typical microcomputer configuration that would support heavy demands of language-based program development.

[REGA83] Regan, Harry J., "Executive Workstations: Efficiencies and Opportunities for Management", Proceeding of the 22nd Annual Technical Symposium of the Washington DC Chapter of the ACM, cosponsored by NBS, June 1983.

This paper discusses the components that may be included in microcomputer based workstations, its capabilities, and the organizational benefits that may be derived from their use. The Boeing Intelligent Terminal System is presented as an example of workstation software.

[SHEP83] Sheppard, Jack, "Automation in the Office: What Can It Do for You?", Desktop Computing, February 1983, pp 32-37.

The purpose of this article is to provide a snapshot of where the office automation industry is, where it is going, and what kind of decisions can be made to maximize the chance of success. Scenarios demonstrate that OA enables a person to screen, select, and process data into a form on which to make immediate decisions. It concludes that office automation properly implemented can offer productivity benefits.

[YOUN83] "The Impact of Low Cost Computing Technology On The Department of Defense", report by Arthur Young and Co., February 8, 1982.

Executives, professionals, administrative, and clerical personnel benefit by the use of microcomputers. All of these benefits are subsets of one overall goal: increased productivity. Concerns over the widespread acquisition of microcomputers are addressed. Guidelines are recommended for controlling acquisition; clarifying the role of microcomputers with respect to mainframe computers; and identifying areas, responsibilities, and strategies for use. The report presents highlights of the most recent and important trends in information processing technology and assesses their implications for management. It discusses the findings of the

study and includes an analysis of microcomputer technology trends, potential applications, and management implications.

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## 7. Related or Limited use

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[BART83] Bartino, Jim, "Study Takes Exception To Belief That Firms Don't Control Micros", Computerworld, Volume 17, Number 51, December 19, 1983, pp 1,6.

This article discusses a study conducted by Price Waterhouse and Co., entitled "Managing Microcomputers: A Guide for Financial Policymakers". The study differs from many others on the same topic, finding a large percent of microcomputers communicating with other computers and a high degree of company wide control over the spread and use of microcomputers.

[WALT83] Walton, William B., "New Support for the End User", Computerworld, Office Automation Issue, Volume 17, Number 32A, August 17, 1983, pp 27-32.

This article discusses microcomputer uses and suggests that the microcomputer will be the primary vehicle for delivering office automation to management. It states that more applications will be sought to increase organization productivity as uses of microcomputers are proven. Some of the current applications discussed include mainframe access, electronic mail, and scheduling.

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11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

Measuring productivity changes in an office environment primarily involves the assessment of the impact of a new technology on qualitative factors which cannot be measured directly. This publication addresses the question of measurement of productivity gains achieved in the functional workplace through the use of microcomputers. An in-depth analysis of the approaches used revealed that there are few effective measures to provide a quantitative assessment of changes in productivity. This report provides summaries of case studies and interviews with a number of large organizations that have introduced microcomputers, analyzes and discusses commonly used productivity measuring techniques and approaches, and presents a methodology for measuring and improving productivity in the functional workplace. An extensive annotated bibliography is also provided. The conclusions drawn are that: current productivity evaluation techniques concentrate primarily on qualitative rather than quantitative metrics. Most of the claims of gains as a result of using microcomputers are based on empirical information; and there is sometimes a decrease in productivity after introducing a new technology due to the associated learning curve. If, however, microcomputers are introduced in a controlled manner and their use is planned and coordinated, there should be significant improvement in the organization.



12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

Added-value; automation; efficiency, measure; methodology; metrics; microcomputers; office environment; productivity; qualitative measurement; quantitative measurement.


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