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Quantitative measurement of automation: an assessment of APADE

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QUANTITATIVE MEASUREMENT OF AUTOMATION:
AN ASSESSMENT OF APADE

by

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and
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March, 1991

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Quantitative Measurement of Automation:
An Assessment of APADE

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ABSTRACT

This study examined the productivity of the Automation of Procurement and Accounting Data Entry (APADE) system, in a before/after quasi-experimental design that measured outputs (workload, productivity), inputs (staff size, staff grade structure, usuage of overtime), and by-product social effects (annual leave, sick leave, and leave without pay) using archival data. While workload decreased , the procurement action lead time (PALT) decreased by 55% after APADE implementation. This result was obtained as the size of the staff decreased and overtime usuage declined sharply. The implementation of APADE streamlined the document process significantly at the test site.

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I. INTRODUCTION

Computer industry literature claims that no longer is automation synonymous with automatic productivity improvement. Organizations are now struggling with developing methods to measure productivity improvement in the white collar sector. The Federal Government has invested millions of dollars in the development of automated procurement systems. However, little has been done with regards to the measurement of change in productivity resulting from the implementation of these systems.

Our intent in this study is to further develop a methodology which can be used to measure productivity for automated procurement systems. An installed Automation of Procurement and Accounting Data Entry (APADE) system is examined to assess the impacts of office automation on productivity. This system has been in operation for over two years at a Navy supply center, which we call NSC Duarte.

APADE was designed to provide the Navy field contracting system with a standard automated procurement mechanism. It has been synonymous with automated procurement in the Department of the Navy since the 1970's. Prior to the current installation of APADE, NSC Duarte was using a system called APADE II. APADE II was essentially a manager's information system which provided management statistics to

supervisors upon request. For the purpose of this study, and for the duration of this thesis, the term "pre APADE" will be used when referring to APADE II.

The current system implementation is called APADE and it includes many of the functions contained in pre APADE. APADE was designed as a decision support system for Navy buyers. Functions such as providing a price history and source file allow the buyer access to on-line information that had previously only been available on a manual basis. The system also provides an automatic document preparation capability, removing the need to manually generate each document. In addition, APADE provides automated document control and tracking status of procurement actions. APADE provides real-time contracting information to management while allowing selective access to appropriate customers. Although APADE can now process large contracts, this thesis will concentrate on contracts under $25,000, procured by the Small Purchasing Branch (SPB) at Duarte on the APADE system. A description of the procurement processes under both APADE and pre APADE is provided in Appendix A.

Our goal is to measure specific organizational factors to determine what effect APADE had on the effectiveness of Duarte's Small Purchasing Branch. In doing this, we used the ratio of outputs divided by inputs to calculate productivity. Productivity is enhanced as the proportion of outputs to inputs increases.

In this study, the inputs used include staff size, grade structure, and overtime hours worked. (See Appendix B) The outputs are the number of purchase orders processed and Procurement Action Lead Time (PALT) measured in days. This study also examines social factors which affect productivity: annual leave taken, sick leave used, and leave without pay taken. (See Appendix C) Lastly, we evaluate productivity as a measure of purchase orders processed per procurement labor hour. (See Appendix D)[1]

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[1]Appendixes B, C, and D contain summary data per pay period. For the comprehensive sample of raw data used by this study contact Professor William J. Haga at the Naval Postgraduate School, Monterey, California.

II. LITERATURE REVIEW

Throughout the 1980's industry has attempted to automate the white collar environment. It had been assumed that productivity improvement would come with automation. However, this may not have been the case and many corporations are now questioning office automation projects more thoroughly than before.

A. WHAT IS NOT HERE

This study does not attempt to consider the measurement of productivity of knowledge workers (professional, technical, administrative, and managerial). The focus of our study concerns the measurement of productivity of clerical workers.

B. BASIC INPUT/OUTPUT MEASUREMENT

There are numerous definitions that have been applied to productivity. Some are vague, "Productivity is a particular type of behavior within an organization. It may be high, a positive and desirable behavior; or low, a negative and undesirable behavior." (Edosomwan, 1987, p. 5) Others are relatively specific "total productivity is a ratio of all measurable outputs to the sum of all measurable inputs." (Edosomwan, 1987, p. 5) However, the basic form that most

definitions follow is that productivity is the ratio of some output to some input.

Bain (1982) indicates that it is not just a simple ratio nor is it a measure of production or output produced. "It is a measure of how well resources are combined and utilized to accomplish specific, desirable results." (Bain, 1982, p.3)

C. IMMEASURABLE PRODUCTIVITY

Measuring productivity in a white collar environment has long been considered difficult at best. Rowe states that "the great nemesis of measuring white collar output has been the inability to quantify the end results of the white collar employee." (Rowe, 1981, p. 43) Even the U. S. Department of Labor states that white collar productivity is so difficult to measure that they only put out that statistic by industries (Leeke, 1988).

Much of the productivity to be gained from white collar workers is of an intangible/immeasurable variety. Leeke (1988) states it is frequently a subjective measurement, often not based on quantifiable characteristics. One can easily see the difficulty in measuring such unquantifiable factors as improved customer service, improved employee morale, and timely information needed for decision making (Barclift and Linson, 1988). Schwartz (1987) states the if there is no reduction in headcount there are no easy means

available for measuring white collar productivity. In fact, the "payoffs become more difficult to assess as information technologies - office systems, personal computers, expert systems, and application enhancement projects - are increasingly directed at improving the performance of white collar workers." (Schwartz, 1987, p. 47)

D. SUBSTITUTING ATTITUDE SURVEYS FOR INPUT/OUTPUT

Another form of measurement that has been used to measure productivity as well as system performance, usage, and effectiveness is the user attitude survey. Miller and Doyle (1987) indicate that there have been a number of instances where the measurement of user satisfaction has been used as a surrogate for overall effectiveness of information systems within organizations.It has been generally accepted within the academic MIS community that user satisfaction can be correlated to information usage and system success (Bailey and Pearson, 1983).

E. VARIETIES OF INPUT/OUTPUT ANALYSIS

There are a number of ways in which productivity improvements may be achieved. Bain (1982) provides a summary:

1. Output increases while input decreases.
2. Output remains the same while input decreases.
3. Output increases while input remains the same.

To this list, Sink (1985) adds two other ways in which productivity improvement may be obtained:

1. Output increases while input increases at a slower rate.
2. Output decreases while input decreases at a greater rate.

In measuring productivity, Bain (1982) states that one must consider the interplay between various factors within an organization. "While the output may be related to many different inputs in the form of productivity ratios, each of the separate productivity ratios is influenced by a combination of many relevant factors." (Bain, 1982, p. 3) The influencing factors to be considered range from the quality and availability of materials to the attitude and skill level of the work force.

In his description of productivity measures, Sink defines two basic categories of productivity measures. The first, static productivity ratios, involve output divided by input for a given period of time. The second category, dynamic productivity ratios, are essentially particular static productivity ratios at one point in time divided by the same ratio at some prior period. This provides us with an index which reflects the change in productivity between different periods in time. Within each category there are three different types of productivity measures. The only

differentiating characteristic between them is the degree of input that is used in the denominator of the equation. Partial-factor measures include only one class of input, such as labor, capital, or energy. Multi-factor measures include more than one class, while total-factor measures include all classes of input. (Sink, 1985)

F. API: ADMINISTRATIVE PRODUCTIVITY INDEX

Bolte (1983) and his colleagues at Intel wished to develop a quantitative system which would focus on improving administrative productivity as well as on reducing head count. In searching the literature they found that there was very little practical information available on quantitatively controlling headcount growth and measuring and improving administrative productivity. As a result, they set out to develop a quantitative system for measuring productivity in administrative functions.

To begin with, Bolte used the definition of productivity currently in use at Intel: output divided by input. Specifically, the physical units of output are divided by the total number of hours it takes to produce them. It was decided not to use financial measures of input or output, such as sales or revenues, because their "definition is understandable and controllable at the line management level, which is where productivity improvements must take place." (Bolte, 1983, p. 47)

Next, a set of indicators was developed which were affected by their measurement systems. The first was to establish a set of quantity and quality indicators. Each department would establish a goal for the quality and quantity of its work. Second the quality and quantity indicators of one function or site would be compared with those of another. Lastly, the ratio between supervisors and employees is employed as a measure of the ratio between direct labor to indirect labor (supervisors).

In an effort to develop a quantitative system for measuring productivity, Bolte conceptualized administrative areas as paper processing factories "with specific inputs and required outputs, much like an assembly line, so that production techniques can be applied." (Bolte, 1983, p. 48) With this in mind he developed an Administrative Productivity Index (API) which would provide a means of comparing productivity against an established base line at different points in time. API is calculated by dividing output by labor hours, the result is expressed in hours per unit (HPU). The output measures must be both physical and countable, while input is all of the hours of work paid for by the organization, less vacation, absenteeism, and sick leave, during the period which the output was generated.

Once baseline API values have been established productivity may be measured over time by comparing the API figures collected over a period. Productivity enhancements

are then obtained through simplifying tasks, applying workload management techniques, and monitoring the API. The labor requirement of a unit to accomplish its mission is reduced, which reduces headcount and thus improves productivity.

G. CONSENSUS MODEL: INFERRED OUTPUT

A consensus model seeks to obtain agreement among managers on the projected inferred benefits to be obtained through the implementation of a specific computer system. Schwartz (1987) states that the inferred output technique is an alternative that may be used to measure productivity when a direct output model cannot be developed. Managers first determine estimates of the value of various tasks. This information coupled with their reasoning is then pooled. A consensus is then formed after repeated estimates and sharing of information. The underlying assumption of this model is that an increase in output will generate an increase in profit. This increased profit can then be used to infer an increase in productivity. General Telephone and Electronics (GTE) has used a consensus model in its operations. The "consensus models are most appropriate for judging potential payoff when there is little quantitative basis for making estimates of value." (Schwartz, 1987, p. 48)

H. INFERRED INPUT MODEL

Inferred input models "use projected increases in efficiency and effectiveness among workers rather than actual, verified cuts in labor or head count." (Schwartz, 1987, p. 48) Generally, the projections generated are based on a task/time matrix that indicates the time that people spend on tasks and the time savings offered by the implementation of the computer system. The Times-Savings/Times Salary (TSTS) model being used by IBM is based on research done by Booze, Allen, and Hamilton, Inc. People first determine the amount of time they expend on activities such as reading and typing. Any savings that are gained through the implementation of a specific computer technology are then multiplied by each employee's salary.

The TSTS model is simple and easy to use, making it a popular model. However, there are drawbacks. Poppel (1982) contends that the TSTS model counts time saved on lower value activities, such as the work of a clerk, equivalently with higher value activities. In other words, TSTS cannot distinguish between making a white-collar worker a better manager or analyst and making that worker a better clerk or receptionist. (Schwartz, 1987)

I. WORK VALUE ANALYSIS

Schwartz (1987) and his colleagues have developed a hybrid model which they named the Work Value Analysis (WVA)

model. This model not only evaluates the efficiency of white collar workers but also provides input on their effectiveness. Efficiency is the increased work accomplished in a period of time, while effectiveness refers to doing the right things. This incorporates the thought that the members of an organization do not spend all of their time at work performing primary activities. A large portion of their time includes performing supporting activities, such as clerical duties.

The WVA model uses two forms of productivity improvement:

1. Technology can shorten the amount of time required to complete a given task or it can allow more of the task to be completed in the same amount of time.
2. Technology can be the basis for a shift in a work pattern that allows more time to be spent on primary activities and less on lower valued activities such as support, clerical, lost time. (Schwartz, 1987, p.52)

The first form identifies improvements in efficiency, while the second form accounts for improvements in the effectiveness of an organization. By identifying its primary or high value activities, an organization can target those activities for improvement with the greatest return/payoff.

Schwartz contends that its strength is in its "objective determination of payoff when external dollar criteria relating to profit of value of work, other than salary,

cannot be measured or otherwise inferred." (Schwartz, 1987, p. 52). However, WVA requires a significant investment in time and effort to implement and the mathematical computations can become complex.

J. COST DISPLACEMENT MODEL

Schwartz (1987) notes that direct input models, such as the cost displacement model, are useful when inputs can be determined and outputs cannot be measured. In order to account for output, the cost displacement model assumes that output either remains the same or increases. Therefore, if output remains the same and inputs decrease, such as number of workers, there is an improvement in productivity.

The largest plus for cost displacement models is that they are simple to use. The only requirement is that real labor cuts or equipment savings be achieved due to the introduction of new information systems. However, without a cut in labor or equipment savings cost, displacement models are inappropriate.

K. NPMM: NORMATIVE PRODUCTIVITY MEASUREMENT METHODOLOGY

The normative productivity measurement methodology (NPMM) seeks to obtain various output/input ratios through a consensus building method called the nominal group technique (NGM). Sink describes NPMM as an "action-research, involvement-participative, organizational, development-

oriented approach to measuring productivity." (Sink, 1985, p. 139)

The process is encapsulated in five stages. The first stage uses the normative group technique to generate a prioritized list of the measures, ratios, or indices of productivity for each of the corresponding organizational units. The second stage involves converting those measures into a workable productivity measurement system. This task is usually referred to productivity analysts for development. The third stage includes briefings, reviews, discussions, and revisions until a workable system is drafted. The fourth stage integrates this new system with other performance measurement and control systems already implemented within the organization. Stage five involves the continuous monitoring and feedback of information based on the previously determined ratios. (Sink, 1985)

NPMM allows the participants to formulate the measures to be used in the measurement system. The inclusion of organizational members provides the advantage of establishing commitment among them which is important is any project is to succeed.

L. MFPMM: MULTIFACTOR PRODUCTIVITY MEASUREMENT MODEL

Multifactor productivity measurement (MFPMM) is a consultative, data base/accounting system oriented methodology which collects its data from system

documentation rather than people. It is diagnostic in a passive, absolute, and objective sense as opposed to an active, relative, and subjective sense (Sink, 1985). In using the various accounting data available within an organization a series of base indices is generated which may be compared with the values in the succeeding periods determine relative productivity improvements/declines.

The multifactor productivity measurement model can be used to provide information on a variety organizational areas. These include:

1. Obtain an overall, integrated measure of productivity for the firm.
2. Assess and evaluate bottom-line results of specific productivity improvement efforts.
3. Monitor the historical productivity performance and measure how much, in dollars, profits were affected by productivity growth or decline.
4. Assist with setting productivity objectives and general strategic planning in areas such marketing and cost management. (Sink, 1985)

MFPMM and other measurement systems similar to it are currently being used in industry. For instance, Westinghouse has used a similar methodology when measuring white collar productivity. Each department would establish its own measurement criteria or performance ratios. This information would then be used to calculate a composite index, which is calculated by assigning weights to the measures and then combining the values into a composite

value (Rowe, 1981). These base indexed measures can then be used to compare the relative change in productivity in succeeding periods.

M. PRODUCTIVITY MAP

The productivity map by Pacesetter Software has been developed to assist managers in establishing and measuring productivity goals of white collar workers. It consists of a multi-step process which establishes and tracks four primary measures of productivity: quantity, quality, timeliness, and cost. (Miller, 1987)

Step one involves answering questions on the characteristics and goals of the next level up in the organization. "Productivity map then prepares an overview report that summarizes your department's mission, strategic direction, and critical success factors based on these answers." (Miller, 1987, p. 43) Questions are then answered regarding your department's role within the organization as well as your perceptions of what the customers' needs are. These are then compared with the customers' needs and relative priorities. The final step involves the development of productivity measures which are then used with the assistance of the program's database, graphics,and report generation abilities to track the productivity of the unit.

N. TOTP (TASK-ORIENTED TOTAL PRODUCTIVITY MEASUREMENT)

A total productivity measure uses the total output with respect to the total input. The Task-Oriented Total Productivity Measurement Model (TOTP) considers all possible measurable input and output components. The measures used in this model are developed into a matrix which can be used to measure changes in productivity.

There are several steps involved in the process. A formal study of the work environment, processes, and procedures is first conducted. The results are then shared with those individuals that will be affected by the implementation. The next step involves the selection of the measurement criteria to be used. Overhead expenses are then allocated among the units on either a "proportional basis" or through a "complexity factor." A base period is selected which acts as a reference period to compare the measurement criteria. Next, various forms and instruments are developed to capture the input and output elements to be measured. Personnel are then trained in the measuring processes and data collection begins. Trend analysis and interpretation of the findings can then begin. (Edosomwan, 1987)

There are several advantages to be obtained by using the TOTP model:

1. The indices can be used in the productivity planning and improvement phases.

2. The productivity indices derived offer flexibility in that they may change as the task parameters, resources used, etc. change.

3. The indices are comparable over time and can be used to measure the productivity of various organizational elements, such as task, work groups, and departments. (Edosomwan, 1987)

However, Bain (1982) indicates that while total factor productivity makes conceptual sense, "it is extremely difficult to identify and capture all related inputs for any component output of the organization." (Bain, 1982, p. 56)

O. OBJECTIVES MATRIX

Many organizations have found that productivity measurement can be quite difficult and complex. In fact, far too few organizations actively pursue effective productivity measurement. The Oregon Productivity Center (OPC) has developed what it believes is an easy-to-implement methodology based on its Objectives Matrix. The Objectives Matrix combines all of an operation's important productivity criteria into one interrelated format, thus overcoming the problem of complexity.

The first step to identify the key performance indicators. Once this is done each indicator is to be thoroughly defined and sources of this information identified. Performance is then assessed over time and the information obtained is used in determining productivity objectives. Next, each indicator is assigned an importance

weighting, usually 100 total points distributed across the indicators (Felix and Riggs, 1983). Improvement/decline in productivity over time is then measured against the initial index.

Felix and Riggs (1983) indicate that there are several advantages obtained by using the Objectives Matrix:

1. Measures are normalized by establishing a uniform quantitative rating system.
2. Many dimensions of performance may be followed at the same time providing a global perspective of the organization.
3. The Objectives Matrix focuses on results rather than on activities.

P. SUMMARY

A review of the available literature revealed the following:

1. There is little documentation available regarding productivity measurement using measurements prior to an automation implementation and after.
2. There is little documentation regarding the measurement of productivity improvement due to the automation of office work.
3. The use of job satisfaction surveys as an indicator of productivity rather than input/output.
4. Although there is still a belief among many that computerization of office work leads to productivity enhancement, there are numerous examples which indicate that this view is changing towards one requiring actual justification.

Q. OBJECTIVE

The preceeding methodologies are based on a common mechanism for the measurement of productivity, which they define as a ratio of outputs to inputs in one form or another. This study will also use this ratio model in the calculation of productivity.

This thesis will:

1. Develop a methodology for productivity measurement that is based on a before/after quasi-experimental design.
2. Conduct an office automation study to test the methodology.
3. Base the study on quantifiable measures of input and output.

III. METHODOLOGY

A. CONDUCT OF THE STUDY

1. Prelude to the Sample

The investigators sampled data from a military procurement organization: the Purchasing Department at the Naval Supply Center (NSC) Duarte, South Dakota. The selection of this site is due to its having an operational APADE installation and the availability of pre-APADE records. This study has provided an opportunity to measure productivity changes since the implementation of APADE at NSC Duarte.

After initial discussions with the staff, it was determined that the primary data needed to conduct this study would be available. We decided on a 'before and after' data collection design to compare productivity statistics prior to and after the implementation of APADE. Data sampled prior to the implementation of APADE were actual purchase orders and reports from the on-site archives. Data for after implementation was acquired from on-site reports as well as documentation generated by APADE.

2. A Description of APADE

The APADE configuration studied is a small purchase, computer-based system designed to provide a Navy field

contracting office with a standard automated procurement mechanism. It's capabilities include:

1. Automated documentation preparation.
2. Automated document control and tracking status.
3. Procurement management information.
4. Buyer support information.

This system provides real-time contracting information to management while allowing selective access by customers. Additional information on APADE is presented in Appendix B.

3. Experimental Design Development

Our study employed a quasi-experimental methodology (Campbell and Stanley, 1968). Samples were taken for a twelve month period before and a twelve month period after APADE implementation. It was determined that three types of data would be used to evaluate productivity:

1. Inputs.
2. Outputs.
3. Social Effects.

a. *Inputs*

These include the measurement of quantifiable elements, such as grade structure, size of staff, and overtime worked.

b. Outputs

Various factors that are the product of work done include Procurement Action Lead Time (PALT), number of purchase orders processed per unit time, and the number of labor hours per purchase order. PALT is the time it takes to process a purchase order. The PALT counter begins upon the receipt of a purchase action request by the Small Purchase Branch and stops when a purchase order has been awarded. The number of purchase orders processed during a year is used to indicate the volume of work, while the number of labor hours needed to perform a single procurement is a measure of productivity.

c. Social Effects

Social effects act as surrogate indicators to the work environment. This study used annual leave, sick leave, and leave without pay.

The amount of annual leave used is determined by management's capability to allow personnel to expend leave. If workload is at a level to where authorizing leave is not detrimental to the organization, leave may be granted. Conversely, if there are significant backlogs in the workload, management may not have the flexibility to allow personnel to take leave on a discretionary basis.

Sick leave policy provides a way for personnel who are unhappy or stressed to avoid the demands of the work

place. Sick leave is earned with the decision to use it made exclusively by the employee. Since no documentation is required from a physician to confirm an employee's status, it is an available escape mechanism for an employee who is dissatisfied with the work environment or workload.

Leave Without Pay (LWOP) is similar to annual leave. The exception is that employees who use LWOP do not receive any monetary compensation while in a LWOP status. An employee would use LWOP as a last resort when they do not have annual leave or sick leave time "on the books."

4. Analysis Strategy

The statistical test selected to evaluate the data is the difference of means in a "Student's t-distribution" test. A series of null hypotheses are tested for rejection/inability to reject, using the t-test for statistical significance.

5. Collection of Data

Pre-APADE data were collected from records maintained in storage for the fiscal year 1987. The data, obtained by manually sampling the physical records, were used to establish the baseline for the activity's PALT. PALT data for the period after APADE installation were obtained by sampling listings generated by the system.

B. THE COLLECTION DESIGN

The Regional Contracting Department is made up of two divisions, which in turn are made up of various branches. This study concerns itself with the data obtained for the Small Purchase Branch, which is currently staffed with 58 people, primarily female civilian employees.

The collection of data from the Contracting Department archives involved sampling purchase orders before and after APADE installation. The following describes how records used for estimating PALT were sampled.

1. Before APADE Installation

The population consisted of 85479 records for fiscal year 1987 purchase orders. This population figure was obtained from the Monthly Procurement Summary of Actions Report (DD Form 1057). These transactions were made up of either a single requisition or multiple requisitions for similar material grouped together from a single customer.

In sampling the purchase orders, we randomly selected records from departmental archives. A total of 532 purchase orders were sampled from the period prior to APADE being implemented.

2. After APADE Installation

The process for sampling post implementation purchase orders is the same except that the samples were taken from listings generated by APADE. Our population

consisted of 59905 records for fiscal year 1989 purchase orders obtained from the DD Form 1057. A total of 637 purchase orders were sampled from the period after APADE had been implemented.

3. **Additional Measures**

Our study also required that we retrieve archival data from other sources as well. Data on the use of annual leave, sick leave, leave without pay, and overtime hours worked was obtained from NSC Duarte Comptroller Department's records and reports. Information regarding the number of personnel employed and grade structure within the Purchasing Division was also obtained from the command's Comptroller Department.

A framework was used to represent the interaction of inputs and outputs, prior to and after the implementation of APADE at NSC Duarte. (See Table I) It provides a means to test the null hypothesis for the measures listed. In testing a null hypothesis, we are attempting to determine if the data sampled before and after this phase of APADE implementation were statistically the same. The alternative hypothesis is that the before and after data are different.

C. INSTRUMENTATION

One method to measure a change in productivity is by analyzing the ratio of inputs to outputs. In a system, a certain amount of input is required to produce some output.

TABLE I. PRODUCTIVITY MATRIX

MEASURES	PRE APADE	APADE
INPUTS	Staff Size Grade Structure Overtime	Staff Size Grade Structure Overtime
OUTPUTS	No. Purchase Orders PALT	No. Purchase Orders PALT
SOCIAL EFFECTS	Annual Leave Sick Leave Leave Without Pay	Annual Leave Sick Leave Leave Without Pay
PRODUCTIVITY MEASUREMENT	Purchase Orders per Labor Hour	Purchase Orders per Labor Hour

If the system is changed so as to require fewer inputs or to produce more output with the same inputs, then productivity is enhanced.

1. **Inputs**

There are several inputs to the requisitioning process that were used in this evaluation:

1. Before and after mean annual number of employees.
2. Before and after mean GS level.
3. Before and after mean overtime worked.

The measurement of the mean annual number of employees provided a figure of the average number of personnel required by the Small Purchase Branch to perform its function. The mean GS level of the staff provided an indicator of the level of expertise to perform the functions of the unit. The mean overtime worked represented the extra time spent, beyond regular working hours, to complete the work assigned.

2. Outputs

The output of the procurement process contained two aspects which were measured. The first considered the difference between the number of requisitions processed prior to and after implementation. The second measured the PALT both before and after implementation.

PALT has been selected as our Productivity Measure of Effectiveness, because it provides a measure of productivity. PALT represents the time it takes to process a purchase order once a requisition has been received by the purchasing division. A typical scenario would begin with the submission of a requisition. After proceeding through the Customer Service and Technical Branches, the requisition is determined to be a purchase item rather than something that is available through the supply system. The PALT timer begins when a requisition is received by the Purchase Division. Once the processing has been completed and the

requisition has been awarded to a vendor, the PALT timer stops. The difference between the award date and the date of receipt of the requisition, plus one day, is the PALT for a purchase.[2]

The quantity parameter considered the volume of work performed by the Small Purchase Branch over a unit of time. In measuring quantity we used the average number of purchase orders processed each month.

3. **Social Effects**

In previous studies which performed similar analyses (Barclift and Linson, 1988) it was noted that various social factors affected unit performance. Reduced workload, increased teamwork, and improvements in training were indicators that were mentioned. The social effects that were measured include:

1. Before and after mean annual leave taken.
2. Before and after mean sick leave taken.
3. Before and after mean leave without pay used.

Although these social factors are not directly measures of input or output, they are objective indicators of satisfaction obtained from the working environment.

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[2]One day is added so that PALT would reflect the inclusive dates of receipt of the requisition and the award date of the contract.

4. Productivity Measurement

The productivity measurement used in this study is simply the number of transactions processed/completed per labor hour. Labor hours were calculated as the total number of hours worked by both purchasing personnel (buyers) and administrative support personnel. This factor provided us with a direct measurement of the productivity of the purchasing and administrative support personnel.

D. ANALYSIS STRATEGY

1. Measurements

A difference of means test was used to compare the various input, output, social factors, and productivity ratio prior to and after the implementation of APADE. Null hypotheses stated that there was no change in the various measurements as a result of APADE's implementation.

A total of 1169 purchase orders were sampled. Of these, 532 records represented the PALT prior to implementation, while 637 records were collected for the post implementation period.

The command's Comptroller Department provided access to staff size, grade and step level, annual leave taken, sick leave used, and leave taken without pay data from on-hand NAVCOMPT FORM 206 records for both periods. Staff size was verified via the small purchase department's point of

contact. Overtime data were also obtained from the command's comptroller departmental records.

2. **Choosing the Appropriate Statistical Test**

When testing hypotheses using two populations, with the samples being either dependent or independent of one another, and having an unknown population standard deviation (σ), the appropriate method would be a student's t-distribution (Porter and Hamm, 1986). We used the t-test to assess differences between the means of various indicators, both before and after APADE implementation, for samples taken independently from the two populations.

The reason for taking independent samples from each population is that the pool of employees within the division was not identical before and after implementation. There was the usual turnover of personnel that organizations endure and a restructuring of the unit because of APADE.

The null hypothesis (H_o) stated that the two populations are statistically the same, while the alternative hypothesis (H_a) stated that the before measure is greater or less than the after measure to a statistically significant degree.

Using MINITAB Fundamental/RW Software for Students (Anderson/Eynon), a one tailed t-distribution test (TTEST) was selected because we were predicting direction. The corresponding significance levels are shown in Table II. We

have chosen the .01 significance level as the appropriate level at which to test all measures collected.

TABLE II. T-DISTRIBUTION SIGNIFICANCE LEVELS

Significance Level	t-value
.05	1.645
.01	2.326

IV. FINDINGS

A. INPUTS

Measures of inputs to the Small Purchase Branch of the Regional Contracting Department located at NSC Duarte, were collected and summarized in the ensuing categories:

1. Size of the staff.
2. Grade structure (GS level).
3. Overtime worked.

These factors were collected for time periods before and after the implementation of APADE.

1. Before APADE

a. Staff Size

The size of the staff was calculated as the mean size of the staff on hand for each pay period at the Small Purchasing Branch (SPB). The mean size of the staff before the implementation of APADE was 73.4 personnel with a standard deviation of 3.5. This represents the period from January 1, 1987 through December 31, 1987. Data were collected from NAVCOMPT FORM 206's maintained by the command's comptroller department.

b. Grade Structure

The grade level of the staff was computed as the average GS level for all personnel at the Small Purchasing

Branch (SPB) per pay period. The mean grade level (GS) of the staff per pay period was GS 5.66, with a standard deviation of 0.098. This represents the period from January 1, 1987 through December 31, 1987. Data were obtained from worker's Service Card (NAVCOMPT FORM 206) maintained by the command's comptroller department.

c. Overtime

Overtime worked by SPB personnel was calculated as the mean number of overtime hours worked by the entire staff for each two-week pay period for the year prior to the implementation of APADE. The average overtime worked per two-week pay period was 519.5 hours, with a standard deviation of 306.0. The mean overtime worked per worker per two-week pay period was 6.7 hours, with a standard deviation of 7.1. The mean overtime worked per buyer in the SPB was 177.3 hours annually, with a standard deviation of 145.6. The mean overtime worked per administrative support worker was 128.9 hours, with a standard deviation of 121.6. The annual mean overtime worked by all SPB personnel was 162.7 hours per worker, with a standard deviation of 139.9.

2. After APADE Implementation

a. Staff Size

The mean size of the staff after the implementation of APADE was 62.4 personnel, with a standard deviation of 1.24. This represents the period from January

1, 1989 through December 31, 1989. Data were collected from NAVCOMPT FORM 206's maintained by the command's comptroller department.

b. Grade Structure

The mean grade level (GS) of the staff per pay period was GS 6.06, with a standard deviation of 0.006. This represents the period from January 1, 1989 through December 31, 1989. Data were obtained from worker's Service Card (NAVCOMPT FORM 206) maintained by the command's comptroller department.

c. Overtime

The average overtime worked per two-week pay period was 124.4 hours, with a standard deviation of 168.9. The mean overtime worked per worker per two-week pay period was 2.0 hours, with a standard deviation of 2.7. The average amount of overtime worked per buyer in the SPB was 58.1 hours annually, with a standard deviation of 71.7. The average amount of overtime worked annually per administrative support worker was 25.2 hours, with a standard deviation of 33.5. The average amount of overtime worked annually by all SPB personnel was 51.3 hours per worker with a standard deviation of 66.8.

3. Testing the Null Hypotheses for Inputs

a. Staff Size

The null hypothesis (H_o) concerning the size of the staff at the Small Purchasing Branch (SPB) stated that the size of the staff per two-week pay period after the implementation of APADE (X) was statistically equal to that prior to implementation (X_o), (H_o: $X=X_o$). The alternative hypothesis (H_a) stated that the size of the staff per two-week pay period after the implementation (X) is less than the size prior to the implementation (X_o), (H_a: $X<X_o$).

Upon analysis, the t-distribution test score for this measure was -44.97 at the 0.0000 significance level (left-tailed test). Since this is less than the t-distribution baseline for this study (t-value -2.326 at the 0.01 significance level), the null hypothesis (H_o) was rejected. Therefore, the alternative hypothesis (H_a) was accepted; mean staff size at the SPB per two-week pay period after the implementation of APADE (X) was statistically less than the mean staff size prior to implementation (X_o).

Table III represents the number of buyers and administrative support personnel immediately before the implementation of APADE and at the end of first full year of APADE operation.

TABLE III. EMPLOYEES

	PRE APADE	APADE
BUYERS	58	50
ADMINISTRATIVE SUPPORT	25	13

b. Grade Structure

The null hypothesis (H_o) of the grade structure of the staff at the SPB stated that the grade level of the staff per two-week pay period after the implementation (X) of APADE was statistically equal to that prior to implementation (X_o): (Ho: $X=X_o$). The alternative hypothesis (H_a) stated that the grade level of the staff per two-week pay period after the implementation (X) is greater than the level prior to the implementation (X_o), (H_a: $X>X_o$).

Upon analysis, the t-distribution test score for this measure was 370.15 at the 0.0000 significance level (right-tailed test). Since this is greater than the t-distribution baseline for this study (t-value 2.326 at the 0.01 significance level), the null hypothesis (H_o) was rejected. Therefore, the alternative hypothesis (H_a) was accepted; mean grade level at the SPB per two-week pay

period after the implementation of APADE (X) was statistically greater than the mean staff level prior to implementation (X_o).

c. Overtime

The first null hypothesis (H_o) concerning overtime stated that the overtime worked by all personnel per two-week pay period after the implementation of APADE (X) is statistically equal to that worked prior to implementation (X_o), (H_o: $X=X_o$). The alternative hypothesis (H_a) stated that the overtime worked by all personnel per two-week pay period after the implementation (X) is less than that worked prior to the implementation (X_o), (H_a: $X<X_o$).

Analysis finds that the t-distribution test score for this measure is -11.93 at the 0.0000 significance level (left-tailed test). Since this is less than the t-distribution baseline for this study (t-value -2.326 at the 0.01 significance level), the null hypothesis (H_o) was rejected. Therefore, the alternative hypothesis (H_a) was accepted; mean overtime worked by all personnel per two-week pay period after the implementation of APADE (X) was statistically less than the mean overtime worked prior to implementation (X_o).

The second null hypothesis (H_o) for overtime worked stated that the overtime worked per worker per two-

week pay period after the implementation of APADE (X) is statistically equal to that worked prior to implementation (X_o), (H_o: $X=X_o$). The alternative hypothesis (H_a) stated that the overtime worked per worker per two-week pay period after the implementation (X) is less than that worked prior to the implementation (X_o), (H_a: $X<X_o$).

Upon analysis, the t-distribution test score for this measure was -14.06 at the 0.0000 significance level (left-tailed test). Since this is less than the t-distribution baseline for this study (t-value -2.326 at the 0.01 significance level), the null hypothesis (H_o) was rejected. Therefore, the alternative hypothesis (H_a) was accepted; mean overtime worked per worker per two-week pay period after the implementation of APADE (X) was statistically less than the mean overtime worked prior to implementation (X_o).

Tables IV and V represent a summary of the total amount of overtime worked before and after implementation.

TABLE IV. PRE APADE OVERTIME

TYPE PERSONNEL	OVERTIME	NO. OF PERIODS	MEAN OVERTIME
BUYERS	10285.0	26	177.3
ADMIN	3221.3	26	128.9
TOTAL	13506.3	26	162.7

TABLE V. APADE OVERTIME

TYPE PERSONNEL	OVERTIME	NO. OF PERIODS	MEAN OVERTIME
BUYERS	2906.2	26	58.1
ADMIN	327.8	26	25.2
TOTAL	3234.0	26	51.3

B. OUTPUTS

Measures of outputs from the Small Purchase Branch of the Regional Contracting Department at NSC Duarte were collected and summarized in the ensuing categories:

1. Number of purchase orders.
2. Procurement Action Lead Time (PALT).

These factors were collected for time periods before and after the implementation of APADE.

1. **Before APADE**

a. Number of Purchase Orders

The number of purchase requests processed is calculated as the number of purchase orders completed for each pay period for the year prior to the implementation of APADE. The average number of purchase requests processed per pay period by the SPB before the implementation of APADE was 3287.7, with a standard deviation of 655.1. This represents both single and multiple item procurements for fiscal year 1987. Data were collected from the Procurement Summary of Actions Report (DD FORM 1057) that was manually generated on site.

b. Procurement Action Lead Time (PALT)

PALT is computed as the average number of days required to complete a purchase request, from the date received by the SPB to the date the contract for the purchase request is awarded to a contractor, plus one day.[3] PALT prior to the implementation of APADE was 52.4 days, with a standard deviation of 33.8. Data were collected from a sampling of the actual purchase order records that were retained on site. See Table VI for a summary of the samples taken prior to the implementation of APADE.

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[3]The one day is added so that PALT will represent the number of days between the receipt date and award date, inclusive.

2. **After APADE Implementation**

a. Number of Purchase Orders

The average number of purchase requests processed per pay period by the SPB after the implementation of APADE was 2304.0, with a standard deviation of 454.4. This represents both single and multiple item procurements for fiscal year 1989 (after the implementation of APADE). Data were collected from the Procurement Summary of Actions Report (DD FORM 1057) that was manually generated on site.

b. Procurement Action Lead Time (PALT)

PALT after the implementation of APADE was 23.5 days, with a standard deviation of 24.7. Data were collected from a sampling of the actual purchase order records that were retained on site. See Table VI for a summary of the samples taken after the implementation of APADE.

TABLE VI. SAMPLE BREAKDOWN BY ISSUE GROUP

PERIOD	ISSUE GROUP 1	ISSUE GROUP 2	ISSUE GROUP 3
PRE APADE (FY 1987)	69 12.97%	260 48.87%	203 38.16%
APADE (FY 1989)	118 18.52%	333 52.28%	186 29.20%

3. Testing the Null Hypotheses for Outputs

a. Number of Purchase Orders

The null hypothesis (H_o) concerning the number of purchase orders stated that the mean number of purchase orders processed per pay period after the implementation of APADE (X) is statistically equal to the number processed per pay period prior to implementation (X_o), (H_o: $X=X_o$). The alternative hypothesis (H_a) stated that the mean number of purchase orders processed per pay period (X) is less than the number processed per pay period prior to implementation (X_o), (H_a: $X<X_o$).

Upon analysis, the t-distribution test score for this measure was -11.04 at the 0.0000 significance level (left-tailed test). Since this is less than the t-distribution baseline for this study (t-value -2.326 at the 0.01 significance level), the null hypothesis was rejected. Therefore, the alternative hypothesis (H_a) was accepted; the mean number of purchase orders processed per pay period after the implementation of APADE (X) was statistically less than that prior to implementation (X_o).

b. Procurement Action Lead Time (PALT)

The null hypothesis (H_o) concerning the average PALT stated that the mean value obtained after the implementation of APADE (X) is statistically equal to the value obtained prior to implementation (X_o), (H_o: $X=X_o$). The

alternative hypothesis (H_a) stated that the mean PALT value (X) is less than the value obtained prior to implementation (X_o), (H_a: $X<X_o$).

Upon analysis, the t-distribution test score for this measure was -29.49 at the 0.0000 significance level (left-tailed test). Since this is less than the t-distribution baseline for this study (t-value -2.326 at the 0.01 significance level), the null hypothesis (H_o) was rejected. Therefore, the alternative hypothesis (H_a) was accepted; the mean PALT after the implementation of APADE (X) was statistically less than that prior to implementation (X_o). Tables VII and VIII represent the summary of Procurement Action Lead Time (PALT) for the before and after periods.

TABLE VII. PALT SUMMARY BY ISSUE GROUP

PERIOD	SAMPLE MEAN			STANDARD DEVIATION		
	IG 1	IG 2	IG 3	IG 1	IG 2	IG 3
PRE APADE (FY 1987)	48.07	55.72	50.21	35.85	35.97	30.62
APADE (FY 1989)	11.20	23.98	30.52	18.29	24.11	26.44

TABLE VIII. PALT SUMMARY BY PERIOD

PERIOD	SAMPLE MEAN	STANDARD DEVIATION
PRE APADE (FY-1987)	52.398	33.792
APADE (FY-1989)	23.52	24.713

C. SOCIAL EFFECTS

Measures of social effects at the Small Purchase Branch (SPB) of the Regional Contracting Department at NSC Duarte, were collected and summarized in the ensuing categories:

1. Amount of annual leave taken.
2. Amount of sick leave used.
3. Amount of leave without pay utilized.

These factors were collected for time periods before and after the implementation of APADE.

1. Before APADE

a. Annual Leave

The amount of annual leave used by SPB personnel was calculated as the mean number of hours used by all buyers and administrative support personnel for each two-week pay period for the year before the implementation of

APADE. The average amount of annual leave used per two-week pay period for the SPB staff was 442.2 hours, with a standard deviation of 202.5. The average amount of annual leave used per worker per two-week pay period was 5.4 hours, with a standard deviation of 2.2. The average amount of annual leave used per buyer in the SPB was 152.9 hours annually, with a standard deviation of 52.0. The average amount of annual leave used per administrative support worker was 105.1 hours annually, with a standard deviation of 50.9. The amount of annual leave used by all SPB personnel was 138.5 hours per worker annually, with a standard deviation of 55.9. See Table IX for a summary breakdown by personnel type for the period prior to implementation of APADE.

b. Sick Leave

The amount of sick leave used by SPB personnel was calculated as the mean number of hours used by all buyers and administrative support personnel for each two-week pay period for the year before the implementation of APADE. The average amount of sick leave used per two-week pay period for the SPB staff was 255.8 hours, with a standard deviation of 69.5. The average amount of sick leave used per worker per two-week pay period was 3.2 hours, with a standard deviation of 1.5. The average amount of sick leave used annually per buyer in the SPB was 82.2

hours, with a standard deviation of 36.4. The average amount used per administrative support worker 75.3 hours annually, with a standard deviation of 46.5. The average amount of sick leave used by all SPB personnel was 80.1 hours per worker annually, with a standard deviation of 39.6. See Table IX for a summary breakdown by personnel type for the period prior to implementation of APADE.

TABLE IX. PRE APADE SOCIAL EFFECTS

TYPE	ANNUAL LEAVE	SICK LEAVE	LEAVE WITHOUT PAY (LWOP)	MEAN ANNUAL LEAVE	MEAN SICK LEAVE	MEAN LWOP
BUYERS	8870	4768	3243	152.9	82.2	55.9
ADMIN	2628	1883	796	105.1	75.3	31.9
OVERALL	11498	6651	4039	138.5	80.1	48.7

c. Leave Without Pay

The amount of leave without pay used by SPB personnel was calculated as the mean number of hours used by all buyers and administrative support personnel for each two-week pay period for the year before the implementation

of APADE. The average amount of leave without pay used per two-week pay period for the SPB staff was 155.4 hours, with a standard deviation of 77.3. The average amount of leave without pay used per worker per two-week pay period was 1.9 hours, with a standard deviation of 5.6. The average amount of leave without pay used per buyer in the SPB was 55.9 hours annually, with a standard deviation of 171.0. The average amount of leave without pay used annually per administrative support worker was 31.9 hours, with a standard deviation of 51.0. The average amount of leave without pay used by all SPB personnel was 48.7 hours per worker annually, with a standard deviation of 145.6. See Table IX for a summary breakdown by personnel type for the period prior to implementation of APADE.

2. **After APADE Implementation**

a. Annual Leave

The average amount of annual leave used per two-week pay period for the SPB staff was 380.1 hours, with a standard deviation of 152.5. The average amount of annual leave used per worker per two-week pay period was 6.1 hours, with a standard deviation of 2.0. The average amount of annual leave used per buyer in the SPB was 158.4 hours annually, with a standard deviation of 63.8. The average amount of annual leave used per administrative support worker was 151.0 hours annually, with a standard deviation

of 27.9. The amount of annual leave used by all SPB personnel was 156.8 hours per worker annually, with a standard deviation of 48.8. See Table X for a summary breakdown by personnel type for the period after the implementation of APADE.

b. Sick Leave

The average amount of sick leave used per two-week pay period for the SPB staff was 262.0 hours, with a standard deviation of 78.3. The average amount of sick leave used per worker per two-week pay period was 4.2 hours, with a standard deviation of 2.4. The average amount of sick leave used annually per buyer in the SPB was 105.3 hours, with a standard deviation of 63.8. The average amount used per administrative support worker was 119.3 hours annually, with a standard deviation of 54.2. The average amount of sick leave used by all SPB personnel was 108.2 hours per worker annually, with a standard deviation of 61.8. See Table X for a summary breakdown by personnel type for the period after the implementation of APADE.

c. Leave Without Pay

The average amount of leave without pay used per two-week pay period for the SPB staff was 112.1 hours, with a standard deviation of 65.5. The average amount of leave without pay used per worker per two-week pay period was 1.8 hours, with a standard deviation of 4.8. The average amount

of leave without pay used per buyer in the SPB was 48.8 hours annually, with a standard deviation of 136.0. The average amount of leave without pay used annually per administrative support worker was 36.6 hours, with a standard deviation of 52.1. The average amount of leave without pay used annually by all SPB personnel was 46.3 hours per worker, with a standard deviation of 123.2. See Table X for a summary breakdown by personnel type for the period after the implementation of APADE.

TABLE X. APADE SOCIAL EFFECTS

TYPE PERSONNEL	ANNUAL LEAVE	SICK LEAVE	LEAVE WITHOUT PAY (LWOP)	MEAN ANNUAL LEAVE	MEAN SICK LEAVE	MEAN LWOP
BUYERS	7918	5262	2439	158.4	105.3	48.8
ADMIN	1963	1551	475	151.0	119.3	36.6
TOTAL	9881	6813	2914	156.8	108.2	46.3

3. Testing the Null Hypothesis for Social Effects

a. Annual Leave

The first null hypothesis (H_o) concerning annual leave stated that the amount of leave taken by all workers per two-week pay period after the implementation of APADE (X) is statistically equal to that prior to implementation (X_o): (H_o: $X=X_o$). The alternative hypothesis (H_a) stated that amount of leave taken by all workers per two-week pay period after the implementation (X) is less than that amount taken prior to the implementation (X_o), (H_a: $X<X_o$).

Upon analysis, the t-distribution test score for this measure was -2.08 at the 0.024 significance level (left-tailed test). Since this is not less than the t-distribution baseline for this study (t-value -2.326 at the 0.01 significance level), the null hypothesis was not rejected. Therefore, the mean annual leave taken by all personnel per two-week pay period after the implementation of APADE (X) was statistically equal to that prior to implementation.

The second null hypothesis (H_o) concerning annual leave stated that the amount of leave taken per worker per two-week pay period after the implementation of APADE (X) is statistically equal to that taken prior to implementation (X_o), (H_o: $X=X_o$). The alternative hypothesis (H_a) stated that the amount of leave taken per worker per two-week pay

period after the implementation (X) is more than that amount taken prior to the implementation (X_o), (H_a: $X>X_o$).

Upon analysis, the t-distribution test score for this measure was 2.90 at the 0.0026 significance level (right-tailed test). Since this is greater than the t-distribution baseline for this study (t-value 2.326 at the 0.01 significance level), the null hypothesis (H_o) was rejected. Therefore, the alternative hypothesis (H_a) was accepted; the mean annual leave taken per worker per two-week pay period after the implementation of APADE (X) was statistically greater than that prior to implementation (X_o).

b. Sick Leave

The first null hypothesis (H_o) concerning sick leave stated that the mean amount of sick leave taken by all workers per two-week pay period after the implementation of APADE (X) is statistically equal to that prior to implementation (X_o), (H_o: $X=X_o$). The alternative hypothesis (H_a) stated that the mean amount of sick leave taken by all workers per two-week pay period after the implementation (X) is greater than that amount taken prior to the implementation (X_o), (H_a: $X>X_o$).

Upon analysis, the t-distribution test score for this measure was 0.40 at the 0.34 significance level (right-tailed test). Since this is not greater than the t-

distribution baseline for this study (t-value 2.326 at the 0.01 significance level), the null hypothesis (H_o) could not be rejected. Therefore, the mean amount of sick leave taken by all personnel per two-week pay period after the implementation of APADE (X) was statistically equal to that prior to implementation (X_o).

The second null hypothesis (H_o) concerning sick leave stated that the mean amount of sick leave taken per worker per two-week pay period after the implementation of APADE (X) is statistically equal to that taken prior to implementation (X_o), (H_o: $X=X_o$). The alternative hypothesis (H_a) stated that the mean amount of sick leave taken per worker per two-week pay period after the implementation (X) is more than that amount taken prior to the implementation (X_o), (H_a: $X>X_o$).

Upon analysis, the t-distribution test score for this measure was 3.50 at the 0.0009 significance level (right-tailed test). Since this is greater than the t-distribution baseline for this study (t-value 2.326 at the 0.01 significance level), the null hypothesis (H_o) was rejected. Therefore, the alternative hypothesis (H_a) was accepted; the mean amount of sick leave taken per worker per two-week pay period after the implementation of APADE (X) was statistically greater than that prior to implementation (X_o).

c. Leave Without Pay

One of the null hypotheses (H_o) concerning leave without pay stated that the mean amount of leave without pay taken by all workers per two-week pay period after the implementation of APADE (X) is statistically equal to that prior to implementation (X_o), (H_o: $X=X_o$). The alternative hypothesis (H_a) stated that the mean amount of leave without pay taken by all workers per two-week pay period after the implementation (X) is less than that amount taken prior to the implementation (X_o), (H_a: $X<X_o$).

Upon analysis, the t-distribution test score for this measure was -3.37 at the 0.001 significance level (left-tailed test). Since this is less than the t-distribution baseline for this study (t-value -2.326 at the 0.01 significance level), the null hypothesis (H_o) was rejected. Therefore, the alternative hypothesis (H_a) was accepted; the mean amount of leave without pay taken by all personnel per two-week pay period after the implementation of APADE (X) was statistically less than that prior to implementation (X_o).

The other null hypothesis (H_o) concerning leave without pay stated that the mean amount of leave without pay taken per worker per two-week pay period after the implementation of APADE (X) is statistically equal to that taken prior to implementation (X_o), (H_o: $X=X_o$). The alternative hypothesis (H_a) stated that the mean amount of

leave without pay taken per worker per two-week pay period after the implementation (X) is less than that amount taken prior to the implementation (X_o), (H_a: $X<X_o$).

Upon analysis, the t-distribution test score for this measure was -0.12 at the 0.55 significance level (left-tailed test). Since this is not less than the t-distribution baseline for this study (t-value -2.326 at the 0.01 significance level), the null hypothesis (H_o) was not rejected. Therefore, the mean amount of leave without pay taken per worker per two-week pay period after the implementation of APADE (X) was statistically equal to that prior to implementation (X_o).

D. PRODUCTIVITY MEASUREMENT

1. Before APADE

The number of purchase orders processed per labor hour is the measurement of the number of purchase orders processed during the year divided by the number of actual labor hours accrued during the year. The mean number of purchase orders processed per labor hour prior to the implementation of APADE was 0.5564 purchase orders per hour, with a standard deviation of 0.1019.

2. After APADE Implementation

The mean number of purchase orders processed per labor hour after the implementation of APADE was .5236 per hour, with a standard deviation of .0882. The data were

collected from both the Procurement Summary of Actions Report (DD FORM 1057) that was manually generated on site and the SPB personnel' Service Card (NAVCOMPT FORM 206 - MECHANIZED).

3. **Testing the Null Hypothesis for Productivity**

The null hypothesis concerning the productivity measurement at the SPB stated that the number of purchase orders processed per labor hour after the implementation of APADE (X) was statistically equal to that prior to implementation (H_o: $X=X_o$). The alternative hypothesis stated that the number of purchase orders processed per labor hour after the implementation is less than that prior to the implementation (H_a: $X<X_o$).

Upon analysis, the t-distribution test score for this measure was -1.90 at the 0.035 significance level (left-tailed test). Since this is greater than the t-distribution baseline for this study (t-value -2.326 at the 0.01 significance level), the null hypothesis is not rejected. The productivity measurement at the SPB after the implementation of APADE (X) was statistically equal to that prior to implementation.

E. SUMMARY OF FINDINGS

A summary of T-Test results of the inputs, outputs, productivity measurement, and social effects are presented in tables XI, XII, XIII, and XIV respectively.

TABLE XI. SUMMARY OF T-TEST RESULTS: INPUTS

INPUTS	PRE-APADE	APADE	T-TEST RESULTS
MEAN STAFF SIZE Std. Deviation	73.35 3.48	62.42 1.24	T = -44.97 p ≈ 0.0000
GRADE LEVEL Std. Deviation	5.66 .098	6.06 .006	T = 370.15 p ≈ 0.0000
MEAN OVERTIME (per 2-week pay period) Std. Dev.	519.46 306.03	124.383 168.894	T = -11.93 p ≈ 0.0000
MEAN OVERTIME (per worker per 2-week period) Std. Dev.	6.7229 7.0831	2.0270 2.6508	T = -14.06 p ≈ 0.0000

TABLE XII. SUMMARY OF T-TEST RESULTS: OUTPUTS

OUTPUTS	PRE-APADE	APADE	T-TEST RESULTS
MEAN PURCHASE REQUESTS PROCESSED	3287.7	2304.0	T = -11.04 p ≈ 0.0000
Std. Dev.	655.1	454.4	----------
MEAN PROCUREMENT ACTION LEAD TIME	52.4	23.5	T = -29.49 p ≈ 0.0000
Std. Dev.	33.8	24.7	----------

TABLE XIII. PRODUCTIVITY MEASUREMENT T-TEST RESULTS

PRODUCTIVITY MEASUREMENT	PRE-APADE	APADE	T-TEST RESULTS
MEAN PURCHASE REQUESTS PROCESSED PER LABOR HOUR	0.5564	0.5236	T = -1.90 p ≈ 0.035
Standard Deviation	0.1019	0.0882	

TABLE XIV. SUMMARY OF T-TEST RESULTS: SOCIAL EFFECTS

SOCIAL EFFECTS	PRE-APADE	APADE	T-TEST RESULTS
MEAN ANNUAL LEAVE (per 2-week pay period)	442.22	380.05	T = -2.08
Std. Dev.	202.46	152.47	p ≈ 0.024
MEAN ANNUAL LEAVE (per worker per 2-week period)	5.3995	6.1203	T = 2.90
Std. Dev.	2.1938	1.9751	p ≈ 0.0026
MEAN SICK LEAVE (per 2-week pay period)	255.83	262.03	T = 0.40
Std. Dev.	69.459	78.313	p ≈ 0.34
MEAN SICK LEAVE (per worker per 2-week period)	3.1539	4.2018	T = 3.50
Std. Dev.	1.5326	2.3732	p ≈ 0.0009
MEAN LEAVE WITHOUT PAY (per 2-week pay period)	155.40	112.05	T = -3.37
Std. Dev.	77.29	65.536	p ≈ 0.0012
MEAN LEAVE WITHOUT PAY (per worker per 2-week period)	1.8717	1.8003	T = -0.12
Std. Dev.	5.6010	4.7991	p ≈ 0.55

V. ANALYSIS AND CONCLUSION

A. INPUTS

1. Staff Size

The mean staff size prior to the implementation of APADE was 73.4 personnel. The mean staff size after implementation was 62.4 personnel. This represents a decrease of 15 percent in the number of personnel in the Small Purchasing Branch (SPB) at NSC Duarte. With the remaining factors being held constant, a decrease in headcount would provide a decreased input measure. Combined with a constant output measure, by definition, using the ratio of outputs to inputs, this by itself would provide an increase in productivity.

The amount of administrative support required prior to implementation was not needed after APADE's implementation. This is due to APADE's design allowing buyers to enter the data into the system as events occur rather than transporting documents to data entry clerks for input. This decreases the number of administrative support personnel required for support. Although a decrease in staff size by itself would act to increase productivity the implementation of APADE is not the only factor which may have had this effect. The number of purchase orders

submitted to NSC Duarte had also decreased. Management sources indicate that the decrease in the number of purchase requests received had no effect on the decrease in the number of personnel between the pre and post APADE periods. However, because regression analysis was beyond the scope of this study we did not address the relative significance of these two factors. Therefore, it can not be categorically stated that the decrease in staff size was in whole or part due to the implementation of APADE.

2. **Grade Structure**

The mean grade level prior to the implementation of APADE was GS 5.66. The mean grade level measured after implementation was GS 6.06. This represents an increase in the grade level in the Small Purchasing Branch (SPB) at NSC Duarte. With all other factors remaining constant, an increase in the mean grade level would reflect an increase in inputs while output remained constant. Productivity would decrease in this scenario as measured by the ratio of outputs to inputs.

There was an increase in the proportion of buyers to administrative support personnel. Buyers made up 69.9 percent of the pre APADE work force while comprising 79.4 percent after implementation. The mean grade level for buyers before APADE was GS 6.04 and after was GS 6.36. The mean grade level for administrative support personnel before

APADE was GS 4.10 and after was GS 4.55. Since there was not a statistically significant increase in grade level for buyers or administrative support personnel between the two periods, the overall increase in GS level in the post APADE period is due to the increase in the proportion of buyers caused by the decrease in the number of administrative support personnel in the work force.

As workload decreases, one would expect to see an eventual decrease in the overall workforce. Although management would not necessarily terminate buyers and administrative support personnel at the same time, the number of personnel in both categories would be expected to decrease to levels in proportion to those at the pre-APADE levels. That was not the case in this study. APADE shifted some of the administrative support personnel tasks to the buyers. (See Appendix A)

While the inclination would be to believe that the accompanying increase in grade structure would indicate a drop in productivity, further inspection reveals that this is not necessarily the case. The increase in grade structure is primarily due to the decrease in personnel, with a proportionally larger decrease in administrative support personnel than in buyers. Therefore, all that can be said about the grade structure is that APADE shifted some of the tasks done by administrative support personnel in the pre-APADE period to the buyers in the post implementation

period. This shift is an expected outcome with the application of technology into the work environment.

3. **Overtime**

The mean amount of overtime time used per pay period for all personnel prior to the implementation of APADE was 519.5 hours. The mean amount of overtime used per worker per pay period was 6.7 hours. The mean amount of overtime used per pay period for all personnel after implementation was 124.4 hours. The mean amount used per worker per pay period was 2.0 hours. This represents a decrease of 76.1 percent in the number of hours of overtime used per period, and a 69.8 percent decrease in the number of hours used per person per pay period. All other factors remaining constant, a decrease in overtime would reflect a decrease in inputs, reflecting an increase in productivity.

The post APADE management policy to use compensatory time in lieu of overtime is a management decision rather than a product of APADE. However, even if compensatory time earned were added to overtime, there would still be a decrease of 57.5 percent per person per pay period.

B. OUTPUTS

1. Number of Purchase Orders

The mean number of purchase orders processed during the year prior to the implementation of APADE was 7123 per month. The mean number of purchase orders processed during

the year after the implementation was 4992 per month. This represents a decrease of 29.9 percent in the number of purchase orders processed per month. This is primarily a reflection of a policy which directed previous NSC Duarte customers to other sources of supply.

2. **Procurement Action Lead Time (PALT)**

The mean Procurement Action Lead Time (PALT) during the year prior to the implementation of APADE was 52.4 days. The mean PALT during the year after the implementation was 23.5 days. This represents a decrease of 55.2 percent in the PALT value between the two years. All other factors remaining constant a decrease in PALT would indicate that some degree of productivity improvement has been attained.

There was a 29.9 percent decrease in purchase requests at NSC Duarte between the two periods measured. Also, the ratio of transactions processed to the number of labor hours worked remained statistically constant between the two periods. This would tend to indicate that the decrease in PALT was primarily due to the decrease in workload.

The document flow charts provided by NSC Duarte for the before and after APADE periods (Appendix A) reflect a significant change in the document flow process. The flow of documentation before APADE required 54 document movements between various clerks, supervisors, and procurement

personnel. After the implementation of APADE the new document flow process required only 15 document movements. Although APADE may not have improved the productivity of the personnel individually, it did streamline the procurement process and reduced the number of potential delays in the system.[4]

Interviews with Small Purchasing Branch (SPB) personnel revealed that they believed that the implementation of APADE was the significant factor in the reduction of PALT. Although there was a 29.9 percent decrease in the number of purchase requests between the before and after periods, there was also a 15.0 percent decrease in staff size.

We can not say with any quantitative certainty the extent to which APADE affected PALT. However, it can be said that APADE played the primary role in the reduction of the document flow within the procurement process. Although it is our opinion that PALT was dramatically reduced at NSC Duarte due to the implementation of APADE, no conclusive determination can be made to ascertain the degree of influence either the implementation of APADE or the decrease in workload has had on PALT.

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[4]Potential delays would be defined as time waiting in inboxes, outboxes, going from desk to desk, awaiting reviews, signatures, etc..

C. SOCIAL EFFECTS

1. Annual Leave

The mean amount of annual leave used per pay period for all personnel prior to the implementation of APADE was 442.22 hours. The mean amount of annual leave used per person per pay period was 5.40 hours. The mean amount of annual leave used per pay period for all personnel after implementation was 380.05 hours. The mean amount of annual leave used per worker per pay period was 6.12 hours. This represents a decrease of 14.10 percent in the number of hours of annual leave taken per period and a 13.3 percent increase in the number of hours per person per pay period.

The amount of annual leave used per pay period for all personnel is not an accurate measure of degree of annual leave taken in that it does not consider the fact that there were fewer staff members after APADE than before. Therefore, the appropriate measure is the leave taken per person per pay period which normalizes the relationship.

All else being equal, an increase in annual leave taken would indicate an increase in management's inclination or ability to allow personnel to take leave. The increase in the amount of leave taken would act to decrease overall worker input hours, thus when taken by itself, could indirectly imply an increase in productivity. Because of the reduction in workload, no conclusive determination can

be made to ascertain the degree of influence either the implementation of APADE or the decrease in workload has had on annual leave.

2. **Sick Leave**

Sick leave is a classic objective indicator of morale - it being the safety valve beyond management scheduling. The mean amount of sick leave used pay period for all personnel prior to the implementation of APADE was 255.83 hours. The mean amount of sick leave used per person per pay period was 3.15 hours. The mean amount of sick leave used per pay period for all personnel after implementation was 262.03 hours. The mean amount of sick leave used per worker per pay period was 4.20 hours. This represents an increase of 2.40 percent in the number of hours of sick leave taken per period and a 33.20 percent increase in the number of hours per person per pay period by SPB personnel.

During the analysis of the sick leave used per worker per pay period, it was noted that the sick leave trend analysis remained virtually unchanged throughout the two periods except during one pay period in the post implementation period. This period included a major natural disaster. During this period that the amount of sick leave taken increased significantly. Although this disaster did not physically affect the APADE system, it can be inferred

that there was a noted increase in the stress and anxiety felt by workers during the period.

Taken by itself, an increase in sick leave would indicate that there was a decrease in worker satisfaction. However, due to the environmental factors beyond the control of NSC Duarte's management, which accounted for a significant portion of that increase, the increase noted cannot be attributed to a decrease in worker satisfaction.

3. **Leave Without Pay**

The mean amount of leave without pay used per pay period for all personnel prior to the implementation of APADE was 155.4 hours. The mean amount of leave without pay used per person per pay period was 1.87 hours. The mean amount of leave without pay used per pay period for all personnel after implementation was 112.05 hours. The mean amount of leave without pay used per worker per pay period was 1.80 hours. This represents a decrease of 27.90 percent in the number of hours of leave without pay taken per period and a 3.80 percent decrease in the number of hours per person per pay period by SPB personnel.

This is a combined worker and management-driven social factor. A worker can request LWOP, but authorization is up to the discretion of management. All else being equal, a decrease in the amount of LWOP taken per worker could indicate a 'not unhappy' condition with the work

place, thus indicating an increase in worker satisfaction in the work environment. This would have a positive overall effect on productivity. In this study, there was no statistically significant increase/decrease in LWOP and therefore the only conclusion that can be drawn is that the implementation of APADE did not affect LWOP in the work environment.

D. PRODUCTIVITY MEASUREMENT

The mean number of purchase orders processed per labor hour for the year prior to the implementation of APADE was 0.5564. The mean number of purchase orders processed per labor hour for the year after the implementation was 0.5236. This represents a 5.9 percent drop in purchase orders processed per labor hour. Although there is a decrease in productivity, as measured by purchase orders processed per labor hour, the difference is not statistically significant. Therefore, the result is a productivity measurement that has remained constant between the two periods.

E. ACCOMPLISHMENTS OF THE STUDY

We applied a before and after pre-experimental design (Campbell and Stanley, 1966) that accumulated historical indicators of inputs, outputs, and social effects of office automation in an organization. The study of the effects of the installation of APADE has further established a

quantitative bench mark for office automation productivity. This was accomplished by using a standard input/output model of productivity.

In this study, we also captured empirical data on the social impact of APADE from objective historical documentation rather than through a subjective user satisfaction survey.

F. SUMMARY OF APADE BENEFITS

The APADE system implemented at the Small Purchasing Branch (SPB) at NSC Duarte was found to enhance the efficiency of the procurement process in a variety of ways:

1. Dramatically decreased the amount of document movement in the procurement mechanism, thus eliminating possible delay points in the process.

2. Allows for automated documentation preparation, thus reducing the requirement for significant administrative (clerical) support.

3. Provides for automated document control and tracking status to procurement personnel and allows customers access to the system to obtain status on their purchase requests. This frees up procurement personnel from having to answer phone calls from customers inquiring on purchase request status.

4. Provides real time contracting information to management which allows them to more effectively manage buyer resources and distribute procurement work load.

5. The process regulates the procurement personnel and work environment. Management can assign buys to specific buyers electronically and all purchase orders can be easily traced by management and buyer personnel.

G. DIRECTION FOR FURTHER RESEARCH

The following is a listing of potential topics for further research:

1. What has been the effect of APADE on all of the major supply stock points where it has been installed? Are the results similar to those found in this study?

2. APADE's primary design intent was to improve the buyer's ability to make quality buys in accordance with established rules, regulations, and guidelines. Has APADE satisfied this intention? Can this type of information be quantitatively measured?

3. What has been the effect of APADE on the users? Do the users' view APADE as a positive influence on the procurement process? How has user perception/attitude affected implementation of APADE at various sites. How can this type of information be quantitatively measured?

4. APADE is currently being implemented in the large procurement process system (purchases > $25,000). A study is needed to measure the before and after effects of APADE on the large procurement cycle.

5. A comparative study is needed on the various automated procurement systems currently being utilized by the federal government. Under what conditions would one system be the preferred choice over the others? Is it appropriate to compare systems with different designs on a single set of measurement criteria?

6. A before and after productivity study on the desktop version of APADE currently under development for use at small procurement sites would be useful.

7. A follow-up to this study on the effects of APADE at the NSC Duarte site is appropriate to determine if further improvements in the productivity are recognized as SPB personnel become more familiar with the system.

8. A study to perform a regression analysis on those factors which may have had an affect on the various inputs, outputs, and social effects addressed in this study.

In today's environment of diminishing resources it has become critical to quantitatively measure the effects of decisions on the organization. This has never been more important than it is today with automation of the white collar work place.

In determining whether an organization has obtained an advantage or "got its money's worth" out of procuring an automated system, planning is a critical factor. If an organization has made the decision to automate or replace an existing system, the organization must first decide what they want to gain from the expenditure.

Once the reason for the procurement has been determined, quantitative measures must be established to compare the before and after effects of the decision. The establishment of these measures and data collection must start early in the new system's development phase. Management is challenged with using not only common 'number crunching' type assessments, but also measures that can be used to evaluate the evolving nature of the organization. One would hope that quantitative and objective qualitative measures exist, or can be developed, to fulfill this requirement.

During implementation of the new system, the measurements should continue, if nothing more than to observe the trend over the implementation phase and provide a better understanding of the dynamics of the implementation process. These measures should continue well into the post

implementation phase, to measure and note the trends in the growth or decline of the system.

Unfortunately, the decision to evaluate the effectiveness of a system often occur after the system has already been implemented. At this point, it is often too late to get an accurate picture. Another mistake occurs when a system is evaluated against criteria that it was not designed to comply with. In the real world decisions to measure the 'effectiveness' of a system are made after the development, implementation, and a significant portion of the maintenance dollars have become sunk costs.

In reviewing the literature on this subject, it has been found that great expectations are given prior to, during, and after the development of new systems. Measurements are not taken until after the question arises whether or not the 'new' system in place actually fulfilled the needs and requirements of the organization.

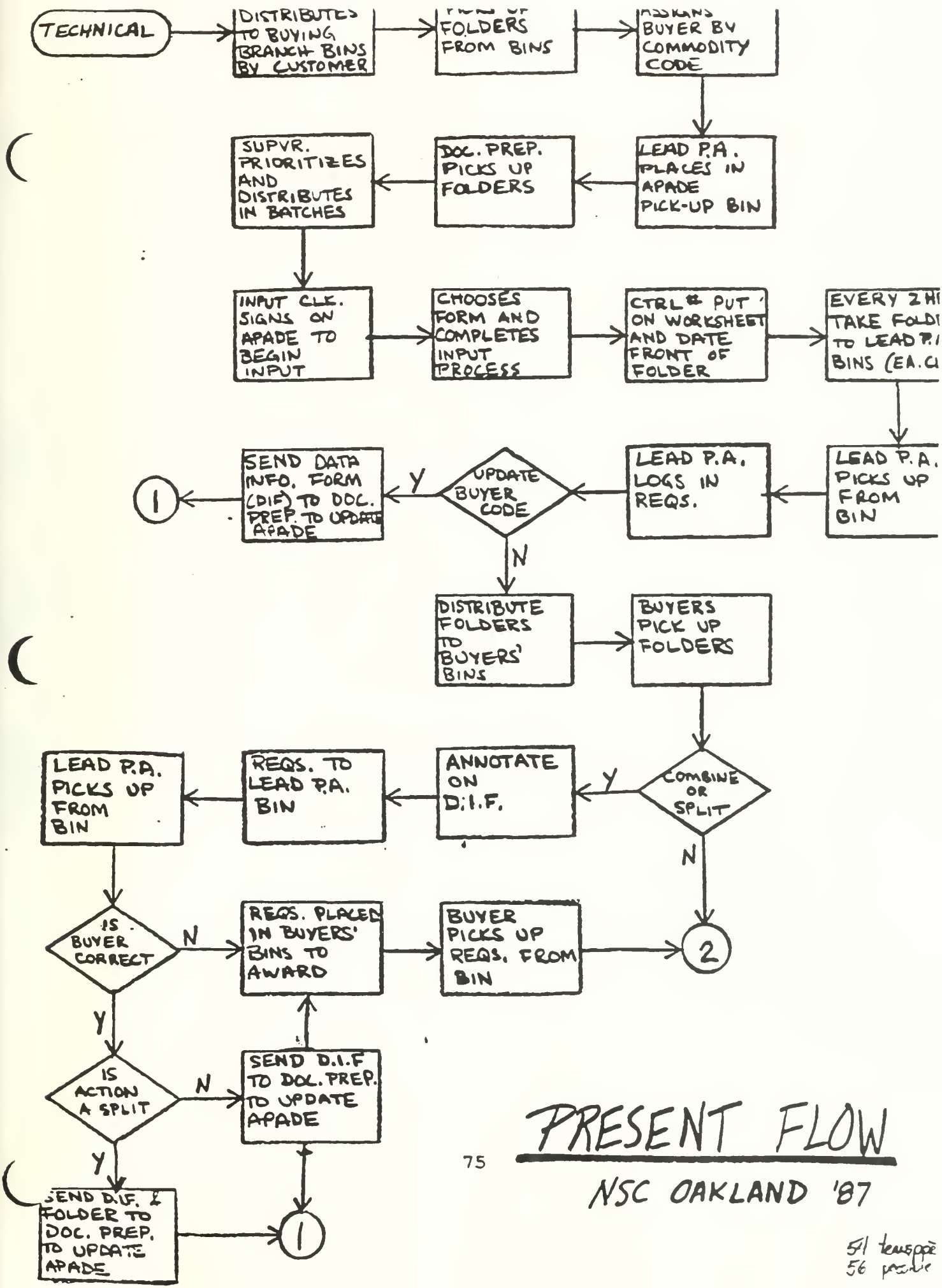
Such is the case with this study. In conversations with individuals who were connected with the APADE project, it was realized that the system was not developed with a direct aim towards increasing productivity. The primary concern of the APADE project was to develop an environment which would assist contracting personnel in the compliance with existing contract laws and regulations and provide an automated climate that would evolve with the ever changing procurement environment.

There may be those who read this study and attempt to use it out of context to determine whether or not the U. S. Navy "got it's money's worth' out of the APADE system. This is not the intent of this study. This study's intention was to further develop a methodology to compare automated procurement systems based on specific productivity measures. We believe that has been done. However, additional research will be needed to establish a precise methodology to further advance this notion of quantitatively measuring the effectiveness of automated systems.

APPENDIX A: DOCUMENT FLOW

DOCUMENT FLOW

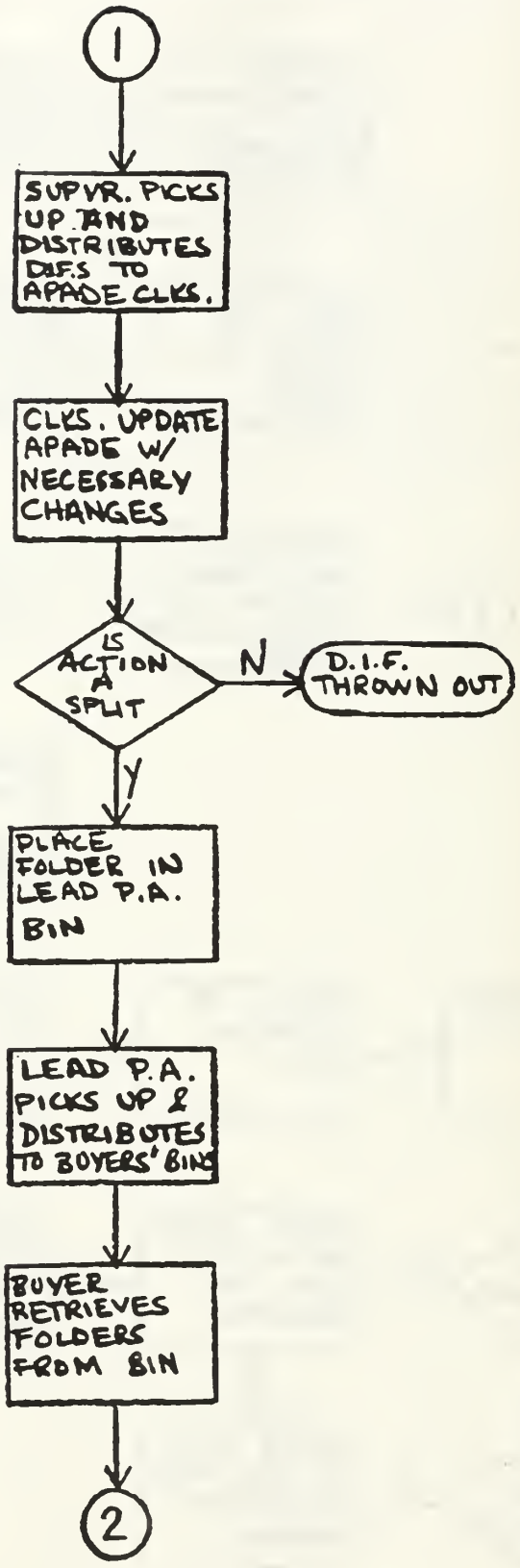
The diagrams that follow have been reproduced from original documents provided by the Small Purchase Branch at the Navy Field Contracting Activity where this study was conducted. Pages 75 through 81 represent the document flow prior to implementing APADE. Pages 82 and 83 represent the document flow using APADE.

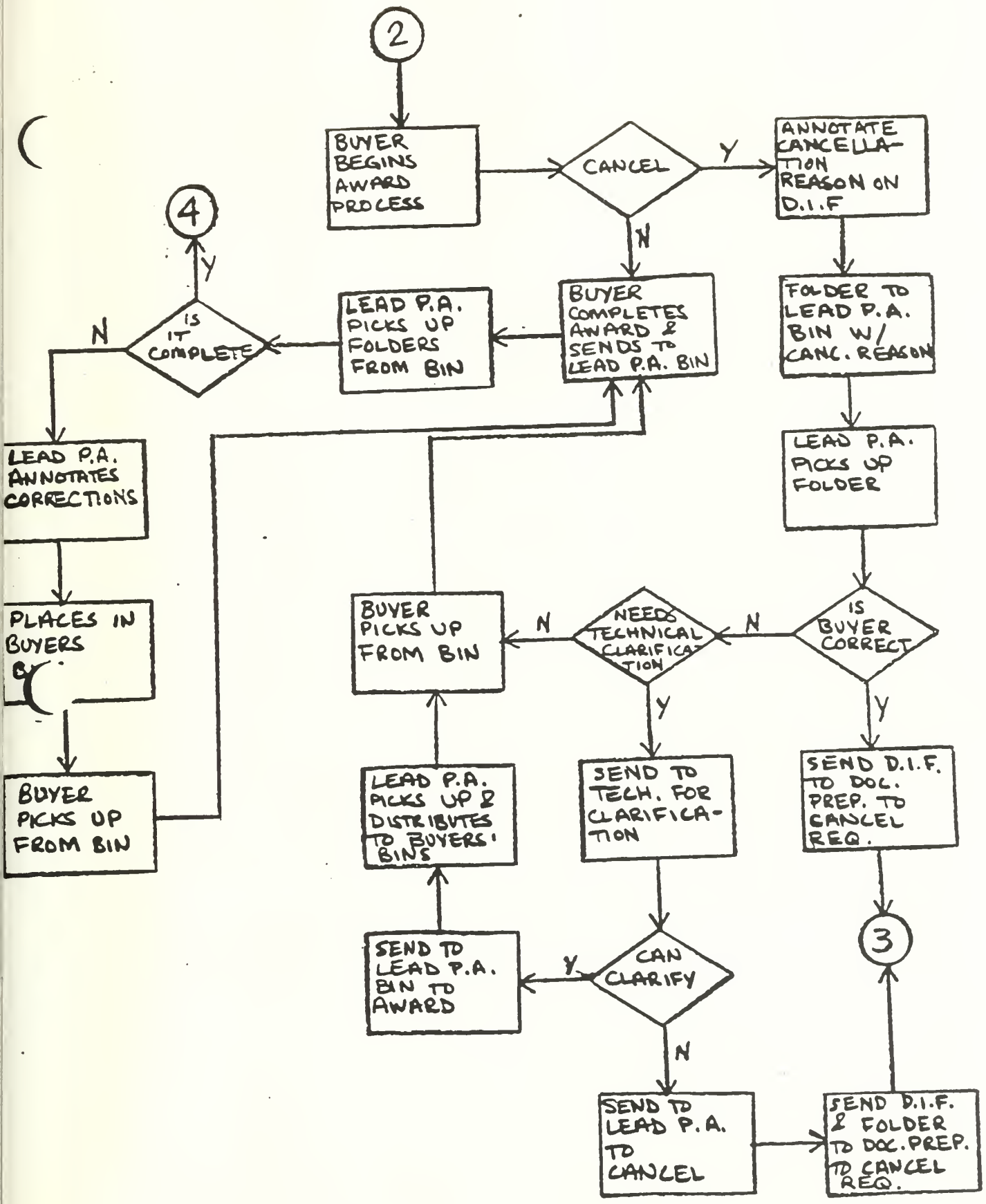


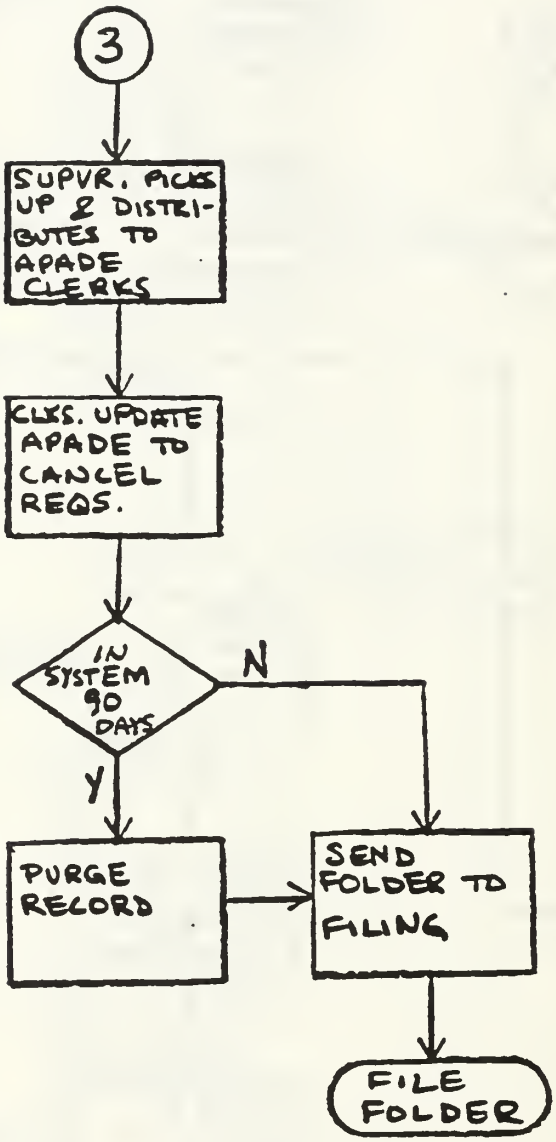
PRESENT FLOW

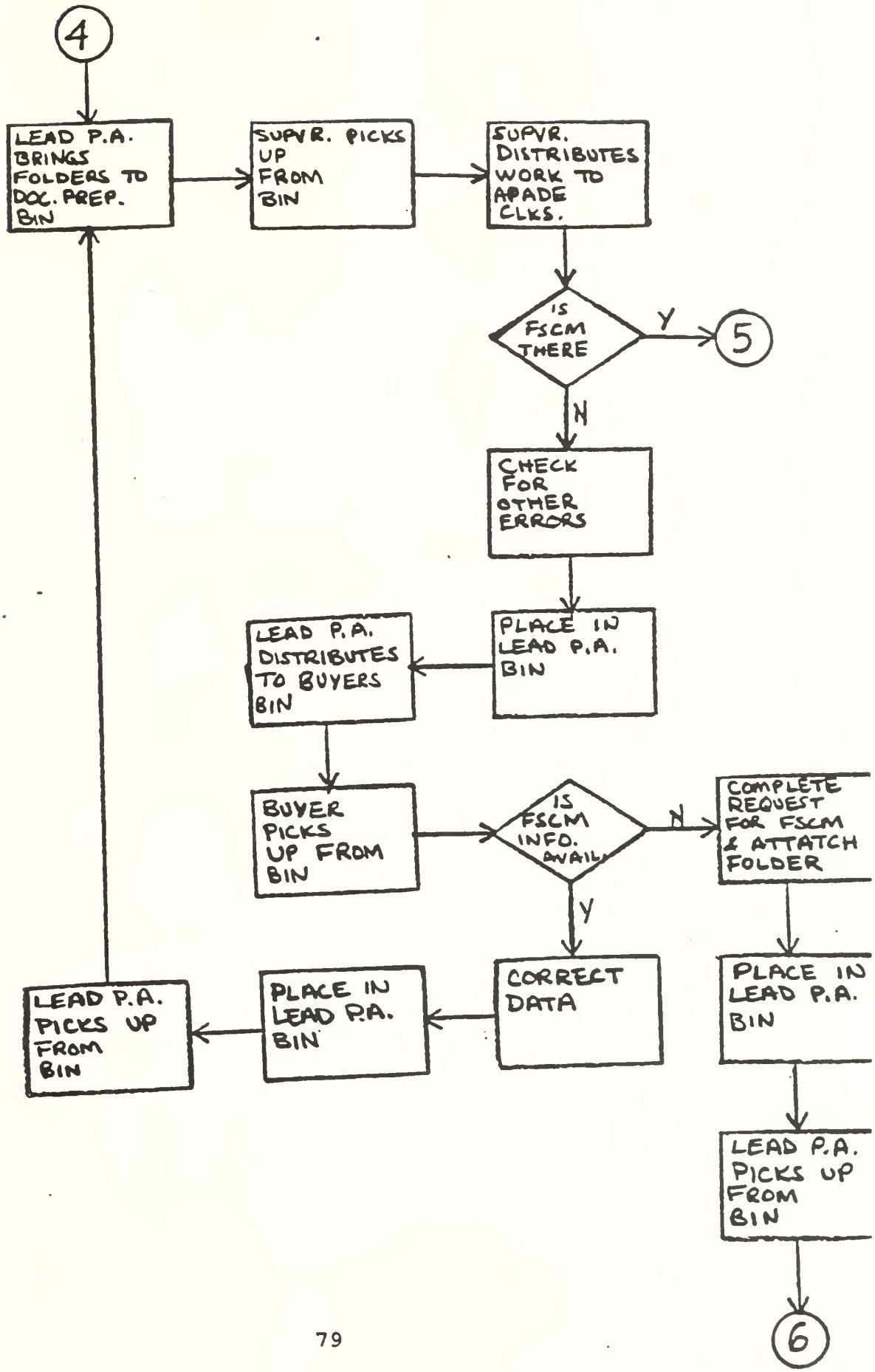
NSC OAKLAND '87

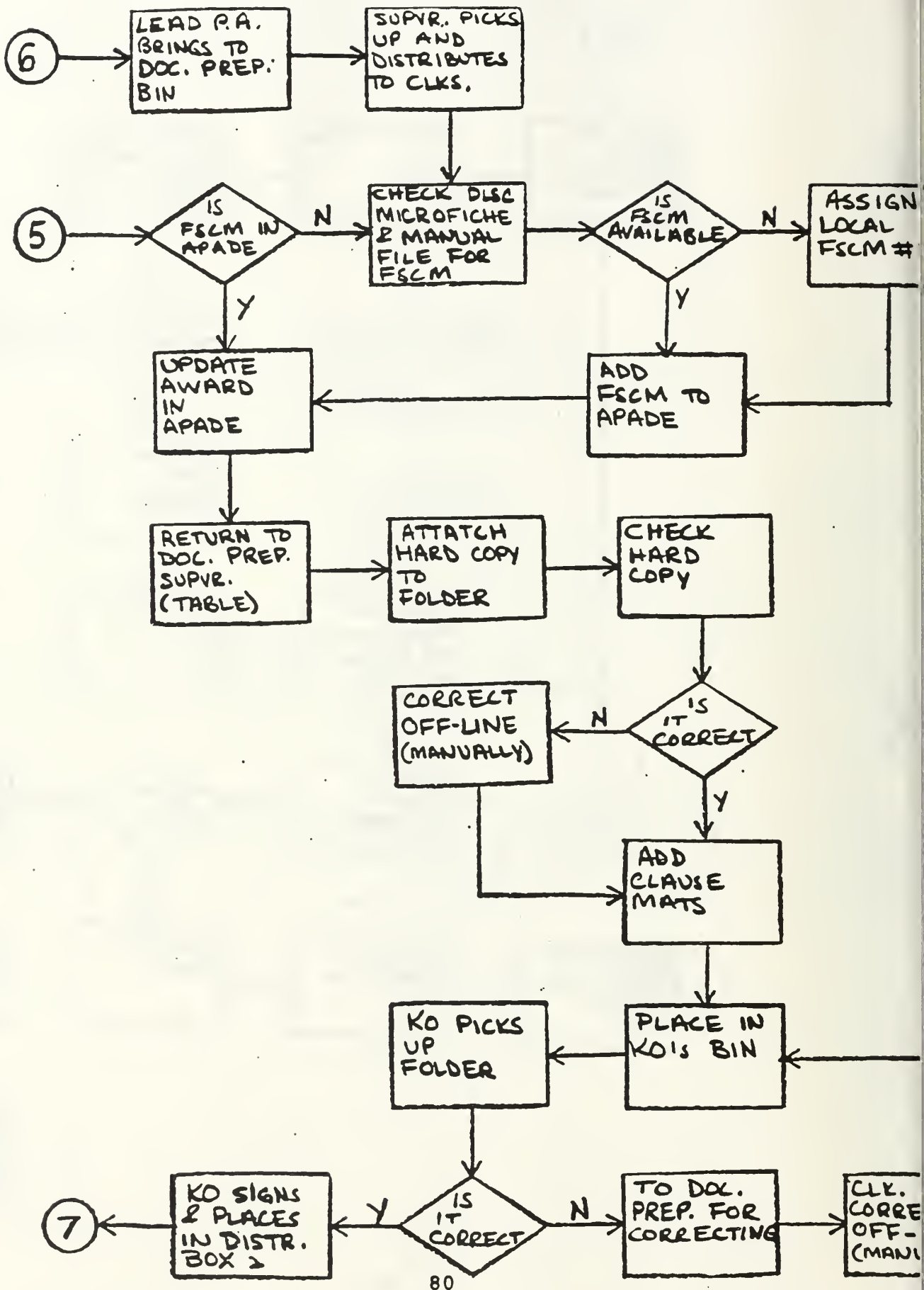
51 transpose
56 possible

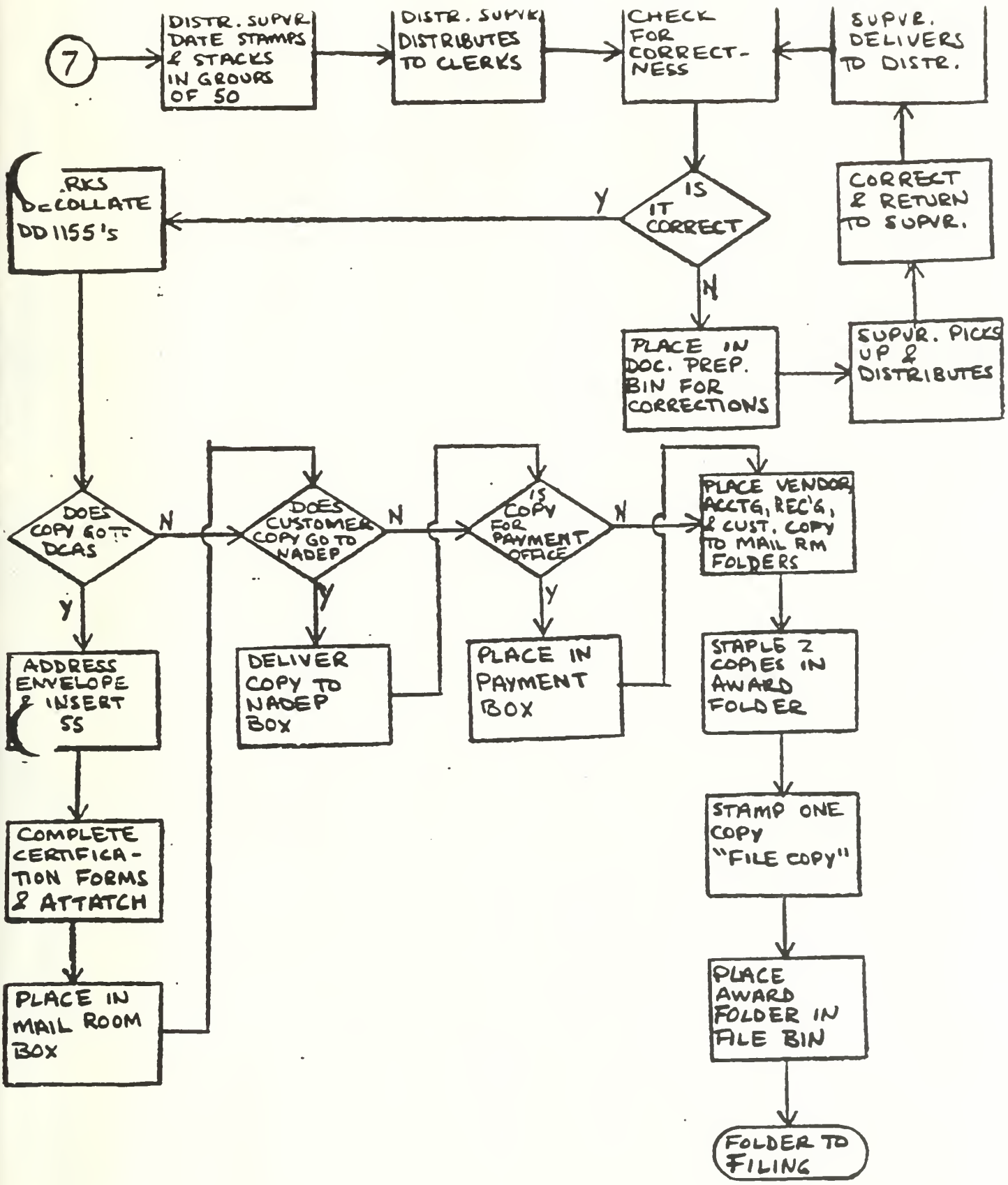

1
SUPVR. PICKS UP AND DISTRIBUTES DIF.S TO APADE CLKS.
CLKS. UPDATE APADE W/ NECESSARY CHANGES
IS ACTION A SPLIT
N
D.I.F. THROWN OUT
Y
PLACE FOLDER IN LEAD P.A. BIN
LEAD P.A. PICKS UP & DISTRIBUTES TO BOYERS' BINS
BUYER RETRIEVES FOLDERS FROM BIN
2

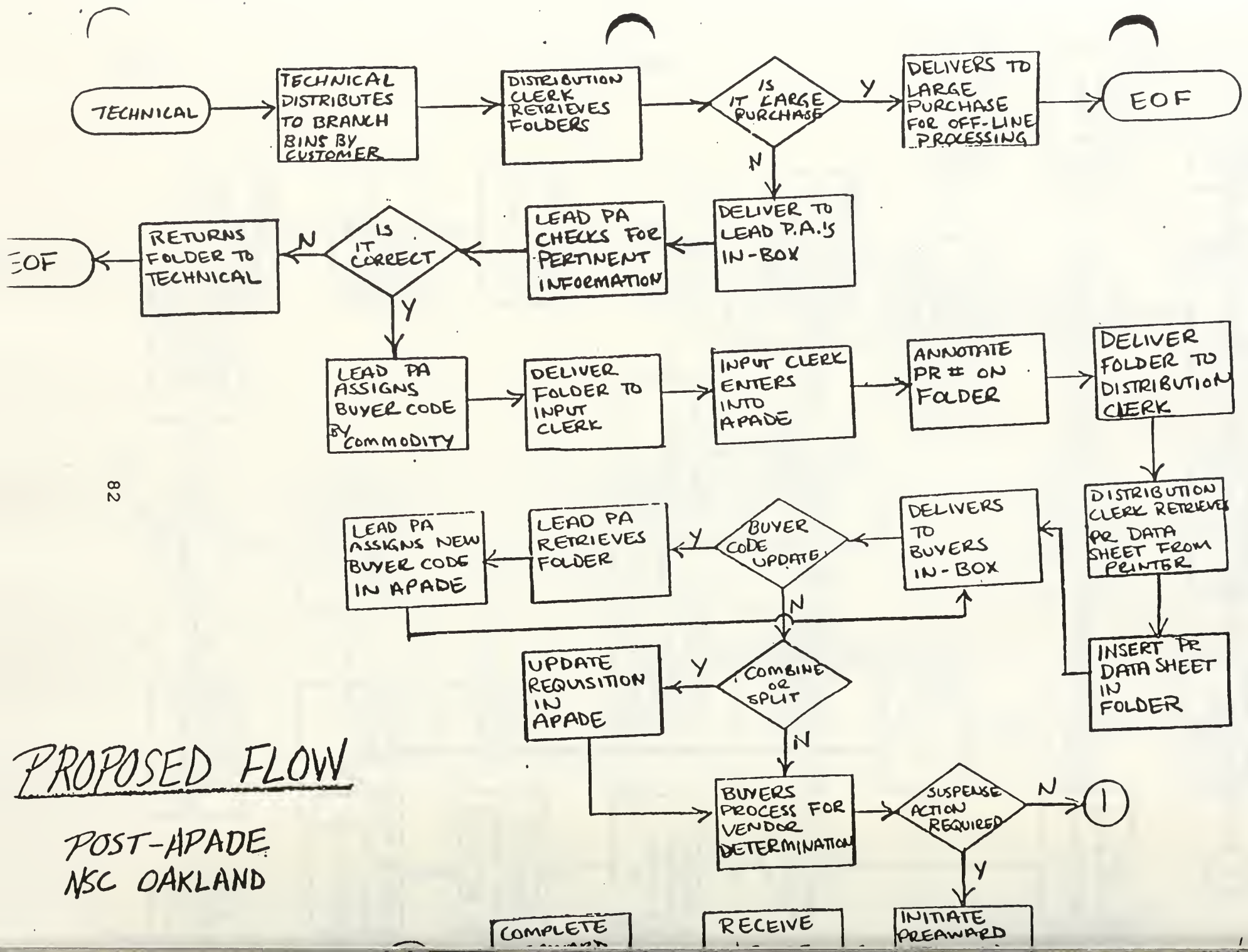

2
BUYER BEGINS AWARD PROCESS
CANCEL
Y
ANNOTATE CANCELLATION REASON ON D.I.F
N
BUYER COMPLETES AWARD & SENDS TO LEAD P.A. BIN
FOLDER TO LEAD P.A. BIN W/ CANC. REASON
4
Y
IS IT COMPLETE
N
LEAD P.A. PICKS UP FOLDERS FROM BIN
LEAD P.A. ANNOTATES CORRECTIONS
LEAD P.A. PICKS UP FOLDER
PLACES IN BUYERS
BUYER PICKS UP FROM BIN
BUYER PICKS UP FROM BIN
N
NEEDS TECHNICAL CLARIFICATION
N
IS BUYER CORRECT
Y
Y
LEAD P.A. PICKS UP & DISTRIBUTES TO BUYERS' BINS
SEND TO TECH. FOR CLARIFICATION
SEND D.I.F. TO DOC. PREP. TO CANCEL REQ.
3
SEND TO LEAD P.A. BIN TO AWARD
Y
CAN CLARIFY
N
SEND TO LEAD P.A. TO CANCEL
SEND D.I.F. & FOLDER TO DOC. PREP. TO CANCEL REQ.


3
SUPVR. PICKS UP & DISTRI-BUTES TO APADE CLERKS
CLKS. UPDATE APADE TO CANCEL REQS.
IN SYSTEM 90 DAYS
N
Y
PURGE RECORD
SEND FOLDER TO FILING
FILE FOLDER


4
LEAD P.A. BRINGS FOLDERS TO DOC. PREP. BIN
SUPVR. PICKS UP FROM BIN
SUPVR. DISTRIBUTES WORK TO APADE CLKS.
IS FSCM THERE
Y
5
N
CHECK FOR OTHER ERRORS
PLACE IN LEAD P.A. BIN
LEAD P.A. DISTRIBUTES TO BUYERS BIN
BUYER PICKS UP FROM BIN
IS FSCM INFO. AVAIL
N
COMPLETE REQUEST FOR FSCM & ATTATCH FOLDER
Y
CORRECT DATA
PLACE IN LEAD P.A. BIN
LEAD P.A. PICKS UP FROM BIN
PLACE IN LEAD P.A. BIN
LEAD P.A. PICKS UP FROM BIN
6

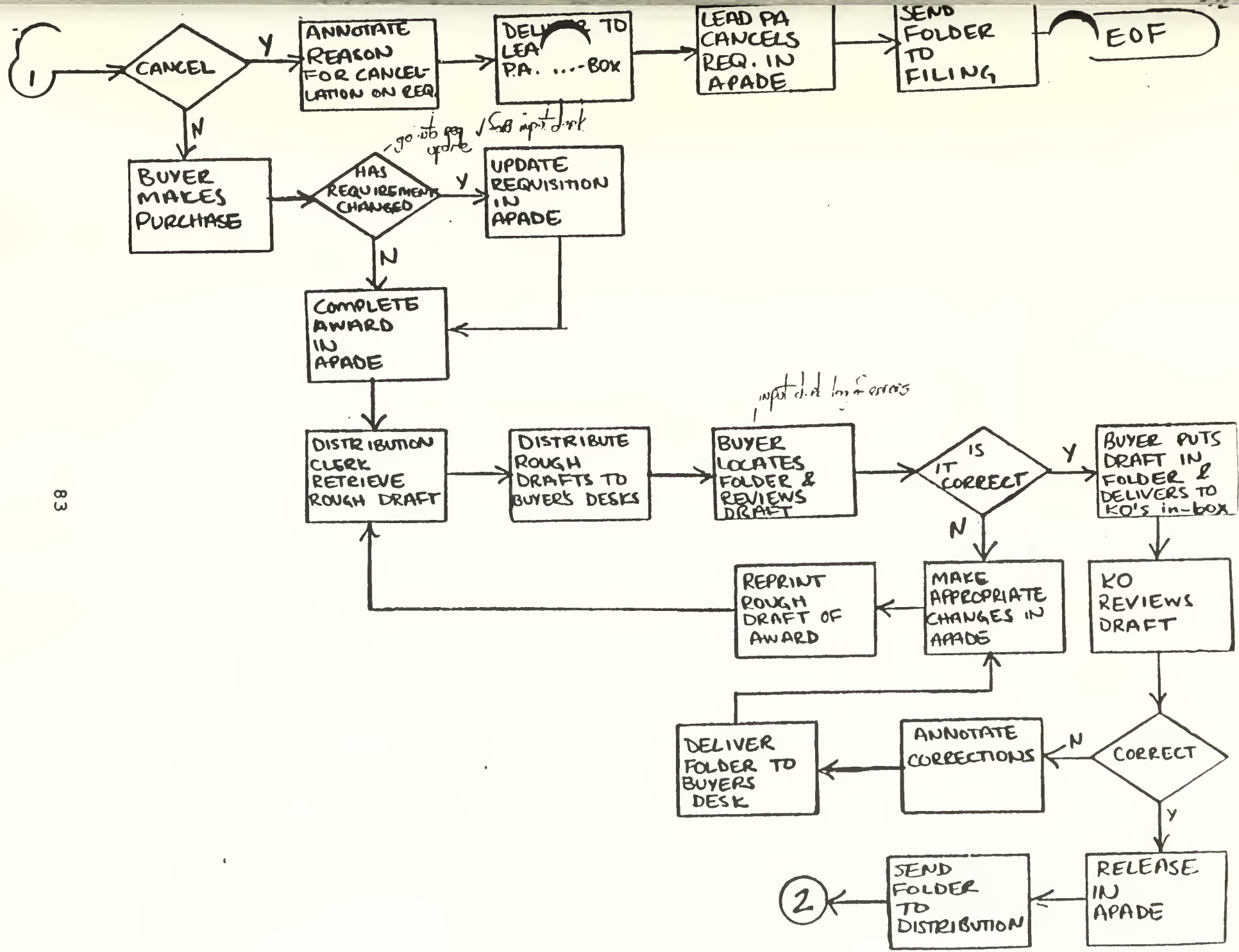

6
LEAD P.A. BRINGS TO DOC. PREP. BIN
SUPVR. PICKS UP AND DISTRIBUTES TO CLKS.
5
IS FSCM IN APADE
N
Y
CHECK DLSC MICROFICHE & MANUAL FILE FOR FSCM
IS FSCM AVAILABLE
N
Y
ASSIGN LOCAL FSCM #
UPDATE AWARD IN APADE
ADD FSCM TO APADE
RETURN TO DOC. PREP. SUPVR. (TABLE)
ATTATCH HARD COPY TO FOLDER
CHECK HARD COPY
CORRECT OFF-LINE (MANUALLY)
IS IT CORRECT
N
Y
ADD CLAUSE MATS
KO PICKS UP FOLDER
PLACE IN KO's BIN
7
KO SIGNS & PLACES IN DISTR. BOX 2
IS IT CORRECT
Y
N
TO DOC. PREP. FOR CORRECTING
CLK. CORRE OFF- (MANU


7
DISTR. SUPVR DATE STAMPS & STACKS IN GROUPS OF 50
DISTR. SUPVR DISTRIBUTES TO CLERKS
CHECK FOR CORRECT-NESS
SUPVR. DELIVERS TO DISTR.
CORRECT & RETURN TO SUPVR.
IS IT CORRECT
Y
N
.RKS DeCOLLATE DD1155's
PLACE IN DOC. PREP. BIN FOR CORRECTIONS
SUPVR. PICKS UP & DISTRIBUTES
DOES COPY GO TO DCAS
N
Y
DOES CUSTOMER COPY GO TO NADEP
N
Y
IS COPY FOR PAYMENT OFFICE
N
Y
PLACE VENDOR, ACCTG, REC'G, & CUST. COPY TO MAIL RM FOLDERS
ADDRESS ENVELOPE & INSERT SS
DELIVER COPY TO NADEP BOX
PLACE IN PAYMENT BOX
STAPLE 2 COPIES IN AWARD FOLDER
COMPLETE CERTIFICA-TION FORMS & ATTATCH
STAMP ONE COPY "FILE COPY"
PLACE IN MAIL ROOM BOX
PLACE AWARD FOLDER IN FILE BIN
FOLDER TO FILING



PROPOSED FLOW

POST-APADE
NSC OAKLAND


1
CANCEL
Y
ANNOTATE REASON FOR CANCELLATION ON REQ.
DELIVER TO LEAD P.A. ...-BOX
LEAD PA CANCELS REQ. IN APADE
SEND FOLDER TO FILING
EOF
N
BUYER MAKES PURCHASE
HAS REQUIREMENT CHANGED
Y
UPDATE REQUISITION IN APADE
N
COMPLETE AWARD IN APADE
DISTRIBUTION CLERK RETRIEVE ROUGH DRAFT
DISTRIBUTE ROUGH DRAFTS TO BUYER'S DESKS
BUYER LOCATES FOLDER & REVIEWS DRAFT
IS IT CORRECT
Y
BUYER PUTS DRAFT IN FOLDER & DELIVERS TO KO's in-box
N
REPRINT ROUGH DRAFT OF AWARD
MAKE APPROPRIATE CHANGES IN APADE
KO REVIEWS DRAFT
DELIVER FOLDER TO BUYERS DESK
ANNOTATE CORRECTIONS
N
CORRECT
Y
2
SEND FOLDER TO DISTRIBUTION
RELEASE IN APADE

APPENDIX B: SUMMARY OF INPUT BY PAY PERIOD

PRE-APADE IMPLEMENTATION

PERIOD	NUMBER OF EMPLOYEES	AVERAGE GRADE LEVEL	OVERTIME
1	68	5.794	0
2	68	5.794	0
3	68	5.794	0
4	68	5.794	0
5	68	5.794	471
6	70	5.757	368
7	71	5.718	733
8	72	5.681	179
9	72	5.681	262
10	73	5.685	565
11	73	5.685	621
12	73	5.685	502
13	73	5.685	410
14	74	5.649	720
15	74	5.649	812
16	74	5.649	852
17	75	5.613	500
18	75	5.613	926
19	75	5.613	589
20	76	5.579	1065
21	77	5.546	573
22	78	5.513	405
23	78	5.513	828
24	78	5.513	872
25	78	5.513	524
26	78	5.513	732

APPENDIX B: SUMMARY OF INPUT BY PAY PERIOD

AFTER APADE IMPLEMENTATION

PERIOD	NUMBER OF EMPLOYEES	AVERAGE GRADE LEVEL	OVERTIME
1	59	6.068	142
2	59	6.068	257
3	60	6.050	310
4	61	6.049	523
5	62	6.048	292
6	62	6.048	341
7	63	6.064	336
8	63	6.064	165
9	63	6.064	0
10	63	6.064	0
11	63	6.064	0
12	63	6.064	0
13	63	6.064	4
14	63	6.064	0
15	63	6.064	0
16	63	6.064	0
17	63	6.064	0
18	63	6.064	0
19	63	6.064	124
20	63	6.064	506
21	63	6.064	218
22	63	6.064	10
23	63	6.064	0
24	63	6.064	0
25	63	6.064	8
26	63	6.064	0

APPENDIX C: SUMMARY OF SOCIAL EFFECTS BY PAY PERIOD

PRE-APADE IMPLEMENTATION

PAY PERIOD	ANNUAL LEAVE	SICK LEAVE	LEAVE WITHOUT PAY
1	257	383	44
2	245	286	57
3	255	355	52
4	320	150	116
5	282	258	73
6	364	277	77
7	388	350	124
8	551	241	116
9	315	169	132
10	482	242	161
11	489	174	236
12	386	274	157
13	382	241	150
14	899	188	108
15	451	215	117
16	568	259	165
17	376	256	167
18	363	192	210
19	274	194	112
20	367	318	156
21	494	252	242
22	339	320	261
23	519	423	247
24	646	223	377
25	349	232	239
26	1142	177	134

APPENDIX C: SUMMARY OF SOCIAL EFFECTS BY PAY PERIOD

AFTER APADE IMPLEMENTATION

PAY PERIOD	ANNUAL LEAVE	SICK LEAVE	LEAVE WITHOUT PAY
1	341	302	60
2	210	275	82
3	301	366	16
4	302	351	65
5	245	418	86
6	300	324	16
7	320	357	110
8	397	155	61
9	232	210	105
10	302	280	88
11	423	204	67
12	385	167	63
13	314	202	46
14	545	261	91
15	530	291	132
16	508	261	106
17	374	301	95
18	285	219	58
19	245	243	135
20	347	229	221
21	568	311	209
22	270	325	135
23	305	225	177
24	488	313	212
25	405	134	222
26	942	81	245

APPENDIX D: PRODUCTIVITY MEASUREMENT PER PAY PERIOD

PRE-APADE IMPLEMENTATION

PERIOD	# TRANSACTIONS	LABOR HOURS	TRANSACTIONS PER LABOR HOUR
1	2537	5156	0.492
2	3080	5252	0.587
3	2738	5178	0.529
4	2738	5254	0.521
5	3540	5698	0.621
6	3540	5570	0.636
7	3138	5950	0.527
8	3028	5431	0.558
9	3248	5806	0.559
10	3370	5840	0.577
11	3602	5881	0.613
12	3913	5845	0.669
13	3891	5796	0.671
14	3838	5844	0.657
15	3831	6348	0.604
16	3739	6180	0.605
17	3739	6101	0.613
18	4684	6561	0.714
19	4842	6408	0.756
20	3129	6623	0.472
21	2444	5985	0.408
22	2560	6125	0.418
23	2677	6279	0.426
24	2675	6266	0.427
25	2669	6344	0.421
26	2288	5918	0.387

APPENDIX D: PRODUCTIVITY MEASUREMENT PER PAY PERIOD

AFTER APADE IMPLEMENTATION

PERIOD	# TRANSACTIONS	LABOR HOURS	TRANSACTIONS PER LABOR HOUR
1	2619	4238	0.619
2	2619	4489	0.583
3	2576	4506	0.572
4	2656	4764	0.557
5	2958	4582	0.645
6	2948	4740	0.622
7	2701	4588	0.589
8	2515	4591	0.548
9	2487	4492	0.554
10	2449	4369	0.560
11	2441	4345	0.562
12	2411	4424	0.545
13	2379	4481	0.531
14	1960	4142	0.473
15	1959	4086	0.479
16	2268	4164	0.544
17	2319	4269	0.543
18	2706	4477	0.604
19	2922	4540	0.644
20	2117	4748	0.446
21	1312	4169	0.315
22	1476	4319	0.342
23	1884	4332	0.435
24	1848	4026	0.459
25	1632	4286	0.381
26	1748	3771	0.464

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