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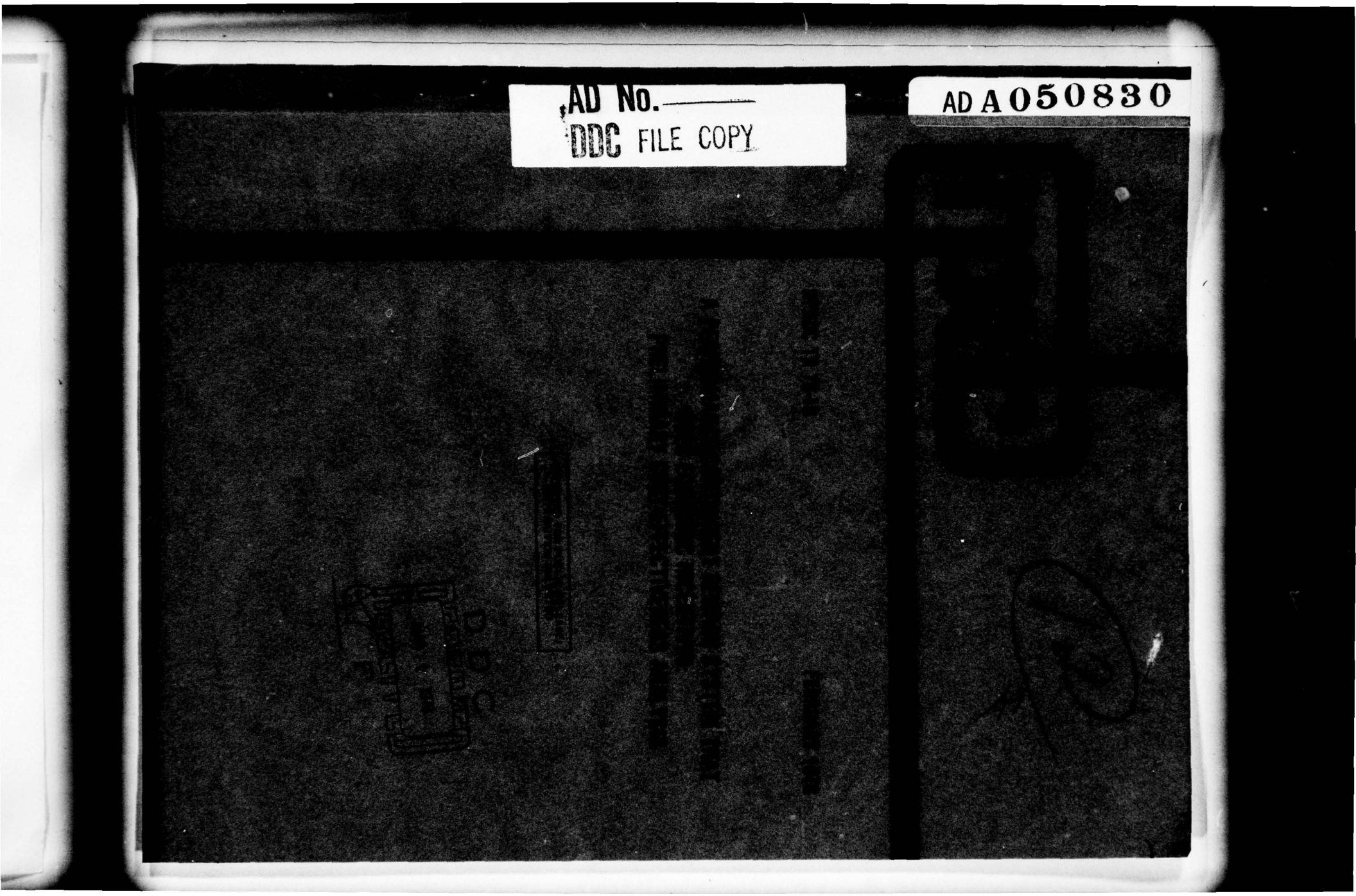

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A PERFORMANCE-CONTINGENT REWARD SYSTEM THAT USES ECONOMIC INCENTIVES: PRELIMINARY COST-EFFECTIVENESS ANALYSIS

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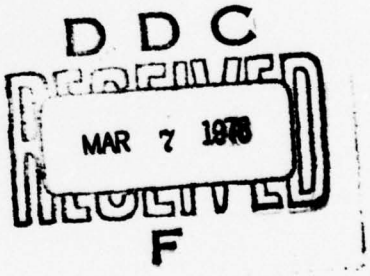

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The cost-effectiveness, cost-savings projections, and related issues of a Performance-Contingent Reward System (PCRS) that uses economic incentives were evaluated. The PCRS was tested on federal civil service data transcribers in the Management Information System Department of the Long Beach Naval Shipyard (LBNSY). Evaluation of the PCRS was conducted primarily from the following perspectives: (1) the cost-effectiveness of the proposed PCRS relative to former production conditions at the test site; (2) issues —(over)

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involving the generalizability of the test-site results to other Navy activities with substantial concentrations of data transcribers; and (3) projections of PCRS-induced cost savings in terms of specified (a) outyears, (b) levels of aggregation of data transcribers, and (c) levels of generalizability of test-site results.

It is recommended that managers of Navy activities with large numbers of civil service data transcribers evaluate the results of the PCRS field test from the perspective of possible implementation at their activities. Such managers should give special attention, of course, to issues underlying the generalizability of LBNSY results to sites under their control.

FOREWORD

This research and development was conducted in support of Exploratory Development Task Area ZF55.521.018, Organizational Management. The primary purpose was to determine the relationship between employee motivation and work performance. A better understanding of this relationship will assist in providing Navy management with information required to evaluate proposed policy changes aimed at making Navy organizations more productive and more compatible with their members.

The results of the study are primarily intended for use by various activities under the Chief of Naval Material: (1) the Production and Analysis Staff (NAVMAT-09H3), (2) the Incentive Awards Office (NAVMAT-09M41), (3) the Industrial Activity Management System Division (NAVSEA-073), (4) the Industrial Activity Performance Evaluation Division (NAVSEA-072), and (5) Navy shipyards. Much of the work is also useful to the Pay Division and the Incentive Awards Division of the Civil Service Commission, as well as to the Navy's Office of Civilian Personnel.

Appreciation is expressed to the staff of the Long Beach Naval Shipyard for their generous support and cooperation. Special appreciation is expressed to CAPT E. A. Miller, Commanding Officer; Elnora Haas, Acting Director, Management Information System Department; Jerry Hodge, Head, Operations Division; Virginia McMullen, Head, Digital Computer Operations Branch; Gene Sherseth, Head, Accounting Office; and the data transcribers who served as subjects.

J. J. CLARKIN
Commanding Officer

SUMMARY

Problem

Due to the high cost of human resources, the need to substantially reduce personnel costs without undermining the long-range quality and effectiveness of the work force continues to be a major Navy-wide concern.

Purpose

The purpose of this study was to evaluate a Performance-Contingent Reward System (PCRS) that uses economic incentives. The PCRS was tested on federal civil service data transcribers in the Management Information System Department of the Long Beach Naval Shipyard (LBNSY).

The evaluation was conducted primarily from the following perspectives: (1) the cost-effectiveness of the proposed PCRS relative to former production conditions at the test site, (2) the generalizability of the test's results to other Navy activities that have substantial concentrations of data transcribers, and (3) projections of PCRS-induced cost savings in terms of specified (a) outyears, (b) levels of aggregation of data transcribers, and (c) levels of generalizability of test-site results.

Approach

The design for the field test of the PCRS was essentially a before-and-after comparison of the productivity of the same subjects under PCRS and non-PCRS conditions. Specifically, the productivity of 17 qualified transcribers during a 13-week trial period was compared with their productivity during an equivalent base period. No control group was used because replication data were available from a similar site implementing PCRS and because the designation of such a group would probably have resulted in adverse effects on their morale.

Production-cost savings associated with the PCRS were derived. The nonrecurring setup costs incurred in implementing the PCRS were subtracted from these savings to determine the net cost savings for the trial period. In addition, the output, efficiency, and quality of the production process for the base and trial periods were compared to determine if cost savings associated with the PCRS had diminished overall production effectiveness.

Results

Based on productivity increases achieved by the 17 data transcribers, production-cost savings realized during the 13-week trial period exceeded $10,000. Since PCRS setup costs were less than $9,000, they were therefore fully recovered in less than one full quarter of operation. Furthermore, a comparative evaluation of the base and trial periods, in terms of production output (total keystrokes), production efficiency (keystrokes per man-hour), and quality of the production process (as measured by the size of the workload backlog and, separately, by the overtime needed), indicated that production-cost savings associated with the PCRS had not diminished overall production effectiveness as measured in physical units. In fact, the production-cost savings were primarily generated by a 14 percent increase in production efficiency.

Projections based solely on test-site parameters estimate cost savings for 1-, 3-, and 5-year periods at $45K, $146K, and $271K, respectively. In addition, projections of cost savings that correspond to specified sectors of the Navy community were derived.

Conclusions

Implementation of the PCRS on data-transcribing activities resulted in (1) a substantial reduction of production costs, and (2) no reduction in overall production effectiveness while reducing production costs. In addition, conditions during the trial period were noted that suggest that the cost savings actually accrued during that period considerably underrepresented the potential for long-range production-cost savings at that site and similar ones.

Recommendations

It is recommended that the managers of Navy activities with large numbers of civil service data transcribers carefully evaluate the results of this field test from the perspective of possible implementation at their activities. Such managers should give special attention, of course, to issues underlying the generalizability of the test-site results to sites under their control.

It is also recommended that appropriate procedures be initiated to evaluate the implications of modifying civil service policy regarding economic incentive awards.

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INTRODUCTION

Problem

The high cost of human resources requires that they be used efficiently to meet Navy goals and operational requirements. This is true for operational commands and their supporting activities alike. Thus, the need to substantially reduce personnel costs without undermining the long-range quality and effectiveness of the work force continues to be a major Navy-wide problem.

Purpose

The purpose of this study was to evaluate a Performance-Contingent Reward System (PCRS). The PCRS, which uses economic incentives, was tested on civil service data transcribers in the Management Information System Department of the Long Beach Naval Shipyard (LBNSY).

The PCRS was evaluated primarily from the following perspectives:

1. Cost-effectiveness of the proposed PCRS relative to former production conditions at the test site.

2. Generalizability of the test results to other Navy activities that have substantial concentrations of data transcribers.

3. Projections of PCRS-induced cost savings in terms of specified (a) outyears, (b) levels of aggregation of data transcribers, and (c) levels of generalizability.

Evaluating the PCRS from these perspectives casts the overall evaluation into a mode that would primarily interest military and civilian line managers in the Navy community. Because evaluating the generalizability of the results to other Navy activities is a major objective of this study, an appropriate balance of emphasis on financial, administrative, behavioral, and other issues dealing with PCRS implementation is required. In particular, data on financial issues will be presented in a form that is designed to be meaningful to all Navy civilian and military line managers (some of whom are not involved in financial analysis) and that enables their technical staffs to extend the data analysis, if necessary, to meet the specialized needs of their respective managers (who will be functioning at various hierarchical levels and in diverse organizational settings). Thus, the data are presented in a manner amenable, for example, to (1) adjusting cost-savings projections of constant dollars into dollars that reflect anticipated inflation, (2) converting future values of cost savings into their net present values, (3) conducting a sensitivity analysis on important parameters affecting the cost savings, and (4) calculating appropriate savings/investment ratios and investment payback periods.

Background

The general status of work incentives and related issues is well stated by Belcher (1974):

> Incentive plans are controversial. Opponents range from those who oppose the idea of performance rewards on the grounds that performance is a function of the organization of work and management practices rather than employee efforts, to those who oppose incentive plans on the grounds that they don't work and cause more problems than they solve. The decline, perhaps the disappearance, of incentive plans is often predicted.
>
> Proponents of incentive plans often believe that a "fair day's work" is not normally attainable in the absence of an incentive plan because the workers produce only about 50 to 60 percent of the output attained by incentive workers. Although they admit that some incentive plans malfunction, they insist that this is usually due to poor installation and maintenance rather than the concept of incentive. (p. 300)

This quotation amply illustrates the deep-seated nature of the controversy surrounding the effectiveness of work incentives. Most managers, wage and salary administrators, labor economists, industrial engineers, and behavioral scientists are well aware that the effectiveness of incentive plans depends on the situation in which they are applied. The following important issues must be addressed in any meaningful evaluation of incentive effectiveness:

1. Are the incentives distributed on an individual, group, or plant-wide basis?

2. Is the work machine-paced or essentially under worker control?

3. Are the employees primarily managerial and professional personnel or clerks and machine operators?

4. Are the incentives awarded for increased effort, performance, or what?

5. What is the basic climate in the work site in terms of such indices as the degree of decision-making participation, union/management relations, and the collective trust that nonmanagement personnel have in their management?

Given that the effectiveness of work incentives is contingent on the interrelationships of several complex issues, discussion of how the PCRS relates to these issues will be deferred until the system's basic procedure has been described and its test results evaluated. For those, however, who wish a fairly comprehensive review of this area, the literature discusses it from various substantive perspectives, of which the following are most relevant to this study: wage and salary administration (Belcher, 1974), industrial engineering (Fein, 1971), industrial/organizational psychology (Lawler, 1971), and labor economics (Perlman, 1969).

APPROACH

Hypotheses

The field study of the PCRS tested the following hypotheses:

1. Implementation of the PCRS will substantially reduce the production costs of data-transcribing activities.

2. Implementation of the PCRS will not diminish the production effectiveness of data-transcribing activities while reducing the costs.

These hypotheses are directly implied by the "Fixed Effectiveness" mode of cost-effectiveness analysis (Fabrycky & Thuesen, 1974). Simply stated, this means that when competing alternatives are equally effective the preferred alternative can be chosen on the basis of cost.

Variables

Independent Variable

The independent variable is the presence or absence of the PCRS. Individual "elements" of the PCRS will not be related separately to the various dependent variables; only the PCRS as a total system will be tested.

Dependent Variables

The dependent variable for measuring "cost" in this study of cost-effectiveness is cost-per-keystroke. In contrast, the dependent variables for measuring "effectiveness" are (1) level of production, (2) efficiency of production, and (3) quality of the production process, as defined in terms of workload backlog and the amount of overtime used.

Sample

The sample consisted of 17 female civil service data transcribers selected from three shifts in the Management Information System Department of the Long Beach Naval Shipyard (LBNSY). Of the 26 data transcribers available, the 17 were chosen because (1) they were fully qualified, as opposed to being in training, and (2) comparative information was available on each data transcriber for a specified interval (13 weeks) before the field test began, against which the trial-period results could be contrasted. It is important to note that the same 17 data transcribers constituted the sample in both the baseline period and the trial period.

Measures

Recharge Rate (RR)

This rate is the most important cost parameter used in this study, and is a multiple-component cost figure that represents the overall cost of the data-transcribing operation. (Derivation of the RR is described

in Appendix A.) The level of the RR is adjusted periodically by LBNSY's comptroller to ensure that data on the hourly cost per data transcriber are kept current. Components of the RR, and their cost levels as of this writing, are as follows:

1.	Basic Salary	$ 4.04
2.	Acceleration*	$ 1.31
3.	Supervision	$ 1.59
4.	Machines	$ 0.38
5.	Overhead (General & Administrative) .	$ 3.50
	Total	$10.82

*Represents the government's share of the costs of leave, pension, and other benefits.

Keystrokes

The number of keystrokes represents the combined print-and-verify activities of the data transcribers. Keystrokes are automatically tabulated for each data transcriber by the machine on which the work is done.

Regular Man-hours

Three kinds of man-hours must be considered:

1. Paycard man-hours--the basis on which a data transcriber's regular salary is calculated.

2. Assigned machine-time man-hours--the amount of time a particular data transcriber is assigned to operate a specified machine.

3. Actual machine-time man-hours--the amount of time actually spent operating the assigned machine.

The interrelationships of these different kinds of man-hours are described in Appendix B, which details the PCRS bonus computation.

Overtime Man-hours

This measure represents the number of man-hours permitted by site management to be paid at the overtime rate to keep the workload backlog within acceptable limits.

Backlog

Backlog, which is measured by the average number of batches of work remaining to be done, is calculated daily and averaged weekly. A batch is a set of tasks that is fairly homogeneous in content but whose size may vary. Thus, "batch" is a meaningful unit only when randomized across considerable periods of time, such as the number of work days in the base period (63 days) and the trial period (64 days).

Data Sources

Data on the measures just described were collected from sources presumed to vary considerably in their ability to reflect the PCRS's impact on various site activities during the trial period. To ensure that the data collected were the best available, the sources were given the following priorities:

1. Site Documents. Most of the extremely critical data regarding keystroke production, man-hours, etc., were taken from computer printouts that had summarized data directly from the source documents. This was almost the sole source for the important data used to calculate the production-cost savings.

2. Estimates From Site Management and Staff. When site documents were not available for required data, estimates were solicited from appropriate managers and from qualified members of the technical staff.

3. Records of Research Team. Sometimes, neither site documents nor site personnel were the best sources of the required data. In those instances, appropriate data were recorded or derived by the research team. An example would be the determination of total man-hours required by the research team from various types of site employees for various purposes.

4. Composite Source. Regarding some issues, none of the sources above was capable of providing adequate information by itself. One such issue dealt with determining possible hidden setup costs that might have been incurred but that were unrecorded and not otherwise readily accountable. Thus, representatives from LBNSY's accounting department and the research team jointly prorated such possible costs from the known setup costs.

Procedure

Brief summaries of the essential procedural steps of the PCRS are described here to illustrate that it is not merely an administrative program for dispensing incentives. Instead, the PCRS is a major organizational modification with a deep impact on several important dimensions of the work process and, thus, requires major changes in the roles of workers and supervisors alike.

The procedural requirements of the PCRS will be discussed in five phases: (1) preliminary issues, objectives, and activities, (2) development, administration, and testing, (3) preliminary evaluation, (4) modification and maintenance, and (5) full-scale evaluation.

Preliminary Issues, Objectives, and Activities

Site management's first major decision necessarily focused on whether or not the PCRS could help solve two serious problems: (1) low productivity, and (2) low morale, especially as it relates to turnover and the number of grievances. These problems, however, cannot always be alleviated by the PCRS. For example, if they are primarily due to the interactive effects of work force distrust of management and chronically bad union/management relations, then attempts to implement the PCRS could even make the problems

worse. This becomes especially apparent when the PCRS requirements that involve performance measurements, the establishment of work standards, and the method of payment are considered.

After LBNSY management had decided to implement the PCRS on a trial basis, an orientation procedure was carefully prepared to explain the system's implications in an accurate and meaningful way to supervisors and union representatives. The importance of this step cannot be overemphasized; without such an orientation, it is highly unlikely that the broad-based support and cooperation that are indispensable for successful implementation would have been received.

Development, Administration, and Testing

The important steps required for the initial development, administration, and testing of the PCRS are summarized below.

Questionnaire Development. This required (1) a careful definition of the problems involving productivity, morale, and related issues, and (2) discussions of how the PCRS might affect them. Information regarding these problems was collected from many sources, including managers, union representatives, workers, supervisors, and staff specialists. The information provided the basis for developing a prototypic questionnaire dealing, among other things, with the general conditions of work, the way employees viewed their own capabilities to attain various levels of performance, employees' expectations of rewards associated with such levels, and the importance of those rewards to recipients (Nebeker, Dockstader, & Shumate, 1978). This information was invaluable for the PCRS's development because the information partially answered two fundamental questions: (1) Did the data transcribers perceive themselves as capable of increasing their performance if effective incentives were available? and (2) What types of rewards would be effective as performance incentives?

Workflow Analysis, Performance Measurement, and Results Feedback. The PCRS requires an analysis of the work process and elimination of inefficiencies, if possible. At LBNSY, for example, each data transcriber formerly picked up her work at the supervisor's station and returned it upon completion. This reduced the time that each data transcriber could spend on the machines. These procedures were modified so that the supervisors passed out and collected the assigned work, thus minimizing disruptions of machine-operation time and increasing productivity. After all of the modifications were completed, means were devised to accurately measure performance under the new work procedures and to feed back the results quickly and regularly. A weekly Operator Analysis Reporting System (OARS) was developed for this purpose.

Goal-setting, Criterion Development, and Work Standards Derivation. The objectives of management and the capabilities of OARS were the primary bases used to establish performance goals and criteria in the Management Information System Department. In addition, performance standards were developed for the 190 procedures performed by the data transcribers. Collectively, these steps are extremely important to the long-range success of the PCRS. Unless they are done well, the PCRS will inevitably fail, regardless of the degree of managerial support and work-force cooperation it receives.

After the performance standards had been derived, it was possible to compare individual performance with the standards to determine each transcriber's relative efficiency. The degree to which a transcriber's efficiency exceeded the standards for assigned tasks determined the size of her financial bonus. Thus, incentive awards were contingent on performance and nothing else.

A common complaint of managers regarding some types of incentive plans is that they require too much time to administer equitably and smoothly. In contrast, a significant attribute of the PCRS is that it requires little management decision making once it is fully implemented; records of performance, bonuses accrued, bonuses paid, etc. are all accomplished by the OARS report. Thus, the fully operational PCRS requires only minimal managerial guidance.

Bonus-payment Procedure. The amount of bonus earned was calculated weekly. When $25 had been accumulated, an individual could request payment. Bonuses were paid monthly. Separate checks were issued for the bonuses because they were not drawn from "Compensation" funds but from funds administered by LBNSY's Incentive Awards Division. In addition, separate checks more clearly identify the bonuses as representing superior productivity; such identification may help motivate each individual to sustain higher productivity.

Supervisory Training. The PCRS implementation required several important changes in the activities and responsibilities of the supervisors involved, especially regarding work distribution.

Preliminary Evaluation

A preliminary cost-effectiveness evaluation of the PCRS was started after the initial results appeared to stabilize into meaningful patterns. After one full quarter of operation, tentative conclusions about the PCRS's effectiveness could already be made (see CONCLUSIONS).

Modification and Maintenance

Even before the preliminary cost-effectiveness evaluation was begun, some necessary modifications were identified, including special training for the supervisor in charge of the Digital Computer Operations Branch, whose responsibilities included dealing with PCRS issues that affected the supervisors of various production shifts. Similarly, an "Incentive Management Coordinator" was trained to initiate resolution of PCRS issues affecting various staff functions such as payroll, comptroller, industrial engineering, and industrial relations.

To ensure the PCRS's continuity, a manual will be developed that gives detailed guidance for updating and generally maintaining the PCRS near maximum effectiveness. The manual will provide guidance, for example, for detecting when work standards must be changed due to task modifications, alterations in technology, changes in worker skill levels, or other important developments in the workplace. The importance of timely modification of the PCRS to adapt to workplace dynamics cannot be overstressed (Fein, 1971).

Full-scale Evaluation

After additional modifications have been incorporated into the PCRS (see RESULTS AND DISCUSSION) a more comprehensive cost-effectiveness evaluation will be undertaken when the PCRS has had an adequate period of full operation. This evaluation will address the basic question of whether or not the PCRS has effected substantial cost savings while not reducing (1) the level, efficiency, and quality of the production process, or (2) the long-range effectiveness and quality of the work force. Moreover, the evaluation will be made on a comparative basis across similar sites; such comparisons can provide valuable information about the cost-effectiveness of the PCRS at a given site relative to other sites that are and are not using it.

If the evaluation gives convincing evidence that the PCRS is desirable in the department used for the original test, management may also wish to test the PCRS in other departments that have different tasks, workers, and settings.

Analysis

Rationale and Scope

As described earlier, this analysis was conducted in accordance with the fixed-effectiveness mode of cost-effectiveness analysis (Fabrycky & Thuesen, 1974; Kazanowski, 1968). This requires that the preferred alternative be chosen on the basis of cost, given that all alternatives are equally effective. The alternatives in the present case are, of course, PCRS and non-PCRS production conditions at the test site.

This analysis was strictly limited to test-site impact. This was very important in determining which costs were to be included in the analysis. The research team's salaries and related costs, for example, were excluded because they were outside the scope specified.

Field-test Design

The design for this field test of the PCRS was essentially a before-and-after contrast that used the same subjects and no control group. There were two important reasons why no control group was used: First, replication data were available from a similar site that was also implementing the PCRS. Second, and even more important, the use of a control group might have resulted in adverse effects on the long-range motivation and morale of those subjects designated as ineligible to receive economic incentive payments during the trial period.

Selection of the base period against which the trial-period results could be contrasted involved two primary considerations--length of period and appropriate calendar interval. In terms of length, one full quarter (13 weeks) was judged adequate for a meaningful preliminary evaluation of PCRS impact.

Choosing the calendar interval for the base period was more difficult. Before-and-after periods, for the best comparison, should generally be contiguous. In the case at hand, however, there was concern that possible awareness by the subjects of preimplementation discussions among site

management could have influenced the base-period data in some unknown way. Such influence could undermine the credibility of the before-and-after contrast. To prevent that, the calendar interval that was designated as the base period began approximately 6 months before the beginning of the trial period. Thus, the base period extended from 5 July through 2 October 1976; the trial period, from 17 January through 16 April 1977.

Technique

The fixed-effectiveness mode of cost-effectiveness analysis was applied to the present case as follows:

1. All PCRS-related costs incurred before and during the trial period were determined and categorized as (a) nonrecurring costs associated with setting up the PCRS and (b) recurring costs associated with actual production. Production costs associated with the PCRS were divided by keystroke output during the trial period to determine that period's cost-per-keystroke. Similarly, base period production costs were divided by that period's keystroke output to yield its cost-per-keystroke.

2. The difference in cost-per-keystroke between the two periods was multiplied by the keystroke output of the trial period. This provided the production-cost savings associated with PCRS implementation.

3. An evaluation was made to determine if implementing the PCRS had diminished production effectiveness while the production-cost savings were being generated.

4. Net savings for the trial period were determined by subtracting setup costs from production-cost savings. Savings projections based solely on trial-period parameters were then derived.

5. Savings projections based on specified levels of aggregation and generalizability were derived.

RESULTS AND DISCUSSION

PCRS Setup Costs

The nonrecurring costs incurred while setting up the PCRS at the test site (as detailed in Appendix C) are summarized below:

1. Recorded Costs

a.	Equipment Purchased	$ 855.55
b.	Software Development	$3693.00
c.	Personnel Training	$3562.18
	Total Recorded Cost	$8110.73

2. Possible Unrecorded Costs

(Estimated 10% of total recorded costs)	$ 811.07
Total Setup Costs	$8921.80

The above figures reflect a determined effort to include all possible nonrecurring setup costs associated with implementing the PCRS. In addition to the explicit costs (e.g., equipment purchased), there were also implicit costs such as (1) the time spent by test-site technical personnel (e.g., the computer programmer who developed the required software), and (2) the decrease in keystroke production while data transcribers and supervisors were being trained for PCRS operations. Finally, a substantial adjustment for possible nonrecorded costs was included.

Cost Savings

The overall cost savings of the PCRS relative to the costs of former production conditions at the test site can be meaningfully compared by focusing separately on (1) the savings generated by production-cost reduction, and (2) the net savings remaining after all setup costs were absorbed.

Production-cost Savings

Deriving the production-cost savings required comparative data on two basic dimensions: production costs and production output. The test-site comptroller derived and periodically updated the Recharge Rate (RR), which represents the overall hourly production cost, per data transcriber, of the following aspects of the data-transcribing operation (detailed in Appendix A): (1) data transcribers' basic salaries, (2) the government's share of the data transcribers' pensions and other benefits, (3) machines used, (4) supervisors' salaries, and (5) overhead.

Production costs for the base and trial periods are compared in Table 1. Production output figures, in terms of cumulative keystrokes, for the base and trial periods were 35,554,496 and 37,117,213, respectively. These figures included the combined print/verify activities of all shifts involved in the data-transcribing operation at the test site, as detailed in Appendix B.

Table 1

Comparative Production Costs of
Base Period and Trial Period

Costs	Base Period	Trial Period
RR x Man-hours[a]	$83,874.48	$76,760.32
OT x Man-hours[b]	1,045.95	243.21
PCRS Bonus Payments[c]	---	916.50
PCRS Administrative Costs[d]	---	450.00
Total	$84,920.43	$78,370.03

[a]Current Recharge Rate (RR) is $10.82 per hour. The base period used 7751.8 total man-hours; the trial period, 7094.3. Of the total man-hours used in comparative periods, the inclusive man-hours paid at the overtime rate are specified in Footnote b.

[b]Overtime rate (OT) is 1.5 times the basic hourly salary. Thus, $2.02 represents the 0.5 overtime component cost. Overtime man-hours for the base and trial periods were 517.8 and 120.4, respectively.

[c]PCRS bonus-payment calculation is detailed in Appendix B.

[d]PCRS administrative costs were estimated by a representative of the test-site comptroller. At the level of costs listed above, the estimate is intended to cover all posssible costs of PCRS requirements for special records-keeping, computer, payroll, and miscellaneous services.

Given the comparative production cost and production output presented above, the production-cost savings can be derived by multiplying the inter-period difference of cost-per-keystroke by the keystroke output of the trial period. The relationships are illustrated in the following formula:

$$\left[\frac{\text{Production Cost (base)}}{\text{Production Output (base)}} - \frac{\text{Production Cost (trial)}}{\text{Production Output (trial)}}\right] \text{Production output (trial)} = \text{Production-cost savings of trial period}$$

Inserting appropriate values into the formula yields the following result:

$$\left[\frac{\$84,920.43}{35,554,496} - \frac{\$78,370.03}{37,117,213}\right] (37,117,213) = \$10,281.47,$$

which indicates that $10,281.47 in production-cost savings were generated during the 13 weeks of PCRS evaluation on 17 civil service data transcribers.

Net Savings

The net savings generated during the trial period were the production-cost savings remaining after subtracting all setup costs. Thus, the production-cost savings of $10,281.47, when reduced by the total setup costs of $8,921.80, leave a net savings of $1,359.67.

Net savings of the PCRS trial period, as derived above, must be carefully interpreted. The primary issue is whether or not it is appropriate to absorb, during the trial period itself, all of the nonrecurring setup costs incurred during PCRS implementation. An alternative way to recover the setup costs is, of course, to prorate them over a specified number of accounting periods. This increases the net savings for the trial period but reduces the production-cost savings during the periods over which the setup costs are prorated. In this study, however, the setup costs were totally absorbed in the trial period for two reasons.

First, this method demonstrated emphatically that such costs were less than the savings generated solely from reductions in production costs during the same period. This is very important; it clearly shows that nonrecurring setup costs were fully recoverable in less than one full quarter of operation. Few investments have such short "payback" periods. Furthermore, the probable recovery periods for other Navy sites implementing the PCRS would be even shorter when possible economies of scale are considered; that is, the setup costs of similar Navy sites implementing the PCRS can reasonably be expected to decrease substantially. Such decreases could occur, for example, by appropriately adapting the software, developed at the test site, to meet the relevant particulars of other Navy sites. These adaptations could effect substantial reductions in setup costs when contrasted with the alternative of each site developing its software from scratch. Similarly, the PCRS-oriented questionnaire that was developed at the test site presumably could be readily adapted to other sites, and could thereby effect another major reduction in setup costs.

Second, this method facilitated interpretation of cost-savings projections that were based solely on test-site parameters. In particular, this method of handling the setup costs permitted the cumulative savings value for the specified outyears to be derived as the sum of (1) trial-period net savings (i.e., after all recurring setup costs were recovered) and (2) posttrial-period savings based solely on production-cost reduction (i.e., without adjustments for distributed setup costs).

Interrelationships among the PCRS setup costs, net savings, and production-cost savings have now been evaluated in terms of their impact on the monetary results of the trial period. Based purely on the reduction of production costs, savings exceeded $10,000 for the PCRS trial period. Given that the trial period involved only 17 subjects for 13 weeks, such savings are noteworthy--especially when generated during a period when the many inevitable problems associated with implementing any new major system had to be solved.

PCRS Impact on Production Effectiveness

The PCRS's superiority to former production conditions at the test site has been demonstrated in terms of costs. Not yet demonstrated, however, is the impact that PCRS implementation had on test-site production effectiveness.

The nonmonetary dimensions of production effectiveness on which the impact of PCRS implementation was evaluated were (1) the level of production, as measured by total keystrokes, (2) the efficiency of production, as measured by keystrokes per man-hour, and (3) the quality of the production process, as measured by (a) the number of higher-cost overtime hours used to keep workload backlog within acceptable limits, and (b) the number of average daily batches (as defined previously under Measures in the APPROACH section) in workload backlog. Quality of production output--as measured by the keystroke error rate--was determined by site management to be within acceptable limits even before the PCRS was implemented. Therefore, the quality of output was not explicity evaluated during the PCRS field test. It should be noted, however, that, since the quantity of output is strictly limited to keystrokes "verified" as correct, the quality of output is essentially held constant across the interperiod comparison of overall production effectiveness. The results of the production effectiveness evaluation are summarized in Table 2.

Table 2

Comparative Production Effectiveness of Base Period and Trial Period

	Base Period[a]	Trial Period[b]	Direction & Amount of Change	Direction of Change Desirable?
Level of Production	(36,118,853)	37,117,213	+2.76%	Yes
(Keystrokes)[c]	35,554,496			
Production Inputs Used (Total Man-hours)[d]	7751.8	7094.3	-8.5%	Yes
Efficiency of Production (Keystrokes per Man-hour)	4587	5232	+14.1%	Yes
Quality of Production Process				
Excess-Cost Penalties (Overtime Man-hours Used)	517.8	120.4	-76.8%	Yes
Workload Arrearage ("Batches")[e]	45.78	2.72	-94.1%	Yes

Note. The dimensions of production effectiveness listed were selected on the basis of relevance to test-site management's goals of increasing the level, efficiency, and quality of data-transcribing workflow.

[a]Base Period extended from 5 July to 2 October 1976. Period had 2 holidays and 63 work days.

[b]Trial Period extended from 17 January to 16 April 1977. Period had 1 holiday and 64 work days.

[c]Computation used adjusted output (in parenthesis) for Base Period, which had one less work day than Trial Period. Adjustment added daily rate to raw total.

[d]Man-hours alone is not an accurate indicator of production effectiveness because the used man-hours can vary considerably for the comparative periods due to the number of holidays, the amount of annual or sick leave taken, etc. When used in conjunction with other production indicators, however, the number of man-hours used is very important (e.g., in determining the efficiency of production in terms of keystroke output per man-hour input).

[e]Measured in terms of the number of swing-shift batches of backlog, on basis of daily average. The comparative ranges of the two periods are as follows: Base Period--High, 76; Low, 23. Trial Period--High, 24; Low, 0. The comparative number of zero-backlog days were 0 and 58 for the Base Period and Trial Period, respectively. The swing-shift was the only work shift for which workload backlog records of the Base Period were available.

Table 2 shows that the overall production effectiveness of the test site was not diminished by PCRS implementation when evaluated in terms of nonmonetary units. In fact, each of the respective values of data corresponding to the dimensions of level, efficiency, and quality of the production process was better during the trial period than during the base period. Tests for statistical significance, therefore, are not required because any statistically significant differences found could only demonstrate the superiority of production effectiveness during the trial period. However, the fixed-effectiveness mode of cost-effectiveness analysis only requires that the alternative preferred on the basis of cost (i.e., the PCRS) is not inferior on basis of effectiveness (Fabrycky & Thuesen, 1974), and Table 2 clearly shows this to be the case. In addition, these results from preliminary cost-effectiveness analysis may have understated considerably the full potential of the PCRS for long-range cost reductions of data-transcribing activities. Some of the major reasons for the probable understatement are the following:

1. The increase in productivity during the trial period led to the elimination of the workload backlog accumulated prior to PCRS implementation. Consequently, there was often insufficient work to keep all data transcribers busy, thus restricting the potential productivity increase.

2. Many of the important but unpredictable problems that inevitably accompany implementation of a major system such as the PCRS had to be solved during the trial period, thus further restricting potential gains in productivity during this period relative to test-site productivity after the trial period ended.

3. Raw data from the PCRS at a similar activity appear to be equal or superior to data from the test site for comparable stages of the trial period.

4. The research team could detect no informal evidence toward the end of the trial period or thereafter to suggest that the PCRS was having other than a primarily positive influence on work-force variables such as turnover, absenteeism, supervisory relations, union/management relations, and morale. However, temporary test-site limitations on information systems relating to these variables necessitated their exclusion from the preliminary cost-effectiveness analysis. Thus, the results presented in this study probably undervalue the long-range cost savings attributable to the PCRS impact on data-transcribing activities at the test site.

PCRS impact on production costs and on the level, efficiency, and quality of the workflow has been tested but its impact on the work force itself remains unknown. Because the PCRS's impact on the aforementioned workforce dimensions has important implications for the long-range trends of the workflow, those dimensions must be systematically evaluated. To provide such information, an appropriate information system must be developed and implemented at the test site. As a minimum, the system must provide information that will permit accurate answers to the following questions: (1) What production, administrative, and other organizational effects are associated with major changes in the level of a work-force variable (e.g., turnover)? and (2) How can such effects be quantified and converted into appropriate monetary units that will enable a cost-effectiveness analysis?

Developing and implementing the information system described is a complex undertaking. Moreover, the literature on human resource accounting is still evolving in terms of the theoretical relationships on which such information systems are based, and results from field tests of such relationships have not established a comprehensive and totally consistent pattern of findings (Flamholtz, 1974; Likert, 1967). As a result, theoretical and empirical guidance regarding such information systems is limited. Developing and successfully implementing the information system will therefore require successive modifications until satisfactory results (in terms of the accuracy and cost of the information provided) are achieved.

If an information system can be implemented at the test site that will provide the information required to include work-force variables in a cost-effectiveness analysis of the PCRS, then the same system will also be implemented at another Navy activity that already has the PCRS in operation. In contrast to the present analysis, which was strictly limited to production costs and workflow variables, a more comprehensive cost-effectiveness analysis then can be conducted that will take into account the following factors: (1) multiple sites, (2) a much larger number of data transcribers, (3) a longer trial period, and (4) multiple cost criteria that reflect work-force as well as workflow variables. Overall, the results from an analysis expanded in this form would add greatly to an understanding of the true cost-effectiveness impact of the PCRS on data-transcribing activities at Navy sites. Until such a comprehensive analysis is done, it must be concluded from the results of the preliminary analysis reported in this study that the PCRS appears to have considerable potential but awaits broad-based confirmation from further field tests.

Test-site Savings Projections

While the net savings associated with implementing the PCRS were noteworthy in and of themselves, of far greater interest to test-site management and others is the cumulative value of the PCRS savings when projected through specified outyears. Projections based on a savings rate identical to the trial period and representing 1, 3, and 5 years are shown in Table 3.

The projections list cumulative values by combining the actual net savings and the projected production-cost savings generated during and after the trial period, respectively. The production-cost savings were compounded monthly because LBNSY used a monthly accounting period to determine the eligibility of individual data transcribers to receive cash bonuses. Since such bonuses represented a portion of the production-cost savings that had already accrued during the monthly accounting period, projections based on coinciding compounding and periodic-payment intervals are warranted (Fabrycky & Thuesen, 1974). In the present case, this simply means that the production-cost savings previously accrued were compounded on the same date that the next monthly increment of savings was accrued.

Table 3

Test-site Savings: Actual and Projected

Outyear (end of)	Lump-Sum Savings Compounding[a]			Periodic Savings Compounding[b]			Total Savings Value
	Lump-Sum Savings (in $)	Compounding[c] Factor	Compounded Value (in $)	Projected Monthly Savings (in $)	Compounding[d] Factor	Compounded Value (in $)	Lump-Sum and Periodic Savings (in $)
1	1,360	1.11	1,510	3,427	12.595	43,163	44,673
3	1,360	1.37	1,863	3,427	42.138	144,407	146,270
5	1,360	1.69	2,298	3,427	78.547	269,181	271,479

Note. Projections for the periodic savings are based on coinciding compounding and series-payment intervals, as described in Fabrycky and Thuesen (1974). Interest rate used is 10 percent, as prescribed in DODINST 7041.3 (Note 1). All projected savings are in Net Future Values (NFV) that reflect effective values at end of specified outyear.

[a]Actual cost savings, after absorbing setup costs, recorded during PCRS trial period.

[b]Projected cost savings after PCRS trial period ended, and exclusive of setup costs that were absorbed previously.

[c]Assume that the actual trial-period net savings were "deposited" 1 month after that period ended, on a lump-sum basis.

[d]Assume that the first payment of projected production-cost savings had accrued exactly 1 month after trial period ended, and would recur monthly.

The lump-sum savings are also compounded monthly to coincide with the compounding cycle of the production-cost savings. This facilitates interpretation of the cumulative projected value derived from combining the actual trial-period net savings and the projected production-cost savings. It should be noted, however, that monthly compounding of the lump-sum savings probably represents a conservative bias in the overall projections because many financial institutions would compound such lump-sum savings on a "continuous" basis, which generates a higher yield. For details on how the compounding factors were derived and on related issues, see Appendix D.

Navy Community Projections

While projections of PCRS savings based solely on trial-period parameters provide valuable information to test-site management, such projections are of limited utility to the Navy as a whole. To be meaningful from that perspective, the projections must reflect (1) specified levels of aggregation of civil service data transcribers in other Navy organizations, and (2) specified levels of generalizability of test-site results to other Navy sites. From this point on, therefore, this report will necessarily deal with issues that, while stemming primarily from test-site results, have important implications for other sites and activities of the Navy community in which the PCRS may be implemented.

Levels of Aggregation

To derive projections of PCRS cost savings that represent a progressively wider scope, civil service data transcribers in Navy organizations were aggregated at three overlapping levels: (1) the full complement available at the test site, (2) the approximate number available in the shipyard community, and (3) the approximate number available throughout NAVMAT.

There were 26 civilians performing data-transcribing activities at the test-site shipyard during the PCRS trial period, some of whom were not eligible for inclusion in the PCRS evaluation. (The criteria for inclusion are described under Sample in the APPROACH section.) All data transcribers at the test site, however, operated under PCRS conditions during the trial period.

At the level of the shipyard community, a survey of personnel staffing levels of the individual shipyards located at least 200 civil service data transcribers. At a still higher level of aggregation, the same survey located at least 725 data transcribers in shipyards, supply centers, ordnance depots, and other NAVMAT activities that require extensive data processing.

Levels of Generalizability

The broad issue of how well the test-site results can be generalized to other Navy activities can be split into subordinate issues dealing primarily with (1) the credibility of the trial-period results as representative of long-range results at the test site, and (2) the comparability of other Navy activities to the test site. Splitting the issues in this manner is somewhat artificial in that many of them are interrelated, but it is helpful in illustrating that generalizability involves two primary components that, though interrelated, can be meaningfully evaluated separately. After the credibility and comparability issues are qualitatively evaluated, their combined impact on the cost-savings projections will be quantitatively derived.

Credibility. Evaluating the following issues will assist in determining the credibility of the trial-period result in terms of representing the long-range results at the test site, assuming that the PCRS is continued in operation:

1. Field-test design and trial-period parameters. In essence, the PCRS field test consisted of comparing data across two 13-week periods on the same 17 subjects with no control group; the primary reasons for not using a control group were explained previously under Analysis. Thus, given the nature of the field test and the limited scope of this preliminary cost-effectiveness analysis, it is inappropriate to assert that the results are unequivocally due to the PCRS. The cost savings derived from higher productivity could, for example, stem mostly from what is broadly known as the "Hawthorne Effect." If true, this would mean, among other things, that the results are due simply to the subjects' reaction to the heightened attention that management and the research team focused on individual and collective productivity during the trial period. The increased productivity during the trial period may not, therefore, be representative of a long-range trend. (It is important to note, however, that the research team had been actively working with the subjects for over a year before the PCRS took effect, during which time no increase in productivity was observed.) Alternatively, it is far more plausible that the data transcribers were motivated toward high productivity by the performance-contingent economic incentives. If this is true, then the increased productivity should be maintained as long as the PCRS remains in effect. Whatever the case, the primary reason for the trial period's increased productivity--and the implied duration of such productivity--cannot be determined conclusively from results of the field test and preliminary analysis. It should be noted, however, that this research has not been concluded. Data from multiple sites, additional performance measures, and more comprehensive analyses will be used in later evaluations.

2. Impact of critical incidents and extraneous factors. Shortly before the trial period began, the director of the Management Information System Department at LBNSY resigned. The impact of this event is difficult to determine because there was no control group. It is possible, however, that the event depressed the possible increase in productivity because the data transcribers may have experienced uncertainty regarding the incentive program's continuance. If it had been discontinued, their increased productivity would have been unrewarded. Thus, the change of directors may have depressed the cost savings generated during the trial period despite the fact that the change occurred after the base period had ended and before the trial period had begun; that is, the cost savings associated with the PCRS were measured, in part, as the difference in production costs between the base period and the trial period, and the incident may have had a deferred impact on the latter.

Another incident that could have influenced the results involved an exchange of shift supervisors on the day and swing shifts in the interval between the base and the trial periods. The incident had important implications because the day shift had a considerably larger number of data transcribers assigned to it than the swing shift. Thus, if the increased productivity during the trial period was primarily due to supervisory practices

and not due to the PCRS, then the exchange of supervisors could have had a major impact on the results. As shown in Appendix E, however, keystroke productivity for the swing shift increased proportionally more than for the day shift when production efficiency in terms of keystrokes per man-hour is contrasted within shifts across periods.

The extraneous factor that may have had the greatest immeasurable impact of all on the trial-period results is the fact that the data transcribers frequently ran out of work during the latter part of this period--even the large workload backlog that was accumulated before the PCRS's implementation was eliminated during this time. If the increase in productivity during the trial period was, in fact, due to the implementation of the PCRS, then this extraneous factor is significant for two reasons: (1) it imposed a situational constraint on the amount of potential productivity increase that the PCRS could demonstrate on the basis of a 13-week trial period, and (2) it may have seriously undermined the data transcribers' motivation to sustain the increased productivity due to their possible anxiety over management's potential reaction to the data-transcribing operation being chronically "overmanned," which primarily resulted from increased productivity during the trial period. Such possible anxiety has its foundation in the fact that management issued no policy statement before or during the trial period to the effect that any overmanning caused by increased productivity would be remedied by normal attrition, voluntary transfers, etc., as opposed to reductions-in-force, involuntary transfers to other departments, or similarly undesirable alternatives.

There is a strong possibility, therefore, that the inadequate workload and its possible consequences prevented the PCRS from demonstrating its full potential for increasing productivity during the trial period.

3. Motivational durability of the PCRS. Another important factor in determining how credible the trial-period results are in terms of representing the long-range results at the test site if the PCRS is continued in operation is, of course, the effect of features inherent in the PCRS itself. Of particular significance are those features involving (a) the derivation, composition, and level of work standards, (b) the level of economic incentives to be awarded for productivity exceeding work standards, and (c) the computation and timing of productivity-bonus payments. The overall question regarding these features is whether or not they collectively form a functional and administrative foundation capable of "motivating" data transcribers toward higher productivity over the long run.

Comparability. In addition to the credibility issues described above, the generalizability of the test-site results to other Navy sites is also greatly dependent on the overall comparability between the test site and other activities. In particular, to what degree can the test-site results be replicated at other sites in the shipyard community or NAVMAT activities that implement the PCRS in data-processing departments? The following are some dimensions that the management of other activities considering PCRS implementation should evaluate:

1. The similarity of basic technology and work force to that at the test site. That is, how comparable are the data-processing equipment, work tasks, and quality of data transcribers at other sites to those at the test site?

2. Site history. If recent history includes the failure of a previous economic incentive program, then support and cooperation from data transcribers and other affected personnel cannot reasonably be expected to be high during implementation of a program similar to the PCRS.

3. Work force "trust" in management. If the work force believes that increased productivity during the PCRS trial period might lead to management setting higher standards for "normal" productivity, or to reductions-in-force due to overmanning (assuming that workload remains constant), then, again, the PCRS trial period will probably not result in noteworthy productivity increases. A policy statement by top management that would address both of these issues would benefit any activity considering PCRS implementation.

4. Union support. If the unions involved do not support the PCRS's basic features, then its ultimate failure is almost a certainty.

The test-site results apparently can be substantially generalized to other Navy sites, based on preliminary data from another Navy shipyard in which the PCRS has also been implemented on a trial basis. Although results from this site have not yet been summarized in a manner permitting statistical comparisons with the test site, the raw data appear to be as good as or better than those of the test site for comparable stages of the trial period.

Quantifying the Credibility/Comparability Issues. The interdependent nature of the credibility and comparability issues can be quantified to estimate their combined impact on the generalizability of test-site PCRS savings to other Navy sites. This is done by assigning numerical weights to the trial-period results in accordance with their subjective values in terms of credibility and comparability implications. For example, if, after careful consideration of test-site conditions and events during the trial period, a manager contemplating PCRS implementation decides that the trial-period results described above were probably lower than what they will generally be for equal-length periods at that test site through the long run, the manager would assign an appropriate numerical weight greater than one (e.g., 1.25) to compensate for the understated trial-period results. This numerical weight would then represent the collective credibility issues in determining the generalizability factor.

Similarly, if the same manager identified important conditions at his site that definitely diminished the comparability between the test site and his own, he would assign an appropriate numerical weight less than one (e.g., 0.75) to compensate for the incomparabilities noted. This numerical weight would then represent the collective comparability issues in determining the generalizability factor.

The separate numerical weights are then multiplied together to form the product that will represent the overall generalizability of the

PCRS cost savings generated during the test-site trial period to the particular conditions at his own site. Thus, the generalizability factor, if the numerical weights in the example are used, is (1.25) x (0.75) = .9375. Given that the production-cost savings associated with the PCRS at the test-site were $10,281.47, then ($10,281.47) x (.94) would be an appropriate estimate of the cost savings that the PCRS would generate during a trial period of equal length at the second site if the same number of data transcribers (17) were used.

Projections Reflecting Combined Aggregation/Generalizability Impact

Projections of production-cost savings that reflect the combined impact of levels of aggregation and levels of generalizability are shown in Table 4. The projections are not based on net savings (i.e., after setup costs are absorbed) for the following reasons: (1) PCRS setup costs are so small relative to production-cost savings that such costs were recoverable in less than one full quarter of operation at the test site; therefore, setup costs have minimal significance in long-range projections of PCRS savings, and (2) setup costs at the test site are amenable to economies of scale from the perspective of other Navy sites. That is, several end-products generated from setup costs at the test site--such as the software package and PCRS questionnaire--can be readily adapted to the data-transcribing activities at other Navy sites.

In Table 4, special note should be given to the extensive range of the projected-savings values that correspond to different levels of aggregation and generalizability. Within the 3-year projections, for example, while at the generalizability level of 1.00, the value of the production-cost savings ranges from $221,000 to $1.7 million to $6.2 million when aggregated from the "Test-site Shipyard" to "All Shipyards" to the "NAVMAT Community." Similarly, within the 3-year projections and remaining at the level of aggregation of All Shipyards, the value of savings ranges from $849,000 at the 0.50 level of generalizability to $2.5 million at the 1.50 level of generalizability.

Due to this extensive range in the value of the projected savings, it is important that managers with control over the various aggregation levels carefully evaluate the credibility/comparability issues that underlie the generalizability of the test-site results to other Navy sites. Without such an evaluation, expectations of savings to be derived from PCRS implementation at other Navy sites may be extremely inaccurate.

Table 4

Projections of Production-cost Savings: By Level of Aggregation and Level of Generalizability

Aggregation Level[a]	Projection Factor[b]	Outyear Savings (in $)[c]		
		1 year	3 years	5 years
Generalizability Level of 0.50				
Test-site Shipyard	2,622	33K	110K	206K
All Shipyards	20,152	254K	849K	1.6M
NAVMAT Community	73,084	920K	3.1M	5.7M
Generalizability Level of 0.75				
Test-site Shipyard	3,933	50K	166K	309K
All Shipyards	30,228	381K	1.3M	2.4M
NAVMAT Community	109,626	1.4M	4.6M	8.6M
Generalizability Level of 1.00				
Test-site Shipyard	5,244	66K	221K	412K
All Shipyards	40,303	508K	1.7M	3.2M
NAVMAT Community	146,168	1.8M	6.2M	11.5M
Generalizability Level of 1.25				
Test-site Shipyard	6,554	83K	276K	515K
All Shipyards	50,379	635K	2.1M	4.0M
NAVMAT Community	182,710	2.3M	7.7M	14.4M
Generalizability Level of 1.50				
Test-site Shipyard	7,865	99K	331K	618K
All Shipyards	60,455	761K	2.5M	4.7M
NAVMAT Community	219,253	2.8M	9.2M	17.2M

Note. Interest rate used is 10 percent, as prescribed in DODINST 7041.3 (Note 1).

[a]The numbers of data transcribers located at the specified levels of aggregation were as follows: Test-site Shipyard, 26; All Shipyards, 200; and NAVMAT Community, 725.

[b]The Projection Factor is determined by the following product: (Trial Period Production-Cost Savings at Monthly Rate) x (Aggregation Factor) x (Generalizability Factor). As detailed previously in text, the test-site savings in production costs during one full quarter (13 weeks) of operation were $10,281.47, which implies a monthly savings rate of $3,427 after rounding. The aggregation factor is N/17, where N represents number of data transcribers at specified level of aggregation, as described in Footnote a; the 17 in denominator represents number of data transcribers used during trial period. Derivation and interpretation of the generalizability factor were described in text.

[c]Compounding factors used in the projections are based on coinciding compounding and savings periods (monthly), as described in Fabrycky and Thuesen (1974). Compounding factors corresponding to the 1-, 3-, and 5-year projections are 12.595, 42.138, and 78.547, respectively. Derivation of the compounding factors is outlined in Appendix D. Projected savings are rounded to nearest unit for the K-valued entries and to nearest tenth of unit for M-valued entries where K = 1000 and M = 1,000,000. All savings are in Net Future Values (NFV) that reflect effective values at end of the specified outyear.

Integration of Results, Projections, and the State-of-the-Art

As reported earlier, the effectiveness of economic incentives is highly controversial because it depends on the overall work situation in which such incentives are applied. While the results described in this report represent data from only 17 subjects at a single test site for a trial period of 13 weeks, the projections based on those results were made for periods extending through 5 years and at levels of aggregation that reflect hundreds of data transcribers from diverse Navy sites. This raises a fundamental question: Are such projections based on a semblance of realism or its substance? If the latter, what inherent features of the PCRS presumably warrant such long-term and broad-based projections? In relation to data-transcribing activities, some of those features are the following:

1. PCRS incentive rewards are tightly linked to documented performance. Because the PCRS is strictly contingent on demonstrated performance, its motivating value should not diminish as a result of employees' expectations that the incentive rewards will be given as a matter of course. Incentive programs can lose their effectiveness when the tight linkage between performance and rewards becomes loosened (e.g., through basing rewards on subjective evaluations of performance by supervisors).

2. Data-transcribing activities provide a precise measure of performance. Few measures of performance can be more objective and precise than keystroke per operator per time period. The PCRS is not hampered, therefore, by a technology that does not provide a precise measure of the performance on which the incentives are contingent.

3. Data transcribers have full control over their own performance. In data-transcribing activities, there is very little performance interdependence with other members of the work group. Performance is, therefore, primarily a function of individual motivation and capability. In contrast, some incentive plans that focus on the individual worker fail because workers perceive too much performance interdependence with co-workers; this causes the individual efforts, outputs, and rewards to be inadequately differentiated. As a result, higher-performance workers may become demotivated because individual rewards do not correspond closely to individual performance.

4. Data-transcribing activities permit short feedback cycles. The machines on which the data transcibing is done automatically record the number of keystrokes for each operator. Under PCRS, these performance totals are accumulated weekly and corresponding bonus payments are paid monthly. Incentive plans can become gradually ineffective if the workers feel they are not being frequently and adequately informed regarding the status of their performance and the implied bonus payments. Dockstader, Nebeker, and Shumate (1977) dealt with feedback, work standards and performance, and related issues.

5. Economic incentives have high utility for most data transcribers. Data transcribers are generally restricted to pay grades of GS-3 or GS-4. The economic incentives of the PCRS can, therefore, reasonably be expected

to have high utility for the vast majority of data transcribers. Incentive plans can fail because the incentives used--economic or otherwise--have low utility for the workers involved and thus do not elicit high performance.

6. PCRS setup costs for data-transcribing activities are relatively low. Such costs were fully recoverable from production-cost savings in less than one full quarter of operation. Thus, Navy managers need not be deterred from testing the PCRS because of its initial cost. Moreover, economies of scale are possible because several types of end-products (e.g., software development and questionnaire development) generated from setup costs at the test site can be readily adapted to other Navy activities. This differs from incentive plans that are sometimes not given a fair field test because the required "sunk" costs would be prohibitive if the test failed.

7. PCRS administrative costs are relatively low for data-transcribing activities. Once the PCRS is completely implemented and fully operational, the recurring administrative costs for special recordkeeping, computer, payroll, and miscellaneous services are small relative to the production-cost savings that are generated. In contrast, it could be necessary to terminate an incentive plan after it becomes fully operational if the time, effort, and other resources required of supervisors, managers, industrial engineers, etc., remain so costly that they negate the benefits of productivity increases from lower-paid production workers.

In summary, these features of the PCRS, as they relate to data-transcribing activities, constitute the primary basis for the long-term projections that were derived from the results of a field test of relatively limited scope. One more major issue, however, remains to be addressed: Will data-transcribing activities in the Navy community undergo such massive technological and other changes that projections based on the field-test results will soon become largely irrelevant, regardless of their previous credibility? This question is extremely important, and equally difficult to answer. Representatives of the test site's Management Information System Department, however, foresee no massive changes in data-processing workload, machine technology, and data-transcribing tasks that will occur soon enough to invalidate the 5-year projections. (Apparently, the event that would most likely precipitate such changes would be a breakthrough in optical character-recognition technology.)

Less massive changes in the data-transcribing activities can, of course, be readily accommodated by the PCRS by updating the work standards, revising the incentive-bonus rate, or similar adjustments. Thus, the PCRS's relevance to data-transcribing activities probably will remain undiminished for the foreseeable future.

Organizational Implications

The major implications of implementing the PCRS extend far beyond the data-transcribing activities to which the system was directly applied in this study. In particular, the management of sites for which PCRS implementation is being contemplated should consider the broad organizational implications of potential perceptions of wage and salary misalignment, conflict resolution, and the effects of PCRS discontinuance.

Potential Perceptions of Wage and Salary Misalignment

The implications of perceived misalignment can be illustrated best by addressing the vertical and horizonal perspectives of this issue separately.

Vertical Perspective. The vertical perspective primarily involves the impact on the relative earnings of the supervisors of the PCRS data transcribers. If the average earnings of the data transcribers increase and those of the supervisors do not, then the earnings differential will be narrowed. As a result, the supervisors responsible for the group performance of the data transcribers may lose their motivation to fully support the PCRS because its success would result in their earning less, relative to their subordinates, than before the PCRS was implemented.

A potential remedy for this problem is to give some portion of the average monetary bonus of the data transcribers to the supervisors. The additional cost that this implies would best be borne by management because the current bonus at the test site is only 11 percent of the cost savings derived from each data transcriber's increase in productivity. The remaining 89 percent accrues to the organization and provides ample funds with which to reward supervisors who help to produce the savings through better work distribution and other efforts. Alternatively, if the supervisory bonus-sharing is deducted from the data transcriber's portion of the production-cost savings, their motivation to maintain higher productivity may be seriously undermined because the bonuses under these conditions may be too small to have incentive value.. Moreover, it should be noted that the current 11 percent portion of the cost savings is already an extremely low sharing rate relative to incentive plans in the private sector (Fein, 1971).

Test-site management and the research team are already evaluating alternatives that would give the supervisors a vested economic interest in the collective performance of data transcribers operating under PCRS conditions.

Horizontal Perspective. It is far more difficult to devise a remedy for perceived horizontal misalignment; that is, the perceptions of non-PCRS employees who do not have a hierarchical relationship with the PCRS employees. The perceived misalignment is especially serious if the non-PCRS and PCRS employees work in close proximity or are highly interdependent. From a broader organizational perspective this perceived misalignment is very important because the PCRS may have a strongly beneficial effect on the motivation, performance, and morale of the data transcribers while non-PCRS workers in the same organization may simultaneously experience a strongly detrimental effect on the same dimensions. In great part, the detrimental effect on the non-PCRS workers would be based on two factors: (1) they are denied the opportunity to share in the PCRS's economic rewards, and (2) they feel that the data transcribers are deriving economic rewards not based entirely on their own activities, efforts, and performance.

Two possible solutions to this problem are: (1) to include non-PCRS employees under the PCRS if their tasks and other work relationships are amenable to PCRS implementation, or (2) to adapt the PCRS from an

individual incentive plan to a group incentive plan on the rationale that many non-PCRS employees have supporting roles that are broadly interdependent with the workflow of PCRS data transcribers. The implications of changing an incentive plan from an individual to a group basis are very complex, however, and must be considered carefully with regard to the many tradeoffs involved (Belcher, 1974).

Conflict Resolution

Implementing the PCRS may precipitate temporary conflicts among various types of employees and organizational functions. The process of setting work standards, for example, may engender conflict among industrial engineers, union representatives, and supervisors. Similarly, the whole concept of economic incentives being necessary to increase productivity may be challenged by the comptroller. Moreover, the new methods of work distribution involving data-transcribing activities may not at first be accepted wholeheartedly by the supervisors. It is imperative, therefore, that management work, from the start of implementation, to quickly and decisively resolve any conflicts to the satisfaction of all concerned.

Further, management must continue to support the PCRS after it is fully implemented and operating smoothly. It is especially important to give immediate attention to any emerging conflicts involving the PCRS. This could include, for example, handling PCRS-related grievances in a manner that permits a quick, fair, and decisive resolution--even if such procedures differ considerably from the normal grievance-resolution process. This is necessary because, if resolving serious problems with an economic incentive plan is deferred for routine processing, irreparable damage to the work unit's effectiveness, production costs, morale, and union/management relations could result (Belcher, 1974; Fein, 1971).

PCRS Discontinuance

It is possible, of course, that management may decide to discontinue the PCRS. Whatever the reasons for discontinuance, it may cause extensive damage to the site's workflow if the process of discontinuance is not systematically thought out and carefully executed. It is unrealistic to expect that, when the PCRS is successfully implemented and tested, it can be arbitrarily discontinued without leaving an aftermath of major undesirable effects on productivity, morale, and union/management relations. In the private sector, for example, managements often use costly "buy out" plans when economic incentive plans are discontinued. Such plans represent an attempt by management to keep peace with unions, to keep productivity at high levels, and to not demoralize the work force as a result of the decrease in individual earnings that often accompany the discontinuance (Fein, 1971).

To minimize the detrimental impact of the discontinuance on the work force, the following procedures might be helpful: First, before the PCRS is discontinued, management should give adequate warning and explanation to all concerned. Workers and unions may be more compliant if they have been adequately consulted and thus understand the reasons for the discontinuance. Second, management should not expect productivity, turnover, absenteeism, and morale to remain at the desirable levels they may

have reached while the economic incentive plan was in effect. Rather, management should expect slippage towards pre-incentive levels and should be wary of initiating preventive sanctions. Such sanctions could be so resented by the workers and unions as to result in open conflict.

CONCLUSIONS

The results warrant the following conclusions with regard to the hypotheses tested:

1. Implementation of the PCRS can substantially reduce the production costs of Navy data-transcribing activities.

2. Implementation of the PCRS will not diminish the production effectiveness of data-transcribing activities while reducing production costs.

These conclusions are based, in part, on production-cost savings of more than $10,000 and on a 14 percent increase in keystrokes per man-hour, achieved during a 13-week field test with 17 data transcribers.

RECOMMENDATIONS

It is recommended that Navy managers who have control over activities with large numbers of civil service data transcribers evaluate the procedures and results of the PCRS field test from the perspective of possible implementation within their operations. Such managers should give special attention, of course, to the issues that underlie the generalizability of the test-site results to sites under their control.

If Navy managers decide that the overall generalizability of test-site results appears sufficient to warrant implementation of the PCRS, it is recommended that they make a firm commitment to provide the resources and support required to ensure that the PCRS receives a full and fair field test. Only then will accurate data be available after the trial period to form a reliable basis for determining whether or not the PCRS should be continued.

It is also recommended that appropriate procedures be initiated to evaluate the implications of modifying civil service policy regarding economic incentive awards (Federal Personnel Manual, Note 2). Of particular importance are the implications of possibly differentiating the levels and bases of economic awards between (1) "one-shot" innovations that result in cost savings due to inventions, new techniques, or similar devices that workers use, and (2) productivity-induced cost savings that stem primarily from the additional effort, higher motivation, or superior ability of the workers themselves. The present guidelines seem more appropriate to awards for once-only procedural or hardware innovations than to increased individual productivity on a continuing basis.

Current guidelines suggest that workers be awarded no more than 10 percent of the net cost savings when those savings are $1000 or less, no more than 5 percent of savings between $1000 and $10,000, and with additional decrements in the worker's share thereafter. Such rates of sharing in the cost savings may provide adequate motivation for attempting inventions or other nonrecurring innovations that may ultimately lead to massive cost reductions for the site or agency and, in turn, to substantial economic awards for the originators. It is less probable, however, that such low ceilings and decremental sharing rates will provide adequate motivation to keep productivity-induced cost savings at high levels over the long run. As a comparative benchmark, it should be noted that participation rates for individual-based economic incentive plans in private industry are generally in the 30 to 70 percent range, with no decrements (Belcher, 1974).

The potential significance of this recommendation is that, unless the guidelines are revised to satisfactorily address the issues described above, the PCRS may be less than totally effective over the long run.

The implications of modifying policy on economic incentive awards are, of course, complex and far-reaching. One such implication deals with the possible effects on the long-range productivity and morale of those employees not covered by the economic incentive plan, a potential problem for which prospective remedies have already been discussed. This example illustrates that considerable care should be taken to ensure that the intricate tradeoffs implied by this recommendation will be systematically evaluated from a broad and long-range perspective.

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APPENDIX A

DERIVATION OF RECHARGE RATE

DERIVATION OF RECHARGE RATE

The Recharge Rate (RR) is an hourly composite cost per data transcriber that includes (1) basic salary, (2) acceleration, (3) supervision, (4) machines, and (5) overhead. Bases for the current level of cost of each of these components are specified below.

Basic Salary of Data Transcriber at Test Site: $4.04

This hourly rate corresponds to the GS-3 Pay Grade, median step, as listed in the official General Schedule for Salaried Positions, effective 10-10-76 (Note 3).

Acceleration: $1.31

This component represents the government's share of the costs of leave, pension, and other benefits extended to the data transcriber. The rate is specified by the LBNSY comptroller's office. Currently, the rate is 32.5 percent of the basic hourly salary described above.

Supervision: $1.59

Each shift has the following supervisory personnel:

Title	Pay Grade	Basic Salary (median step)
Lead Data Transcriber	GS-4	$4.53
Shift Supervisor	GS-5	5.07
	Total	$9.60

Since there is an average of 6 data transcribers per shift, $9.60/6 = $1.60 per data transcriber. This value differs by a penny from the cost level specified by LBNSY's comptroller. No basis for the disparity is known, but its significance is minimal. The reference for basic salaries of the respective types of supervisors is cited above.

Machine Costs: $0.38

The cost of CMC data-transcribing machines (described in Appendix B) is $1180 per month, as specified by the test-site comptroller. The number of data transcribing hours in a 30-day month having 3 shifts per work day is determined as follows: 30(5/7) = 21.4 work days, which implies that there are approximately 64 shifts per month. Since each shift has 8 hours, there are 512 hours eligible for data-transcribing activities each month. Accordingly, $1180/512 = $2.30 per hour per shift. Finally, since each shift has an average of 6 data transcribers, the hourly machine cost per data transcriber is $2.30/6 = $0.38.

Overhead: $3.50

This represents the current general and administrative overhead cost that the Management Information System Department charges all LBNSY divisions that "purchase" its data-transcribing services. The level of overhead cost is determined by the test-site comptroller and is periodically updated. The current rate is $3.50 per hour per data transcriber.

Summary of Recharge Rate Components

Basic salary	$ 4.04
Acceleration	1.31
Supervision	1.59
Machines	0.38
Overhead	3.50
Total	$10.82 per hour per data transcriber

APPENDIX B

PCRS BONUS CALCULATION

PCRS BONUS CALCULATION

Terminology

Symbol	Title	Definition	Numerical Expression
*MT	Machine Time	Time spent operating the data transcribing machines.	Time on CMC machines + time on IBM machines.
RR	Recharge Rate	Multiple-component hourly cost of data transcribing operation, on a per data transcriber basis.	Overall cost: $10.82. (Components, and the derivation of their respective costs, are described in Appendix A.)
SPI	Superior Productivity Increment	Productivity exceeding the "normal" level designated as standard.	PF-1.0. PF represents the Productivity Factor described below.
*PF	Productivity Factor	Composite factor representing the product of (1) the total efficiency of a data transcriber across designated data transcribing tasks, and (2) the proportion of time utilized on a CMC machine to time assigned on same.	1. Total Efficiency = $\dfrac{\frac{\sum \text{Recorded } KS_i}{\sum HR_i}}{\frac{\sum (\text{Standard } KS_i \times HR_i)}{\sum HR_i}}$ where HR_i represents hours of operating time on CMC-T, defined below, for task i; KS is # of keystrokes; and (Standard KS_i x HR_i) represents the weighted average of keystroke standards for all tasks i performed by a given data transcriber. 2. Utilization Rate = $\left(\dfrac{\sum HR_i}{\frac{\text{CMC-T}}{0.75}}\right) \leq 1.25$.
CMC-T	CMC Machine Time	Time assigned to CMC machines in terms of cumulative hours.	(# of work days in accounting period) x 8 + (Overtime hours on CMC machine) - (Leave Time + Admin Time + Time assigned to IBM).
DTSR	Data Transcriber Sharing Rate	Portion of productivity-induced cost savings received by data transcriber.	0.11

*It should be noted that the Productivity Factor (PF) refers to only the CMC machines, while Machine Time (MT) also includes the IBM machines. This reflects the fact that site management wants all data transcribing to be done on the newer CMC machines whenever possible because they are technologically superior to the older IBM machines. Thus, only the CMC machines are used in deriving PF, which is the basis of the incentive bonuses. On the day shift, however, the higher workload demands that some work still be done on the IBM machines; to permit data transcribers forced to use these machines to be eligible for incentive bonuses, these machines are also included in Machine Time. These interrelationships are illustrated in the basic formula for calculating PCRS bonuses, described below.

PCRS Bonus Formula

Using the given terminology, the basic formula for calculating the dollar bonus for a specified accounting period is as follows:

$$\text{Bonus} = MT \times RR \times SPI \times DTSR.$$

Functionally, the formula can be meaningfully interpreted in the following sequence:

1. MT represents the cumulative time, in hours, spent on direct production activities for a given data transcriber.

2. (MT)RR represents the cumulative cost of the direct production activities per data transcriber.

3. (MT x RR)SPI represents the productivity-induced cost savings for the PCRS site when a given data transcriber has effected superior productivity (i.e., SPI > 0).

4. (MT x RR x SPI)DTSR represents the portion of the PCRS cost savings received by the data transcriber who generated them.

PCRS Bonus Computation Example

A realistic example of a monthly bonus might include the following values for parameters:

1. Productivity Factor

   a. Efficiency component: 1.6
   b. Utilization rate: 1.05

2. Machine Time: 150 hours

3. Recharge Rate: Currently $10.82 per hour per data transcriber

4. Data Transcriber Sharing Rate: Currently 0.11

Inserting these values into the basic formula gives the following results

$$\begin{aligned}\text{Bonus} &= MT \times RR \times SPI \times DTSR \\ &= 150 \times \$10.82 \times [(1.6)\ (1.05) - 1.0] \times 0.11 \\ &= \$121.40\end{aligned}$$

Bonus and Salary Relationships

One way to evaluate the potential utility of the PCRS bonus to the data transcriber is to contrast it with the data transcriber's basic salary. Appendix A indicates that the basic salary at the GS-3 paygrade (median step)

is $4.04 per hour. Evaluating the term 30(5/7)8 indicates that there are 171.44 regular work hours in a 30-day month, which means that the basic salary is $692.62 before deductions. Numerically rounding both the bonus value in the example above and the salary gives the following percentage of bonus earnings relative to basic salary:

$$\frac{121\ (100)}{693} = 17.5 \text{ percent.}$$

APPENDIX C

NONRECURRING SETUP COSTS OF PCRS

NONRECURRING SETUP COSTS OF PCRS

Equipment

Item	Cost	Quantity	Total
Table	80.00	10	800.00
In-Basket	1.85	30	55.55
			$855.55

Software Development

Item	Cost	Quantity	Total
GS-11(5) Programmer	*@S&A($12.31)	300 Man-hours	$3693.00

*S&A: Salary plus "acceleration" (32.5% of hourly salary), as described in Appendix A.

Personnel Training and Development

Item	Cost	Quantity	Total
Selected Interviews	GS-3(5) *@RR ($10.82)	20 Man-hours	$216.40

*RR = Recharge Rate, a multiple-component hourly cost derived by site comptroller for GS-3(5) data transcribers as described in Appendix A.

Item	Cost	Employees	Man-hours each	Total
Questionnaire Admin I	GS-3(5) @RR	22	(1.25)	297.55
	GS-4(5) @S&A (6.00)	3	(1.25)	22.50
	GS-5(5) @S&A (6.72)	3	(1.25)	25.20
				$345.25
Questionnaire Admin II	GS-3(5) @S&A	22	(1.00)	238.04
	GS-4(5) @S&A	3	(1.00)	18.00
	GS-5(5) @S&A	3	(1.00)	20.16
				$276.20

Personnel Training and Development (continued)

Item	Cost	Employees	Man-hours each	Total
PCRS Introduction	GS-3(5) @RR	22	(1.00)	238.04
	GS-4(5) @S&A	3	(1.00)	18.00
	GS-5(5) @S&A	3	(1.00)	20.16
				$276.20

Supervisory Development of Head of Digital Computer Operations Branch

Item	Cost	Weekly Man-hours	Number of weeks	Total
PCRS Introduction	GS-11(5) @S&A ($12.31)	3.5	(1)	43.03
PCRS Training (NPRDC)				
Time	@S&A	16.0	(1)	196.96
Travel	Reimbursed Cost(Auto and Food)			30.00
PCRS Maintenance (weeks 6-13)	@S&A	10	(8)	984.80
				$1254.84

PCRS--Monitor Development

Item	Cost	Weekly Man-hours	Number of weeks	Total
PCRS Introduction	GS-11(5) @S&A	3.5	(1)	43.08
PCRS Training (NPRDC)				
Time	@S&A	16.0	(1)	196.96
Travel	Reimbursed Cost (Auto and Food)			30.00
PCRS Maintenance (weeks 1-5)	@S&A	15	(5)	923.25
				$1193.29

TOTAL PERSONNEL TRAINING AND DEVELOPMENT $3562.18

Possible Unrecorded Costs

Add 10 percent of sum of all above costs to adjust for possible unrecorded costs. $ 811.07

Summary of Nonrecurring PCRS Setup Costs From Test-site Perspective

Recorded Costs

Equipment	$ 855.55
Software Development	3693.00
Personnel Training & Development	3562.18
Total Recorded Costs	$8110.73

Possible Unrecorded Costs

(Estimate 10% of recorded costs)	811.07
TOTAL NONRECURRING SETUP COSTS	$8921.80

The setup costs are deliberately given a liberal computation. That is, in addition to actual expenditures (e.g., equipment and travel) there is the inclusion of implied costs due to decreased productivity while data transcribers and direct supervisors were being trained for PCRS implementation during work hours; also included was reimbursement for staff use (e.g., computer programmer who did the software development and, separately, development of the on-site PCRS monitor) and for use of higher level supervision (e.g., Head, Digital Computer Operations Branch). Finally, a substantial adjustment for possible nonrecorded costs is also included.

Even given the liberal computation of nonrecurring setup costs described above, such costs were more than fully recovered during the trial period from the production-cost savings associated with PCRS implementation, as documented in text.

APPENDIX D

DERIVATION OF FUTURE COMPOUNDED-VALUE FACTORS

DERIVATION OF FUTURE COMPOUNDED-VALUE FACTORS

Effective Interest Rate Determination

DODINST 7041.3 (Note 1) specifies that the interest rate to be used in the economic analysis of DoD programs and end-products is 10 percent, compounded annually. As explained in the text, however, the PCRS cost savings are accrued and compounded on a monthly basis. Accordingly, the nominal annual interest must be converted into its effective annual rate. This is done by the following formula (Fabrycky & Thuesen, 1974):

$i = [(1 + \frac{r}{c})^c - 1]$, where i = effective annual interest rate, based on monthly compounding,
r = nominal annual rate, based on annual compounding, and
c = number of annual interest periods.

Inserting parameters from the present case, the value of i is determined as follows:

$$i = [(1 + \frac{0.10}{12})^{12} - 1] = 10.47.$$

Dividing the effective annual interest rate by the number of annual interest periods gives the effective interest rate per specified period. Thus, for the present case, 10.47/12 = 0.87 percent per month.

Determining Future Compound-value of Cost Savings

Lump-sum Compounding

The basic formula for determining the future value of a single payment that is compounded over a specified number of periods is the following:

$F = P\ (1 + i)^n$ where F = future compounded value at end of last period,
i = effective interest rate per specified period,
p = present value of single payment, and
n = specified number of periods.

Sometimes the value of F is already known, but its present value needs to be determined. Then, with the same terminology, the following formula is used:

$$P = F\ [\frac{1}{(i+1)^n}].$$

Series-payments Compounding

The basic formula for determining the future value of a series of regular, equal payments that are compounded over a specified number of interest periods is the following:

$$F = A\left[\frac{(1+i)^n - 1}{i}\right],$$

using terminology analogous to that described above for lump-sum compounding, and where A represents the amount of each payment in the series.

When the present value of the series payments needs to be determined, the following formula is used:

$$P = A\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right],$$

using terminology analogous to that described above for series-payments compounding.

The future-compounded-value and net-present-value formula for both lump-sum and series payments are cumbersome to evaluate numerically when the number of periods gets large. Accordingly, references are available (Fabrycky & Thuesen, 1974) that provide equivalent "factors" for frequently-used combinations of interest rates and interest periods. Less-frequent combinations can be derived by interpolating the factors already known, as explained below.

Derivation of Compounded-value Factors

The series-payment, compounded-value factors for the 3-year projections shown in Tables 3 and 4 in the text can be derived via interpolation by using the following information from appendices in Fabrycky and Thuesen (1974):

Effective Monthly Interest Rate	Number of Series Payments	Compounded-value Factors
1.00	35	41.660
0.75	35	39.854
1.00	40	48.886
0.75	40	46.446

As described above, the effective annual interest rate corresponding to the nominal annual rate of 10 percent is 10.47 percent when compounded monthly. Dividing the effective annual interest rate by 12 gives the effective monthly rate: 0.87 percent. The compounded-value factors associated with this effective monthly rate for interest periods of 35 and 40 can be derived as follows:

For 35 interest periods,

$$(41.660 - 39.854)\left(\frac{.87-.75}{1.0-.75}\right) + 39.854 = (1.806)(0.5) + 39.854 = 40.757.$$

For 40 interest periods,

$$(48.886 - 46.446)\left(\frac{.87-.75}{1.0-.75}\right) + 46.446 = (2.44)(0.5) + 46.446 = 47.666.$$

Then, determine the difference between compounded-value factors for interest periods corresponding to 35 and 40 at the effective monthly interest rate of 0.87 percent. Prorate the difference in relation to the specific number of interest periods wanted (in the present case, 36), and add to the factor corresponding to lower number of interest periods:

$$(47.666 - 40.757)\left(\frac{36-35}{40-35}\right) + 40.757 = (6.909)\ (0.2) + 40.757 = 42.138,$$

when rounded conservatively.

This compounded-value factor can then be multiplied by the amount of series payment to result in a value equal to that resulting from the use of the basic compounded-value formula for series payments:

$$\text{(Series Payment) (Compounded-Value Factor)} = \text{(Series Payment)}\ \left[\frac{(1+i)^n - 1}{i}\right] = F,$$

when $\underline{F}$ represents the future compounded-value of the payment series at end of last period; $\underline{i}$ = effective interest rate per specified period; and $\underline{n}$ = number of periods. Thus, for the 3-year projections of production-cost savings from 17 data transcribers shown in Table 3, the value of $\underline{F}$ is determined as follows:

$$(\$3,427)(42.138) = \$3,427\ \left(\frac{(1+0.87)^{36} - 1}{0.87}\right) = \$144,407.$$

The process for deriving the compounded-value for lump-sum savings, or net-present-value factors of either lump-sum or series-payments savings, is analogous to the example given.

APPENDIX E

COMPARATIVE PRODUCTION EFFECTIVENESS OF WORK SHIFTS

COMPARATIVE PRODUCTION EFFECTIVENESS OF WORK SHIFTS

Tables E-1 and E-2 show the comparative production effectiveness within work shifts across periods. The following is a summary of important findings:

1. All shifts substantially reduced overtime man-hours. Keeping the full complement of data transcribers busy after the workload backlog was eliminated became an occasional problem on all shifts.

2. The grave shift's production efficiency decreased slightly while that of the other shifts increased. Since the grave shift is the last shift for each work day, the decrease might be primarily due to an insufficient workload; a lack of complete understanding of bonus computation by some data transcribers on this shift may also have influenced the decrease.

3. Swing shift production efficiency increased dramatically: 75.3 percent. Since tasks, data transcribers, and machines were essentially identical for this work shift across the comparative periods, the increase was presumably attributable primarily to the effects of two factors: (a) the PCRS, and (b) the exchange of day shift and swing shift supervisors that occurred between the periods. Given the nature of the field test, it is difficult to determine the relative impact of these factors on the productivity increase of this work shift.

Table E-1

Production Effectiveness Across Work Shifts for Base Periods and Trial Periods

Shift[a]	Base Period[b]				Trial Period[c]			
	Key-strokes[d]	Total Man-hours	Overtime Man-hours	Keystrokes Per Man-hour[e]	Key-strokes	Total Man-hours	Overtime Man-hours	Keystrokes Per Man-hour
Day (N = 9)	(14,287,059) 14,063,824	3940.3	222.3	3569.2	14,994.043	3763.6	68.1	3984.0
Swing (N = 4)	(6,613,361) 6,510,027	1696.8	36.8	3836.6	11,888,619	1768.0	6.9	6724.3
Grave (N = 4)	(15,218,433) 14,980,645	2114.7	258.7	7084.1	10,234,551	1562.7	45.4	6549.3
	(36,118,853) 35,554,496	7751.8	517.8	4587	37,117,213	7094.3	120.4	5232

Note. This table is intended to be used in conjunction with Table E-2, which reflects changes across the comparative periods on a relative basis.

[a]All data transcribers were on the same respective shifts for both periods. The number of data transcribers operating under PCRS conditions on each shift is represented by N.

[b]The Base Period extended from 5 July to 2 October 1976 and included 2 holidays and 63 work days.

[c]The Trial Period extended from 17 January to 16 April 1977 and included 1 holiday and 64 work days.

[d]Computation used adjusted output (in parentheses) for the Base Period, which had 1 less work day (as explained in footnotes b and c). Adjustment added daily rate to raw total.

[e]Keystrokes per man-hour were computed on the basis of the raw total of keystrokes (i.e., before the adjustment described in footnote d). The overall average keystroke rate per man-hour across shifts is, of course, a weighted average with unequal weights.

Table E-2

Relative Production Effectiveness Across Work Shifts for Base Period and Trial Period

Shift	Interperiod Change: Percent and Direction				Direction of Change Desirable ?			
	Key-strokes	Total Man-hours	Overtime Man-hours	Keystrokes per Man-hours	Key-strokes[a]	Total Man-hours[a]	Overtime Man-hours[b]	Keystrokes per man-hours
Day (N = 9)	+4.9	-4.5	-69.4	+11.6	Yes	Yes	Yes	Yes
Swing (N = 4)	+79.8	+4.2	-81.2	+75.3	Yes	No	Yes	Yes
Grave (N = 4)	-32.7	-26.1	-82.4	-7.5	No	Yes	Yes	No

Note. This table is intended to be used in conjunction with Table E-1, which shows the comparative data on which the interperiod changes reflected in this table are based. Interperiod changes across all shifts combined are shown in Table 2 in text.

[a]As separate types of indicators, keystrokes and man-hours are only meaningful in terms of "desirability" in the general sense that more production (keystrokes) is preferable to less and, analogously, lower cost (man-hours) is preferable to higher. In the present case, however, keystrokes and man-hours by themselves are not reliable indicators of production effectiveness because they can vary considerably due to the number of holidays, the amount of leave taken, etc., within the respective periods. It is only when keystrokes and man-hours are used in conjunction with each other as a composite indicator of overall efficiency (i.e., keystrokes per man-hour) that their interactive importance is primarily demonstrated.

[b]Overtime man-hours is an important indicator of production effectiveness in the present case because (1) it reflects the substantial decrease in workload backlog during the trial period, and (2) it represents an excess cost production penalty due to overtime pay being higher than regular salary.

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