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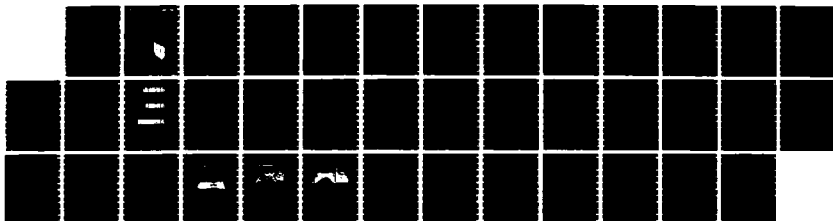
OFFICE PRODUCTIVITY: CONTRIBUTIONS OF THE PHYSICAL
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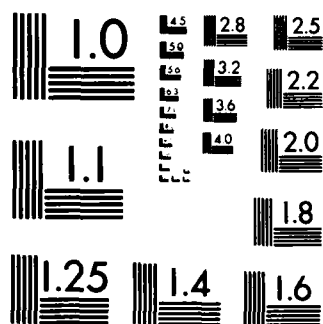
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US Army Corps
of Engineers
Construction Engineering
Research Laboratory

USA-CERL

TECHNICAL REPORT P-86/13
September 1986

Office Productivity: Contributions of the Physical Setting

by
JoEllen Francis
David L. Dressel
Scott A. MacArthur
Robert D. Neathammer

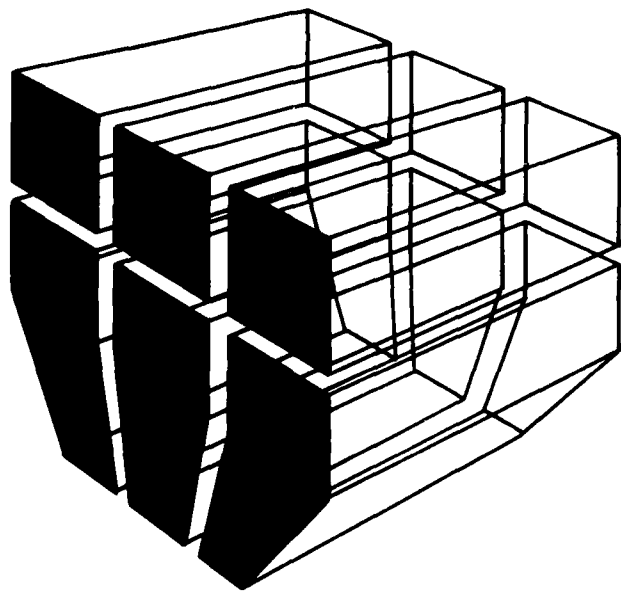
This study investigated the effect of ergonomically-suited, task-oriented workstations on employee productivity and satisfaction, and analyzed the costs and benefits of providing new state-of-the-art office furniture. Facility managers can use the information in this report when appraising work environments.

A new workstation design and arrangement was composed for two work sections at the Defense Logistics Agency, Defense Construction Supply Center (DCSC), Columbus, OH, using two different types of furniture: systems furniture (components attached to partitions/panels), and conventional General Services Administration (GSA) furniture. A productivity index, derived from archival performance data, and employee satisfaction ratings were compared before and after furniture installation.

Results from the group receiving systems furniture showed that environmental improvement has a significant positive impact on both productivity and satisfaction.

Results from the group receiving enhanced conventional furniture did not show the expected significant increase in productivity, but did demonstrate significantly improved satisfaction with the workstation. It can be concluded that improved office environments can facilitate productivity and foster office satisfaction.

Amortization of the cost of providing a workstation equipped with systems furniture, when space savings and increased productivity were considered, was computed to be 10.8 months.



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Amortization of the cost of providing a workstation equipped with systems furniture, when space savings and increased productivity were considered, was computed to be 10.8 months.

FOREWORD

This research was conducted for the Defense Logistics Agency, Defense Construction Supply Center (DCSC), Columbus, OH, by the Facility Systems Division (FS), U.S. Army Construction Engineering Research Laboratory (USA-CERL), Champaign, IL, under reimbursable order SC0700-4-0017.

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Mr. Edward A. Lotz is Chief of USA-CERL-FS. The principal investigator was Mr. David L. Dressel. Mr. Jerrold T. Piro, Architect, managed the design and installation of the experimental offices.

COL Norman C. Hintz is Commander and Director of USA-CERL, and Dr. L. R. Shaffer is Technical Director.



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OFFICE PRODUCTIVITY: CONTRIBUTIONS OF THE PHYSICAL SETTING

1 INTRODUCTION

Background

Recent advances in office automation are changing the office environments of white-collar workers. As electronic methods of managing information replace mechanical methods, the traditional requirements for storage space, lighting, and work surfaces change. In response to these changing requirements, government facility managers are faced with determining the cost-effectiveness of replacing office furniture. A comprehensive cost/benefit analysis should consider how changes in the office environment will affect employee productivity.

At the request of the Directorate of Installation Services, Defense Construction Supply Center (DCSC), Columbus, OH, the U.S. Army Construction Engineering Research Laboratory (USA-CERL) assessed the extent to which improving environmental conditions in an office setting influenced productivity and office satisfaction.

It was hypothesized that a significant increase in productivity and office satisfaction would result from improved workstation design and layout. Savings realized from greater productivity were expected to exceed the cost of improving the office environment.

Objectives

The objectives of this research were to evaluate the effect of redesigned workstations on employee productivity and satisfaction, and to analyze the costs and benefits of providing new state-of-the-art office furniture.

Approach

This study employed a multimethod approach using employee self-reports to subjectively measure satisfaction and archival raw data to objectively measure productivity.

Individual workstation requirements, work group requirements, and existing design problems were identified through interview and questionnaire responses. A detailed discussion of the research procedure is given in Chapter 2.

Based on the information gathered, workstations were redesigned and furniture was installed in two work groups. The groups were given similar workstation designs and layout. One group received new systems furniture and the other was given additional pieces of conventional General Services Administration (GSA) furniture.

Productivity data were collected monthly for 10 months before and 11 months following furniture installation. Employee questionnaires were administered shortly after the furniture was installed and again 9 months later. A statistical analysis of the

productivity data and questionnaire responses is given in Chapter 3. A cost/benefit analysis of the new furniture is detailed in Chapter 4. Facility management guidance is offered in Chapter 5.

Scope

Some limitations of this study deserve mention here. First, the sample size of the experimental groups was somewhat small (14 agents). Second, the groups were not randomly selected. Selection was based on homogeneity of variance. Also, because the starting backlog correlated moderately with productivity before manipulation, it may be speculated that there may be pressures on employees to work harder or meet goals at certain times. This may have affected the productivity data, either by inflating or underestimating the change in performance before and after. The variability demonstrated in the performance data cannot be explained, statistically or from discussions with DCSC management. No major changes in work method, work unit composition, or work content occurred during the period of study.

Past Studies

The adequacy of subjective satisfaction and productivity ratings has come under increasing scrutiny. Seidel in his review of various environmental-behavioral research techniques, suggested that user attitude and/or preference studies have only moderate credibility. His review recommended a multimethod approach integrating objective and subjective data.¹ Danford, Starr and Willems, in a well-controlled experiment, offered strong evidence for the invalidity of the subjective, cognitive report, due primarily to "instrument bias" in the methods.²

The supposed link between the construct "satisfaction" and the construct "productivity" has been a controversial one receiving only moderate support. Vroom's review of the literature showed negative correlations between satisfaction and turnover (range -.13 to -.42) and between satisfaction and absenteeism (range -.14 to -.38).³ Further studies (Lawler, Steers) theorizing that satisfaction causes performance or performance causes satisfaction received only weak support.⁴

A study conducted by Westinghouse with a group of Blue Cross/Blue Shield clerical workers integrated both subjective and objective measures. The study spanned 17 months and included 122 employees. They found employees receiving systems furniture (components attached to partitions/panels) were more satisfied with the furniture and

¹A. D. Seidel, "The Credibility Inherent in the Use of Various Environment-Behavior Research Techniques," in A. E. Osterberg, C. P. Tiernan, and R. A. Findlay Eds. *Design Research Interactions* (Environmental Design Research Association, Inc., 1981).

²S. Danford, N. Starr, and E. P. Willems, "The Case Against Subjective, Cognitive Report in Environmental Design Research: A Critical Test," in A. D. Seidel and S. Danford Eds., *Environmental Design: Research, Theory and Application* (Environmental Design Research Association, Inc., 1979).

³V. H. Vroom, *Work and Motivation* (Wiley, 1964).

⁴E. E. Lawler, *Motivation in Work Organizations* (Brooks/Cole, 1973); R. M. Steers, *Introduction to Organizational Behavior* (Goodyear, 1981).

office appearance and showed a 6 percent productivity increase compared with the control group.⁵ The increase was significant at a 99 percent level of confidence ($p < .01$).

In a related experiment, Springer conducted research with 118 video display terminal (VDT) workers in the insurance industry to assess how well workstations and the surrounding environment supported the functions of VDT-oriented jobs. His thorough, well-controlled investigation simulated daily dialogue and data entry tasks. Four workstation types were designed to support these tasks. Results found that two workstation designs resulted in significant performance improvements (10 percent - dialogue task; 15 percent - data entry task) over existing workstations.⁶

A study conducted by the management of the Southwest Region Internal Revenue Service found a 7.4 percent increase in white collar productivity after designing and installing new workstations in their office facility. The productivity increase cannot be interpreted to have resulted only from new workstations, as a new procedure for processing incoming and outgoing work was introduced after furniture installation. Payback for the cost of the new furniture was calculated to be 2.14 years.⁷

The Westinghouse study also addressed employee satisfaction with particular environmental factors. Satisfaction was measured before and after systems furniture installation. The "before" layout was described as a "bullpen" arrangement of standard gray metal desks. The "after" condition consisted of furniture components from the Westinghouse system in an open plan layout, equipped with task lighting. Significant satisfaction increases were found with the following environmental factors: personal workspace; amount of furniture, floor space, work surface, and storage space; privacy; chair; appearance of personal workspace; ease of rearranging furniture; air quality; reduced noise level; ease of adding or displaying personal things in the workstation; ease of communication with other departments; the general office area; office lighting; safety and security; and appearance of the office.

In a 3-year study of over 4,000 employees in approximately 50 public and private offices, Brill et al.⁸ concluded that satisfaction with 21 environmental factors affected ratings of both job satisfaction and job performance. Although the results of this study were based solely on subjective data, they are of interest here in that specific environmental factors were identified as influencing office satisfaction for a very large sample of employees. Employees were surveyed before and after office design changes occurred. Government workers demonstrated a significant increase in environmental satisfaction when moved from a traditional "bullpen" office layout to a partitioned, open office layout. In addition to the factors identified in the Westinghouse study, the

⁵ Westinghouse Furniture Systems Division, *Changes in Employee Attitudes, Behaviors, and Productivity as Causally Related to Installation of Westinghouse ASD Open Plan Office Furniture Systems* (Westinghouse Electric Corporation, 1982).

⁶ T. J. Springer, "VDT Workstations: A Comparative Evaluation of Alternatives," *Applied Ergonomics*, Vol 13, No. 3 (1982), pp 211-212.

⁷ F. McLeMore, B. Jones, R. Reyna and L. McFadin, *Productivity Enhancement Project: Workstation Analysis Study, Centralized Services Branch, Oklahoma City District*, Document SWR 5002-E, 5-80 (Internal Revenue Service Southwest Region, December 1980).

⁸ M. Brill, S. T. Margulis, E. Konar, and Buffalo Organization for Social and Technological Innovation, *Using Office Design to Increase Productivity*, Vol 1 (Workplace Design and Productivity, Inc., 1984).

following factors were found to influence environmental satisfaction: degree of enclosure; temperature consistency; pathfinding; comfort of chair and worksurface height, depth, and width; individual control of lighting; and status (symbolization of employee position in the organization).

2 RESEARCH METHODS

Subjects

DCSC management designated Contracts Division I as the subjects for this study. DCSC Contracts Division I (Directorate of Contracting and Production) consisted of 198 employees grouped into 9 sections.

The function of Contracts Division I was primarily procurement of military supplies. Job-related activities were similar within and between the sections, distinguished by the types of materials procured. Job titles within each section included the following: Supervisory Procurement Agent, Procurement Agent, Procurement Agent Trainee, Secretary, and Procurement Clerk. Productivity was measured only for procurement agents and procurement agent trainees. Paygrade of procurement agents was evenly distributed between sections. The average employee age was 44 years and approximately 67 percent of the subjects were female. The average length of employment with the agency was 12.5 years.

Between 8 and 13 procurement agents (average = 10), and up to 3 procurement agent trainees (average = 2) worked in each of the 9 sections. The section designation, experimental status and total number of agents and trainees is given in Table 1.

Procedure

The study procedure was multimethod; subjective and objective data were collected.

An Office Improvement Questionnaire (Appendix A) was distributed to Division I employees in February 1983, to determine workstation requirements. Respondents were requested to indicate the types of activities they performed in their job functions and the percentage of time spent daily on each task. In addition, respondents were asked to estimate the amount of materials (in linear feet) which they used. The supervisors of the

Table 1

Section Status and Number of Subjects

Section	Procurement Agents/ Trainees
PCAA	12
PCAB	12
PCAD Experimental Group 1	14
PCBA Control Group	9
PCBB	12
PCBD Control Group 2	10
PCCB Control Group 1	16
PCCC Control Group	11
PCCD Experimental Group 2	14

two experimental groups and the Assistant Division Chief were interviewed by USA-CERL representatives to elicit further requirements for workstation design and layout.

On the basis of the questionnaire data and interviews, workstation designs and layouts were developed. The new workstations contained more storage and workspace. Task lighting was also added. Partitions defining the workstations and the section provided more efficient and more private work spaces. A side chair was shared between two workstations. A small partitioned conference area was added for each group.

The type of furniture differed between the two experimental groups, although the design and layout of the experimental workstations was as identical as possible. Experimental group 1 (E1) received new systems furniture: workspaces, files, and bookshelves which are attached to partitions/panels in a variety of configurations. Steelcase Series 9,000 furniture was chosen because it offered the required components and, at the time of the study, was one of the few manufacturers to offer unit assemblies which simulated modular furniture. Since that time, several other manufacturers have brought modular lines to the marketplace. It was USA-CERL's understanding that the GSA would be placing emphasis on the use of modular furniture in the future. The systems furniture group also received new ergonomic chairs. Experimental group 2 (E2) received additional GSA general office steel furniture including bookshelves, an additional workspace, additional filing space, task lighting, a shared side chair, and partitions to supplement their existing furniture.

Several years before this study, DCSC had painted the conventional GSA furniture either gold or orange and placed laminated wood surfaces on desk tops and tabletops. The Steelcase furniture was tan with brown accent panels. The workstation design and layout for both groups, and illustrations before and after redesign, are shown in Appendix B.

Both experimental groups had similar GSA general office metal conventional furniture and a similar open arrangement before August 1983 when the furniture was installed.

Archival records of several different productivity indicators were obtained for analysis:

1. Number of line items: The number of completed purchase request line items for each group was recorded at the end of each month. Small purchase request line items were recorded separately from large purchase request line items, since significantly more effort is required to procure a large line item.

2. Workhours: The number of workhours, excluding sick leave, annual leave, or other compensated absences, was recorded for each group on a monthly basis.

3. Sick leave: Total sick leave hours were recorded monthly for each group.

4. Backlog: A measure of purchase request line items which had not been completed by the end of the month was collected for each group.

A Combined Productivity Index (CPI) was developed to combine small and large line items. This index proportionately weights large and small line items and divides the weightings by workhours. Weighting was necessary because the time required to complete a small purchase item was less than the time required to complete a large purchase item. The equation is as follows:

$$\text{CPI} = \frac{\text{Number of small items} + (2.89) \text{ Number of large items}}{\text{Workhours}} \quad [\text{Eq 1}]$$

The coefficient, 2.89, was derived from historical data; the total number of small line items divided by the number of hours spent working on those items equalled the total number of large line items divided by the number of hours spent working on the large items, when the latter is multiplied by the coefficient.

Data were obtained for the 30-month period from January 1982 to June 1984. However, in September 1982, a new policy changed the classification of purchases in the \$10,000 to \$25,000 range from large to small purchases. On the average, less time is required to complete a small purchase item than a large. Since the items affected comprised the upper end of the small item classification and required more time than typical small items, the overall pool of small purchase items became more difficult to process. Because this policy change correlated positively and significantly with productivity figures, the productivity data up to and including September 1982 were not used.

Data were analyzed monthly for procurement agents in all groups for 10 months before and 11 months after furniture installation. Data were subdivided into classifications, with October 1982 through July 1983 being the months "before" furniture installation and August 1983 through June 1984 constituting the months "after." A control group consisting of four sections (PCCB, PCBD, PCBA, and PCCC) was formed by analysis of variance of "before" productivity scores and contrasted *a posteriori* by means of Duncan's Multiple Range Test ($\alpha < .05$). All four sections served as the control for productivity. Sections PCCB (C1) and PCBD (C2) also served as control groups for the office satisfaction survey discussed below. Since recording line items purchased is a recurring activity within the Division, the subjects were aware that their work was being recorded but were not aware that their productivity data were part of the study.

An Office Satisfaction Questionnaire (Appendix C) was administered on three different occasions: February 1983, August 1983, and May 1984. The first administration of the questionnaire to four groups (E1, E2, C1, and C2) occurred 6 months before installation of the new office furniture. The survey was given to three of the four groups 1 month after furniture installation (C2 did not receive the survey on this occasion as a control for the effect of two post administrations). The survey was administered a third time to all four groups 9 months after furniture installation to control for effects of "newness" or "uniqueness" of the furniture. Table 2 lists critical dates in the study.

Respondents were requested to rate their satisfaction with features of their workstation and the office building in which they worked. A 5-response Likert scale was used. Several features of the workstation, such as furniture, control over visual and noise distractions, amount of floor area, and filing/storage space, were listed. Features of the office building included lighting, air and people circulation, heating, and other items. An item followed each of the lists of features which asked respondents to rate their general level of satisfaction with their workstation and with their office building.

All features were again listed in a final question in which respondents were asked to rank the five most important features of their workstation and office building.

Table 2

Study Dates

Date	Activity
October 82	Productivity data collection began
February 83	Satisfaction survey administered to four groups (E1, E2, C1, and C2)
August 83	Furniture installed
September 83	Satisfaction survey administered to three groups (E1, E2, and C1)
May 84	Satisfaction survey administered to four groups (E1, E2, C1, and C2)
June 84	Productivity data collection completed.

3 RESULTS AND ANALYSIS

Productivity

The procurement agents' productivity data results support the hypothesis that improving environmental conditions in an office increases productivity. Experimental group 1 demonstrated a significant ($p < .02$)* increase in productivity (20.6 percent). Experimental group 2 showed a 4 percent increase in productivity that was not significant. The control group demonstrated a productivity increase of 0.6 percent. The average increase for all groups combined was 5.3 percent. Figures 1 and 2 display each group's productivity over time. Due to the variability of the productivity data, before and after comparisons were made only within each group; comparisons of performance scores were not made between groups. A decline in productivity occurred in August 1983. This decline was probably due, in part, to work being interrupted during furniture installation. The decline disappeared by September 1983.

Sick leave data produced no significant results for any of the groups.

Backlog data (line items which had not been completed by the end of the month) showed a correlation ($r = .22$; $p < .001$ **) with CPI when examined for all groups and all months. At no time was the backlog for any group at or near zero. The backlog/CPI correlation coefficient for all groups was 0.37 for the months before furniture installation, but was only 0.06 for the months following furniture installation.

Statistical testing for quarterly trends in the productivity data produced no significant results.

Satisfaction

The satisfaction questionnaire results generally confirm the hypothesis that improved workstation design and layout would significantly increase office satisfaction. The group receiving systems furniture showed significant improvement in satisfaction with the workstation and the facility on both 1-month and 9-month before/after comparisons (Table 3). The group receiving improved conventional furniture (E2) showed a similar improvement with workstation satisfaction. However, E2 showed no significant change across all three times in satisfaction with the facility. Both satisfaction control groups (C1 and C2) showed no significant change in either workstation or facility satisfaction.

Table 4 demonstrates the significant improvement in satisfaction level of the experimental groups on those features of the work place which the employees rated as most important.

Satisfaction with "control over noise distractions" and "lighting" improved for both experimental groups from moderate dissatisfaction before furniture installation to moderate satisfaction following furniture installation. Significant improvement also occurred with respect to "control over visual distractions."

*This means that the researchers are at least 98 percent confident that the increase is real and not a chance occurrence.

** r = simple correlation coefficient

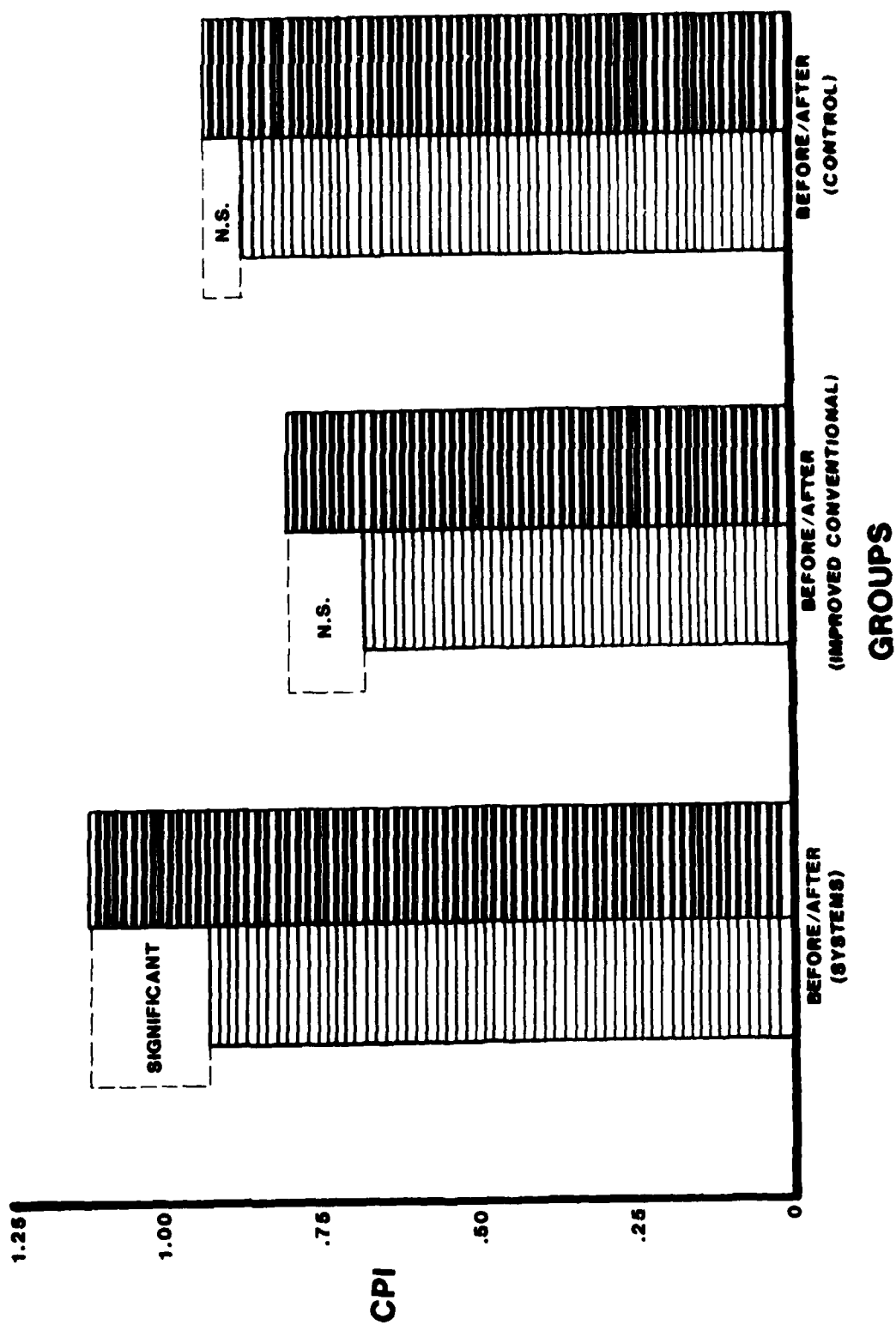


Figure 1. Combined Productivity Index before and after furniture installation.

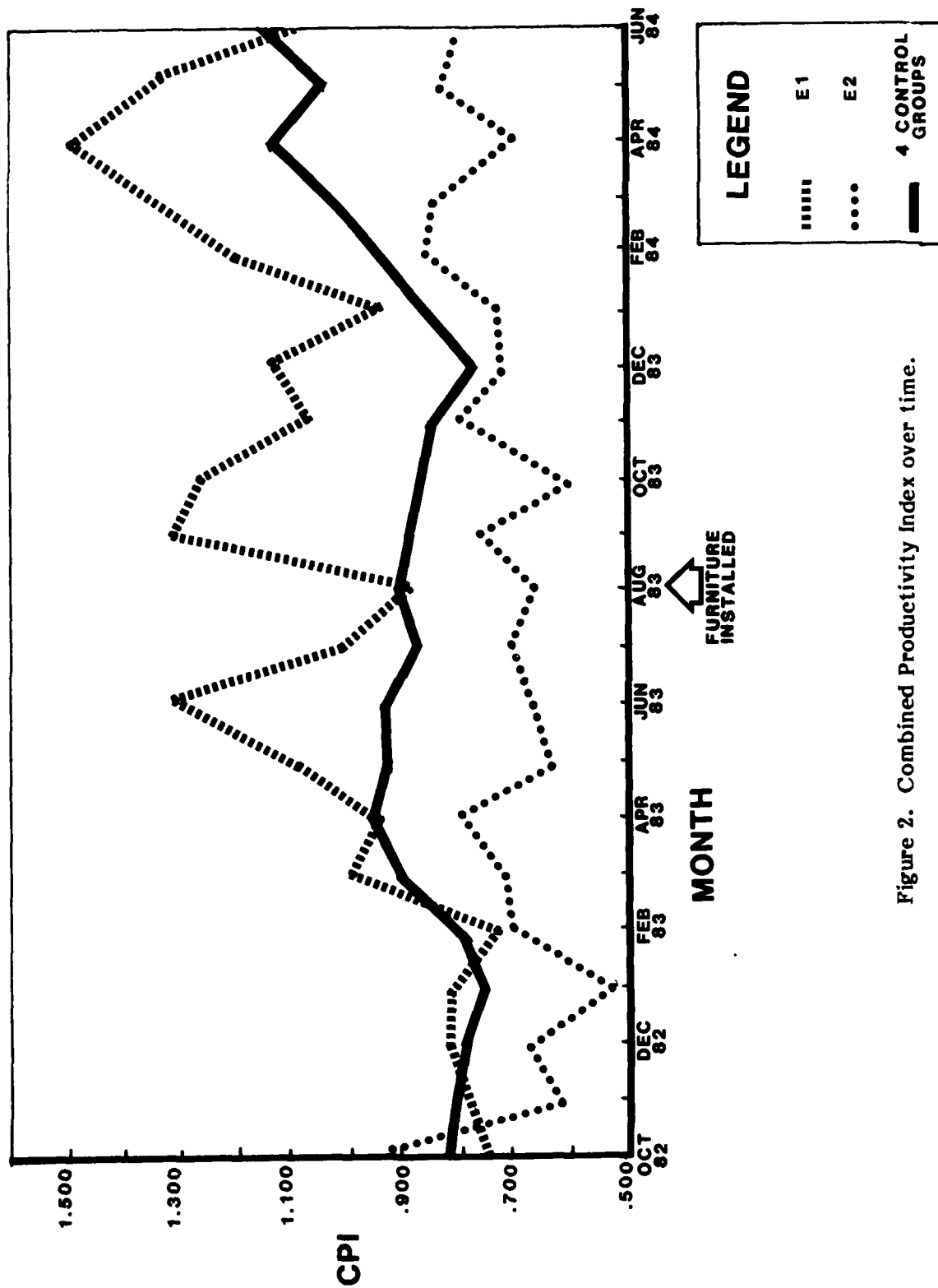


Figure 2. Combined Productivity Index over time.

Table 3

Change in Mean Satisfaction with the Workstation and Facility

Group	Before	Workstation Satisfaction Facility Satisfaction		Probability*	
		1 Month After	9 Months After	1 Month After Before	9 Months After Before
E1	2.77	1.54	1.50	< .001	< .000
	3.08	1.64	1.56	< .001	< .000
E2	2.92	2.00	1.83	< .007	< .004
	3.25	2.63	2.50	NS	NS
C ₁	2.67	2.69	3.18	NS	NS
	3.27	3.50	3.17	NS	NS
C ₂	2.83	--	3.29	NS	NS
	2.42		2.86	NS	NS

*t-test, 2-tailed

Key: 1 = highly satisfied; 2 = moderately satisfied; 3 = neutral; 4 = moderately dissatisfied; 5 = highly dissatisfied; NS = not significant.

Experimental group 1 also showed significant improvement in satisfaction with "air circulation" and "workstation chair."

Table 5 illustrates all features of the workstation and facility which received significantly improved satisfaction ratings by both experimental groups: furniture arrangement and adaptability, control over noise and visual distractions, work surface space and arrangement, conference facility availability, and electrical outlets.

Group E1 (but not E2) showed significantly greater satisfaction with the new furniture's state of repair; color, stability and work surface height; all features of the chair; lighting brightness level; conference facility location; and air circulation.

Group E2 (but not E1) indicated significantly improved satisfaction with the amount of floor area in the workstation and task lighting for the work surface. To accommodate the larger conventional furniture while maintaining equivalence in amount and type of furnishings for both groups, the floor area in E2 workstations was made slightly larger. Task lighting in both groups consisted of a fluorescent lamp mounted underneath the desk-top organizer on the primary work surface.

As expected, the control groups did not significantly improve their satisfaction ratings following the experimental manipulation. Instead, C1 was significantly less satisfied with work surface height (before Mean = 1.9; after 9 months Mean = 2.8; $p < .037$) and C2 was significantly less satisfied with the amount of filing space in the workstation (before Mean = 2.3; after 9 months Mean = 3.6; $p < .004$). Although no change was experienced by the control groups, they were aware of improvements being made in other work areas.

Table 4
Change in Mean Satisfaction for Features Rated
as Most Important

Feature		Before	After 1 Month	After 9 Months	Change: Before/ After 9 Months (Probability)*	Direction (+) Increase (-) Decrease
Control over Noise						
	E1	4.31	2.29	2.31	P = .000	+
	E2	4.33	2.31	2.50	P = .001	+
	C1	3.60	4.39	4.17	NS	-
	C2	3.75	--	3.50	NS	+
Lighting						
Brightness Level Task Lighting	E1	3.54	2.36	2.20	P = .001	+
	E2	3.58	2.38	2.33	P = .012	+
	C1	3.74	3.78	3.63	NS	+
	C2	2.42	--	2.77	NS	-
Air Circulation						
	E1	4.38	3.69	3.44	P = .039	+
	E2	4.50	3.25	3.75	NS	+
	C1	4.20	3.69	3.58	NS	+
	C2	4.00	--	3.71	NS	+
Heating & A/C System						
	E1	3.85	3.64	3.06	NS	+
	E2	4.09	3.56	3.58	NS	+
	C1	4.00	3.58	3.39	NS	+
	C2	3.50	--	3.11	NS	+
Chair						
	E1	3.24	1.07	1.18	P = .000	+
	E2	3.23	2.92	3.28	NS	-
	C1	3.01	2.90	2.95	NS	+
	C2	3.23	--	3.55	NS	-
Control Over Visual Distractions						
	E1	2.85	1.29	1.38	P = .000	+
	E2	3.33	1.75	1.40	P = .000	+
	C1	2.80	3.15	3.50	NS	-
	C2	2.92	--	3.29	NS	-

*t-test, 2-tailed

Key: 1 = highly satisfied; 2 = moderately satisfied; 3 = neutral; 4 = moderately dissatisfied; 5 = highly dissatisfied; NS = not significant.

Table 5

**Features of the Workplace Receiving Significantly Improved
Mean Satisfaction Ratings Following Furniture Installation**

Feature	Before/After 9 Months Mean Satisfaction		Probability*	
	E1	E2	E1	E2
Furniture in the Workstation:				
Adaptability	2.8/1.5	2.6/1.7	.000	.027
Arrangement	2.9/1.9	3.3/1.8	.017	.009
State of Repair	2.9/1.4	3.2/2.8	.000	NS
Control Over Noise	4.3/2.3	4.3/2.5	.000	.001
Control Over Visual Distractions	2.9/1.4	3.3/1.4	.000	.000
Amount of Workstation Floor Area	2.5/2.2	2.5/1.5	NS	.009
Worksurfaces in the Workstation:				
Amount of Space/Area	2.5/1.3	3.3/1.9	.0003	.002
Arrangement/Layout	3.4/1.9	3.1/1.7	.001	.000
Color	2.6/1.3	2.9/2.6	.000	NS
Stability	2.3/1.3	2.2/1.9	.000	NS
Height	2.3/1.3	2.5/1.9	.000	NS
Chair in the Workstation:				
Comfort	3.3/1.1	3.1/3.3	.000	NS
Ease of Adjustment	3.8/1.2	3.7/3.7	.000	NS
Back Support	3.5/1.2	3.1/2.8	.000	NS
Color	2.7/1.5	3.1/3.2	.001	NS
Mobility	3.5/1.1	3.3/3.4	.000	NS
Stability	3.0/1.1	2.9/3.1	.000	NS
State of Repair	2.9/1.1	3.4/3.5	.000	NS
Amount of Workstation Filing Space	3.2/1.6	2.4/2.0	.002	NS
General Satisfaction with the Workstation	2.8/1.5	2.9/1.8	.000	.006
Lighting:				
Task (Worksurface)	2.8/1.9	3.6/2.3	NS	.012
Brightness Level	3.5/2.2	3.5/2.8	.011	NS
Conference Facilities:				
Ease of Access (Location)	2.2/1.4	3.1/2.3	.010	NS
Availability	2.4/1.4	3.3/2.4	.005	.026
Air Circulation	4.4/3.4	4.5/3.8	.039	NS
Electrical Outlets	2.8/1.9	3.3/1.8	.021	.003
General Satisfaction with the Office Facility	3.1/1.6	3.3/2.5	.000	NS

*t-test, 2-tailed

Key: 1 = highly satisfied; 2 = moderately satisfied; 3 = neutral; 4 = moderately dissatisfied; 5 = highly dissatisfied.

4 COST/BENEFIT ANALYSIS

As expected, the group which received the systems furniture demonstrated a significant increase in productivity which can be credited to the design and characteristics of the individual workstations. This result has both functional and economic implications.

Systems furniture is more adaptable to automation than is conventional furniture. While systems furniture is more expensive, it can be placed in less floor space than conventional furniture.

To procure the systems furniture for this study, it was necessary to show that the cost could be amortized in a span of 8 years. This was done by comparing the space required for systems furniture with that required for conventional furniture and calculating the difference in leased space cost avoidance. In the area immediately surrounding DCSC, the average cost of leased office space is \$9/sq ft. Table 6 shows the systems furniture investment.

As this study has shown, the economy of systems furniture does not stop with the advantage of more efficient use of space. When the increase in worker productivity is accounted for, the amortization of the furniture expenditure is much more rapid than 8 years. Experimental group 1 showed an increase in productivity of 20.6 percent after the introduction of adequately appointed systems furniture. The annual labor cost of a

Table 6
Cost Comparison Analysis

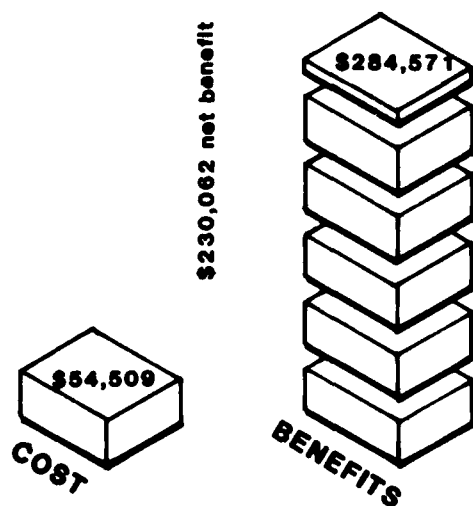
	Option 1 Systems	Option 2 Conventional
Total Initial Furniture Cost (Including Installation)	\$54,509	\$34,511
Savings in Initial Furniture Cost	---	\$19,998
Total Square Footage (Including Circulation)	1,370	1,750
Annual Recurring Cost of Leased Office Space (\$9.0/sq ft, including utilities)	\$12,330	\$15,750
Cost of Leased Space Over 8 Years*	\$65,781	\$84,026
Savings in Recurring Leasing Cost Over 8 Years	\$18,245	.
Total Project Cost Over 8 Years	\$120,290	\$118,537

*Costs were discounted using the 10 percent factor specified by the Office of Management and Budget for normal economic analyses.

typical worker in this group is \$19,735 and the average cost of one workstation is \$3,894. Taken alone, the cost of the new furniture should be amortized in only 11.5 months, when this increase in productivity is considered.

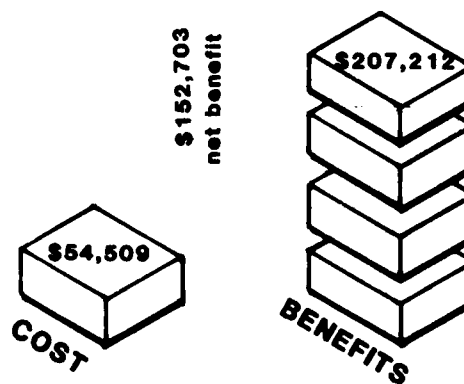
Figure 3 presents two estimates for net benefit. The first estimate represents the payback based on a 20.6 percent increase. For comparison, a productivity increase of 15 percent is used to compute a payback of 16 months. This comparison is useful in the event that productivity would slightly decrease over time.

When space savings and the increase in productivity are considered together, the cost of the average workstation can be amortized in only 10.8 months as shown in Table 7.



NET BENEFIT ESTIMATE #1

Productivity increase of 20.6%
based on a five year period.
Payoff in 11 1/2 months.



NET BENEFIT ESTIMATE #2

Productivity increase of 15%
based on a five year period.
Payoff in 16 months.

Figure 3. Estimates of net benefit.

Table 7

Amortization Analysis

	Systems	Conventional
Space Cost (cost/employee/year)	\$880.71	\$1,125.00
Labor Cost (cost/employee/year)	\$15,669.19*	\$19,734.50
Total Costs (cost/employee/year) (x number of employees)	\$16,549.90 x 14	\$20,859.50 x 14
= Total cost/year	\$231,698.60	\$292,033.00

SAVINGS PER YEAR = \$292,033 - \$231,698.60 = \$60,334.40

FURNITURE COST = \$54,509

MONTHS TO AMORTIZE = (\$54,509/60,334.40) x 12 = 0.903 X 12 = 10.8 MONTHS

*Based on 20.6 percent productivity increase per employee.

While this study has shown that systems furniture can contribute to significantly higher employee productivity, there is reason for further inspection of the information that was collected. The Task Analysis Questionnaire and interviews showed that the workstations used by the control groups were inadequate. Not only was there insufficient furniture but the advent of computerization made the existing furniture inappropriate and dysfunctional. Providing adequate conventional furniture contributed to increased productivity in experimental group 2. Adequate and ergonomically correct furniture provided to experimental group 1 resulted in significant productivity increases and less floor space used.

When the furniture industry developed an alternative to conventional furniture, the result was "systems furniture." With this type of furniture, many components depend on other components for stability. Work surfaces must be mounted to partitions. This limitation can be a problem when systems furniture is rearranged. There are also many items to be inventoried; a drawer hanger bracket becomes an inventory item. Several manufacturers are now marketing an alternative: "modular furniture." Modular furniture can best be described as a hybrid of conventional and systems furniture. Like systems furniture, it was developed during the automation boom, so the components are usually ergonomically suited to the modern office. There are, however, important differences. Most pieces of modular furniture are free-standing. It tends to be less adaptable to individual idiosyncracies; there is less capability for each employee to tailor his/her workstation to the way he/she works. However, a more complete configuration of modular furniture provides fewer furniture inventory items. Modular furniture is generally less expensive per workstation than systems furniture. Modular furniture does tend to consume more floorspace than systems furniture, but this work has shown that in economic terms, space use is not the overriding variable contributing to amortization of furniture costs.

Based on the results of this study, one would expect to find similar productivity increases whether systems or modular furniture is used.

5 FACILITY MANAGEMENT GUIDANCE

Functional office requirements should be determined on a regular basis. While the Office Improvement Questionnaire and interviews were the primary information-gathering tools in this study, quicker methods of assessing requirements can also prove useful to the facility planner/manager.

A "walk-through" of the facility, observing how the existing workstations are being used, should reveal the more obvious factors needing improvement.⁹ In addition, attention should be given to circulation paths and high-use areas.

Assigning priority values to office features can assist the facility manager with programming decisions. Given a list of office features, employees should be able to quickly rank the items they feel most need improvement. The list should be complete, and spaces should be provided for employees to add items. If it would not be practical to survey all employees, a representative sample should be surveyed.

Supervisors and managers could determine required adjacencies for their own work unit employees and for the relationship of their work unit to surrounding organizational elements by producing a "bubble diagram." The bubble diagram is a representation of each employee and each space (such as central files, conference room, shared CRT, and copy machine) by a circle. The circles are then connected by numbered lines to indicate required adjacencies and priorities.

Caution should be exercised in facility planning to avoid removing flexibility and individual control from the office design. Adjustable furniture and task lighting allows each individual to achieve comfort within the workstation. Employees should be given some degree of control within the workstation to satisfy their needs for privacy, territoriality, and personalization.¹⁰

⁹J. Zeisel, *Sociology and Architectural Design* (Russel Sage Foundation, 1975).

¹⁰H. M. Proshansky, W. H. Ittelson, and L. G. Rivlin, "Freedom of Choice and Behavior in a Physical Setting," in H. Proshansky, W. Ittelson, and L. Rivlin, Eds., *Environmental Psychology: People and Their Physical Settings*, 2nd ed. (Holt, Rinehart and Winston, 1976).

6 CONCLUSIONS AND RECOMMENDATIONS

The results lend support to the theory that environmental improvements in the workplace can lead to greater productivity. Clearly, the archival records represent a hard measure of productivity, which, in conjunction with satisfaction data, provide good support for an environment-productivity link. However, in this respect, it is uncertain to what extent satisfaction is a necessary or sufficient cause for productivity; future studies also employing a multimethod approach will lend increasing evidence to this issue.

Based on a productivity increase of 20.6 percent, the cost of systems furniture should be amortized in only 11.5 months; a productivity increase of 15 percent would amortize the cost in 16 months. Systems furniture requires less floor space than conventional furniture. When reduced space and increased productivity are considered together, the average cost of a workstation can be amortized in only 10.8 months.

It is recommended that local facility managers consider employee satisfaction ratings of the facility and workspace, and how employee satisfaction can affect office productivity.

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APPENDIX A:

OFFICE IMPROVEMENT QUESTIONNAIRE

INTRODUCTION

As part of DCSC's program to improve office areas, we need information about what you do, the equipment you use and the materials you work with. This data will be used to develop workstations which will meet your job needs and allow for efficient management and standardization of space and furnishings. **PLEASE RESPOND TO EVERY ITEM ON THIS QUESTIONNAIRE.**

We are not interested in identifying any individual answers to this questionnaire. Your responses will be pooled with those of other DCSC employees for statistical summary. No individual's responses will be made known to other DCSC personnel. The questionnaire number (below) will not be associated with a specific individual.

Definition. Throughout this questionnaire, "**Your workstation**" refers to your immediate work space, including any furniture or equipment which is used **primarily by you**, such as your desk, filing cabinet, side table, side chair, and so forth.

A. PERSONAL DATA

Questionnaire

Number _____

Your Job Title _____

Your Pay Grade _____ Job Series _____ Your Division Branch Section _____

Brief Description of what you do: _____

B. MATERIALS AT YOUR WORKSTATION

For the following list of materials, please indicate whether you typically store each kind of material at your workstation (by placing an "X" in either the YES or NO column).

If you mark "yes," please estimate the linear feet of each type of material you store. Round to the nearest half foot. (Please denote in decimals, such as 1.5, 2.0, .5, etc.)

Definition. Linear feet is defined as how high the pile would be if all materials of the same kind were piled in one stack.

	Yes	No	Linear Feet
1. Standard size papers (8 1/2 x 11) (loose or held in folders)			
2. Legal size papers (11 x 14) (loose or held in folders)			
3. Bound documents (books, reports, catalogs, <i>3 ring binders</i>)			
4. Computer paper printouts			
a. Stacked (loose or bound)			
b. Suspended or hanging			
c. Rolls of computer paper			
5. Drawings, illustrations, maps			
a. Rolled (measured as if rolls arranged side by side in a single row)			
b. Hanging (measured from front sheet to back sheet)			
c. Flat (measured as if stacked in a single pile)			
6. Microfilm			
7. Microfilm reels or cartridges			
8. Computer cards			
9. Computer tapes			
10. Computer disk packs			
11. Computer floppy disks/diskettes			
a. 5 1/4 inch diameter			
b. 3 1/2 inch diameter			
c. Other (specify) _____			
12. Special purpose equipment, such as drafting equipment or photographic equipment materials (measured as if placed in a 5 1/2 inch and 12 inch wide drawer, how long would the drawer be?)			
13. Other (specify) _____			

C. LOCATION OF REFERENCE MATERIALS AT YOUR WORKSTATION

Of the materials you marked "yes" on the previous page (Section B), please indicate whether you typically store any **active reference materials** in each of the **locations within your workstation** listed below. If you mark "yes," please estimate the linear feet of active reference material you store in each of the following locations in your workstation (in the same manner explained in Section B).

Definition. Active Reference Materials include any materials, such as those listed in the previous section, which contain information which you access frequently (i.e., several times a week).

	Yes	No	Linear Feet
1. Files			
2. Drawers (Desk or Table, at 5" high and 12" wide, how long?)			
3. Work surfaces			
4. Bookshelves			
5. Other (specify)			

6. Of the active reference material at your workstation, do you typically store papers, notes, drawings or charts **on a tackboard**? If yes, please estimate the square footage of tackboard surface on which these materials are displayed (measured by multiplying the length by the width of the tackboard surface covered by these materials).

Yes	No	Square Footage

7. Of the materials stored in your workstation, do you store inactive reference material (information which you rarely access)? How much?

Yes	No	Linear Feet

D. GENERAL QUESTIONS

1. About how much of your work time do you usually spend at your workstation?

0-24%	25-40%	41-60%	61-80%	81-100%

2. Is having visual and auditory accessibility to your co-workers more or less important to your job function than having privacy from your co-workers?

More Important	Less Important	Equally Important	Doesn't Matter

3. Are your current filing/storage needs adequately met?

Yes	No

If "NO," please briefly explain.

4. If you could have an additional piece of furniture or equipment in your workstation, what would you need to do your job more efficiently? (Please specify only **one** item).

E. YOUR JOB ACTIVITIES AND EQUIPMENT

On the next three pages is a list of activities and equipment. There are two steps involved in responding to each item.

Step 1 Review the entire list of activities and equipment. Place an "X" in the YES column for each item you do as part of your job. If you do not perform the activity, place an "X" in the NO column.

Step 2 For each item that you marked "Yes," additional information is needed:

- First, estimate the **portion of your usual total work time** you spend in each YES item. Place an "X" in one of the five columns (1-5, 6-25, 26-50, 51-75, 76-100). The total time may add up to more than 100 percent if several activities are done at one time.
- Next, estimate the typical duration of each occurrence of the "YES" item. Place an "X" in one appropriate column for each activity marked "YES."
- In some cases, a third response is needed. For these items, estimate the typical number of persons, **including yourself**, that participate in the activity with you. Place one "X" in the appropriate column.

The items in this section are divided into two parts.

Part 1 These items refer to general activities which you do **in your work**.

Part 2 These items refer to activities performed **at your workstation**. Place an "X" in the YES column **only** if you perform the activity or use the equipment in your workstation (see definition in the "Introduction"). Place an "X" in the NO column if you do not perform the activity at your workstation, even though you may perform the activity or use the equipment elsewhere (such as a library, central computer room, common-use area, or a co-worker's workstation).

IT IS IMPORTANT THAT YOU COMPLETE ALL ITEMS IN BOTH STEPS 1 AND 2.

STEP 1

STEP 2

Part 1 IN YOUR WORK, DO YOU

	Percent of work time spent in activity			Typical duration each time you perform activity		Typical number of persons involved at one time (incl. self)					
	Y I S	N O		Less than 20 min	20 min to 1 hour	More than 1 hour	2	3	4	5	More than 5
1. Supervise employees:											
a) 5 or less											
b) 6-15											
c) more than 15											
2. Communicate in person with co-workers or with others who are from outside DE SC (such as vendors, customers, etc.):											
a) At your workstation											
b) In meeting or conference rooms											
c) At co-workers workstation											

STEP 1

STEP 2

Part 2

AT YOUR WORKSTATION, DO YOU

	Y I S	N O	Percent of work time spent in activity					Typical duration each time you perform the activity		
			1-5	6-25	26-50	51-75	76-100	Less than 20 min	20 min. to 1 hour	More than 1 hour
3 Read or write on papers or documents (such as reports, correspondence and other bound or loose materials, drawings, manuals, books, catalogs, and other references, etc.)?										
a) Materials with legal-sized pages or smaller										
b) Folded or bound computer paper										
c) Drawings or other materials smaller than 24" x 36" but larger than legal-sized pages										
d) Drawings or other materials larger than 24" x 36"										
e) Other (specify)										
4 Draw, illustrate or do drafting?										
a) Media smaller than 24" x 36"										
b) Media 24" x 36" or larger										
c) Other (specify)										
5 Operate or use office equipment?										
a) Typewriter										
b) Typewriter with mag card reader										
c) Computer terminal/CRT										
d) Adding machine or calculator										
e) Dictation machine										
f) Transcriber										
g) Telephone										
h) Microfilm or microfilm reader										
i) Other (specify)										
(1)										
(2)										
(3)										
(4)										

F. SHARED EQUIPMENT/FACILITIES: OUTSIDE YOUR WORKSTATION

Below is a list of office equipment and facilities which are often shared by several employees. Please indicate whether or not you **share** each of the items with your co-workers in a location **outside your immediate workstation** (by placing an "X" in either the YES or NO column).

For each item marked "Yes," please estimate the percentage of your work time which you typically spend using the facility or equipment, the usual duration each time you use the item (in the same manner explained in Section F).

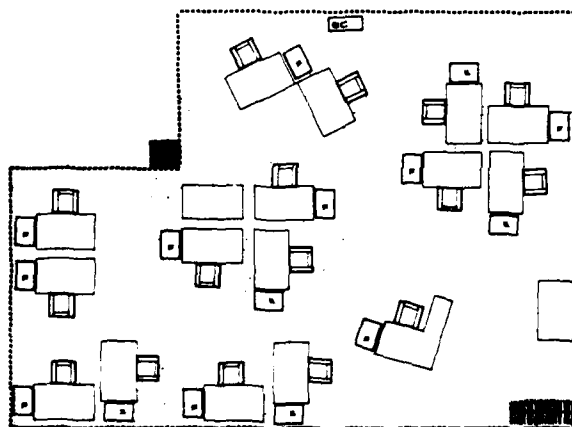
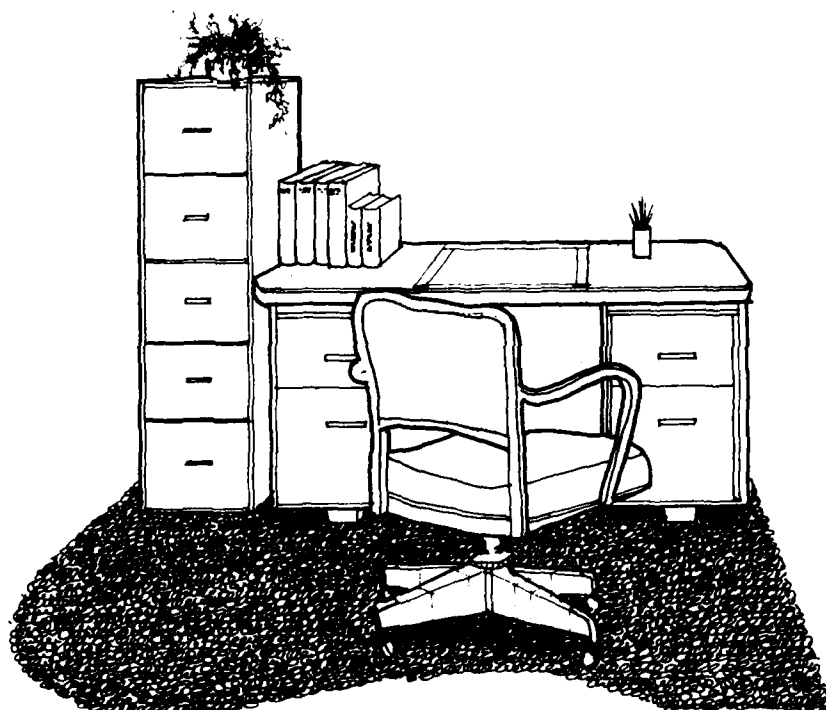
STEP 1

STEP 2

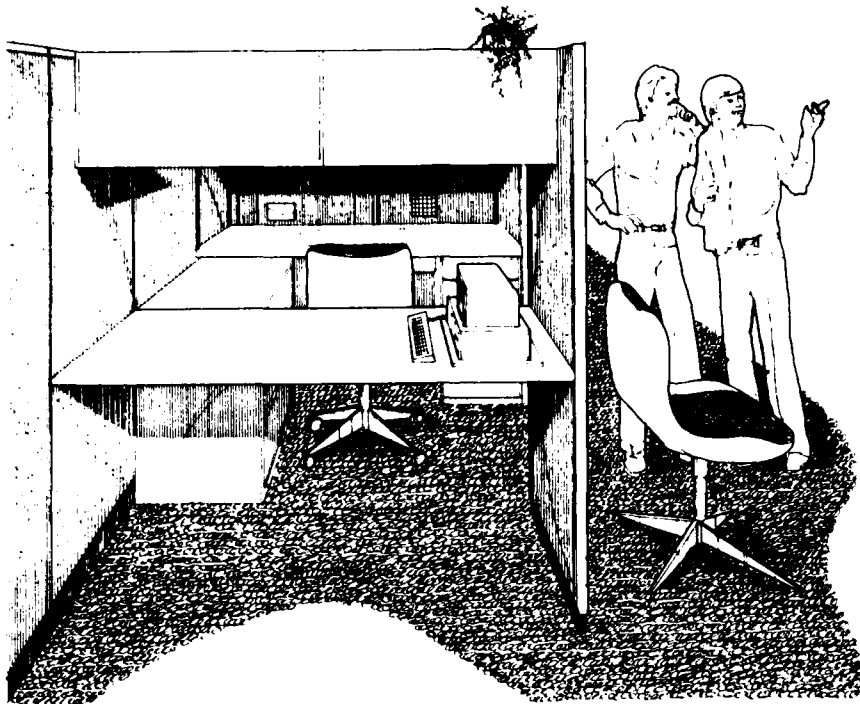
IN YOUR WORK, do you use or share work facilities or equipment?	Y I S	N O	Percent of work time spent in activity					Typical duration each time you perform the activity		
			1-5	6-25	26-50	51-75	76-100	Less than 20 min	20 min. to 1 hour	More than 1 hour
a) Computer terminal										
b) Computer printer or print-out distribution center										
c) Word processor										
d) Copy machine										
e) Microfilm/tiche reader/printer										
f) Typewriter										
g) Mail distribution center										
h) Special communication telex, dictation										
i) Central book/caset(s)/reference										
j) Central filing										
k) Other (specify)										

APPENDIX B:

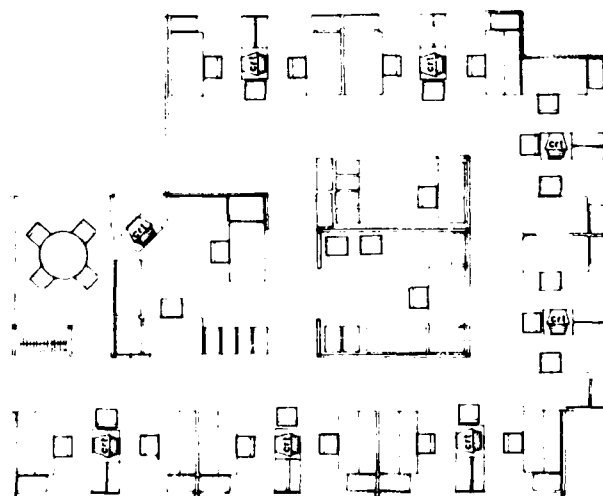
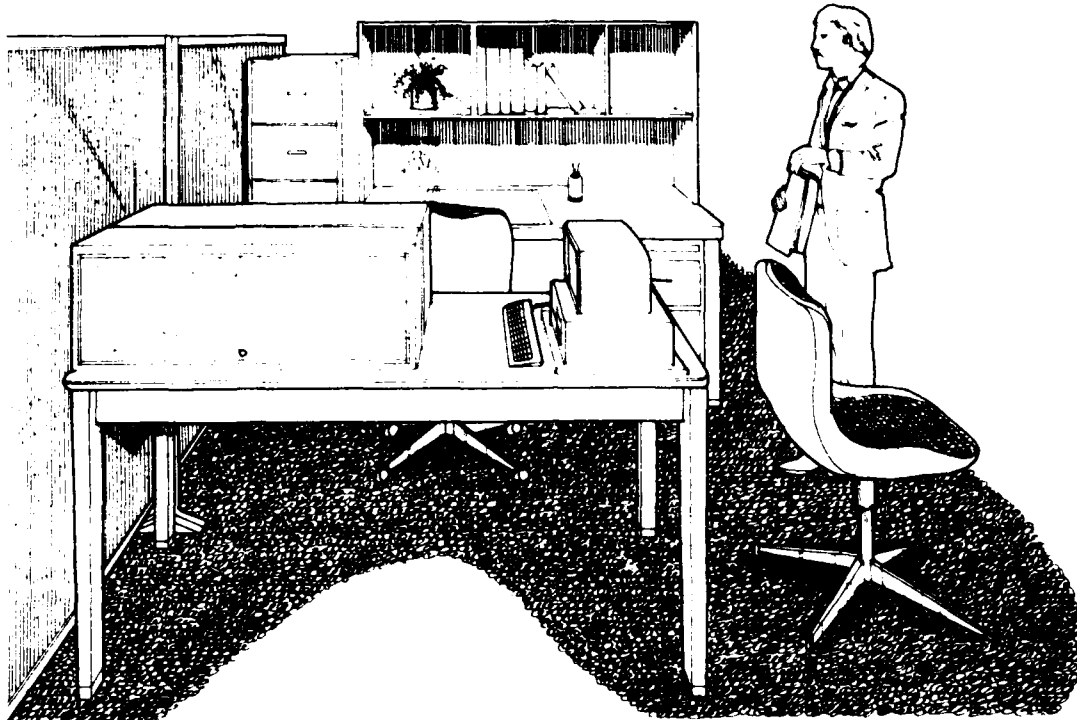
**WORKSTATION DESIGN AND LAYOUT FOR
EXPERIMENTAL GROUPS BEFORE AND AFTER**



**CONTROL GROUP AND ALL GROUPS BEFORE
(CONVENTIONAL FURNITURE)**



EXPERIMENTAL GROUP I
(SYSTEMS FURNITURE)



EXPERIMENTAL GROUP II
(IMPROVED CONVENTIONAL FURNITURE)

APPENDIX C:

OFFICE SATISFACTION QUESTIONNAIRE

QUESTIONNAIRE # _____

INTRODUCTION

DCSC is interested in learning its employees' attitudes concerning their office spaces in order to identify needed improvements. As an occupant of your office area, your experience and opinions will be very valuable in this effort.

In the following questionnaire, you will be asked to indicate how satisfied you are with various features of your present office (Section A). You will also be asked to rate five of the items listed which you consider to be most important to you (Section B).

Do not put your name on this questionnaire: We are not interested in identifying any individual responses. The questionnaire number (above) will not be associated with a specific individual. Your responses will be pooled with those of other DCSC personnel for statistical summary.

BACKGROUND

Age: _____

Sex: _____

Length of employment with DCSC: _____ (years)

GS-level (grade): _____

SECTION A

INSTRUCTIONS

Below is an example of the questions given in this Section.

	HIGHLY SATISFIED	MODERATELY SATISFIED	NEUTRAL	MODERATELY DISSATISFIED	HIGHLY DISSATISFIED
Carpeting					
Color:	X				
State of repair:				X	

The responses marked for these items indicate a high degree of satisfaction with the color of carpeting, but moderate dissatisfaction with its state of repair.

Please read each item carefully and check only one of the five response categories which best represents your feelings about that item.

IT IS IMPORTANT THAT YOU MARK ONLY ONE RESPONSE FOR EACH ITEM.
PLEASE DO NOT SKIP ANY ITEMS.

The items in this section are divided into two parts:

PART 1: These items refer to **your workstation**: Your immediate work space, including any furniture or equipment which is used primarily by you, such as your desk, filing cabinet, side chair, and so forth.

PART 2: These items refer to **the facility** in which you work: The office building in which your workstation is located.

PART 1

Please rate your satisfaction with each of the following items concerning your workstation:

	HIGHLY SATISFIED	MODERATELY SATISFIED	NEUTRAL	MODERATELY DISSATISFIED	HIGHLY DISSATISFIED
1. Furniture in your workstation (desks, tables, files, bookcases)					
Ability to adapt for several different functions:	_____	_____	_____	_____	_____
Arrangement:	_____	_____	_____	_____	_____
State of repair:	_____	_____	_____	_____	_____
2. Control over noise distractions (conversations, machinery):	_____	_____	_____	_____	_____
3. Control over visual distractions:	_____	_____	_____	_____	_____
4. Ease of communication with and access to co-workers from within your workstation:	_____	_____	_____	_____	_____
5. Amount of floor area within your workstation:	_____	_____	_____	_____	_____
6. Worksurfaces in your work- station (desk and table tops)					
Amount of space/area:	_____	_____	_____	_____	_____
Arrangement/layout:	_____	_____	_____	_____	_____
Color:	_____	_____	_____	_____	_____
Stability:	_____	_____	_____	_____	_____
Height:	_____	_____	_____	_____	_____
7. Chair in your workstation					
Comfort:	_____	_____	_____	_____	_____
Ease of adjustment:	_____	_____	_____	_____	_____
Back support:	_____	_____	_____	_____	_____
Color:	_____	_____	_____	_____	_____
Mobility:	_____	_____	_____	_____	_____
Stability:	_____	_____	_____	_____	_____
State of repair:	_____	_____	_____	_____	_____
8. Filing/storage spaces in your workstation (drawers, files, bookcases)					
Amount:	_____	_____	_____	_____	_____
Type: (vertical or lateral, hanging or floor-supported):	_____	_____	_____	_____	_____
Ease of access:	_____	_____	_____	_____	_____
9. In general, your workstation:	_____	_____	_____	_____	_____

PART 2

Please rate your satisfaction with each of the following items concerning the facility in which you work:

	HIGHLY SATISFIED	MODERATELY SATISFIED	NEUTRAL	MODERATELY DISSATISFIED	HIGHLY DISSATISFIED
10. Lighting					
Ambient (ceiling):	_____	_____	_____	_____	_____
Task (worksurface):	_____	_____	_____	_____	_____
Brightness level:	_____	_____	_____	_____	_____
Type (incandescent, fluorescent, sodium):	_____	_____	_____	_____	_____
11. Conference facilities					
Ease of access (location):	_____	_____	_____	_____	_____
Availability:	_____	_____	_____	_____	_____
12. Ease of circulation of people					
Workstation entrance/exit:	_____	_____	_____	_____	_____
Section entrance/exit:	_____	_____	_____	_____	_____
Ease of building circulation (movement to/from public spaces, halls, other Sections):	_____	_____	_____	_____	_____
13. Heating system:	_____	_____	_____	_____	_____
14. Air conditioning system:	_____	_____	_____	_____	_____
15. Air circulation (elimination of smoke and stale air):	_____	_____	_____	_____	_____
16. Electrical outlets:	_____	_____	_____	_____	_____
17. In general, your facility:	_____	_____	_____	_____	_____

SECTION B

INSTRUCTIONS

Below is a condensed list of the items in Section A. Please read through the entire list and then select five features which are most important to you.

As shown in this example, place the letter of the feature you have selected on the appropriate line for the 1st, 2nd, 3rd, 4th, and 5th most important items.

<u>E</u>	1st Most Important
<u>C</u>	2nd Most Important
<u>B</u>	3rd Most Important
<u>E</u>	4th Most Important
<u>D</u>	5th Most Important

- A. Paint
- B. Flooring
- C. Doors
- D. Window Coverings
- E. Walls/Partitions
- F. Ceiling

PLEASE FILL IN A LETTER FOR EACH OF THE FIVE BLANKS PROVIDED.

_____	1st Most Important
_____	2nd Most Important
_____	3rd Most Important
_____	4th Most Important
_____	5th Most Important

- A. Furniture in your Workstation
- B. Control Over Noise Distractions
- C. Control Over Visual Distractions
- D. Ease of Communication with and Access to Co-workers
- E. Amount of Floor Area within your Workstation
- F. Worksurfaces in your Workstation
- G. Chair in your Workstation
- H. Filing/Storage Spaces in your Workstation
- I. Lighting
- J. Conference Facilities
- K. Ease of Circulation of People
- L. Heating System
- M. Air Conditioning System
- N. Air Circulation
- O. Electrical Outlets

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ATTN: Tech Monitor

ATTN: DAEN-IMS-L (2)

Ft. Belvoir, VA 22060

ATTN: Canadian Liaison Officer

Defense Technical Info. Center 22314

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END

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