# Planning ADES

## A System for Computer Assisted Planning

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### Abstract

A system for computer-assisted space planning is presented. The capabilities of the computer assisted process are outlined and compared to traditional manual methods. A method for gathering data suitable for CAD is discussed, along with programs for the "stacking", layout, and evaluation of plans. A methodology for the use of the system is also presented.

The programs and techniques discussed have been implemented and used successfully in the space planning of two office facilities, each with nearly 1000 employees and over 250,000 square feet of space.

### Introduction

Conventional space planning is a lengthy and costly process which often produces unsatisfactory results. Companies move into facilities they have outgrown before move in. Hospitals move into facilities that obsolesce during construction. Both constantly re-plan existing facilities in an endless effort to better organize and better utilize available space.

Many of the deficiencies of space planning are the result of the natural limitations of the traditional manual process. The data that is gathered is highly subjective. It provides a poor basis for the analysis, design, and evaluation which follow. These processes themselves are imprecise and ill-defined. In addition, the time and cost of each process limits the interaction between them. The feedback between successive processes is minimized, making the continual iterative improvement of a plan unfeasible.

The application of computer technology to space planning can overcome many of these limitations. Data can be quantified. Specific criteria can be established for the analysis, design, and evaluation of a plan, allowing for the partial automation of each. All activities can be condensed in time and cost, permitting more cycles of iterative improvement than manual planning allows. As a result, better, quicker, and more reliable planning can be achieved.

The authors of this paper have developed a system of programs to assist in the space planning process. It is called the Planning Analysis, Design and Evaluation System, or Planning ADES. Experience with Planning ADES has shown it to yield the benefits described above. The capabilities and use of the system are discussed below.

### Traditional and Computer Assisted Planning

Space planning is a three phase activity of analysis, design, and evaluation. The analysis produces the specifications for the design. In it, the functional inter-relationships and area requirements of all departments are determined. The design transforms these specifications into a physical form. This process groups the departments into floors and then plans each floor, aiming for a functionally optimal layout. The evaluation validates the results of the design. It verifies the feasibility and functionality of the plans and provides feedback for re-analysis and re-design.

#### Analysis

The initial phase of the planning activity is the analysis of the spatial and functional needs of the facility being planned. The analysis produces area requirements and functional inter-relationships, or affinities, between departments. The areas represent the spatial needs and the affinities the functional needs of the facility.

Affinities. In traditional programming, a team of designers gathers adjacency information by interviewing selected members of the client's staff. Generally, only company officers and departmental managers are interviewed. The resulting affinities are expressed in such terms as "should be near" or "should be very near". These qualitative terms are subject to varied interpretation. Each individual uses his own criteria for defining a set of affinities as well as for evaluating those affinities produced by others. As a result, this data is inconclusive and occasionally misleading.

When applied to large facilities, this process becomes even less useful. In such applications, it becomes unwieldy. The logistics of interviewing assume cumbersome dimensions and foreboding complexities.

In general, the affinities produced by traditional analysis provide a poor basis for the phases to follow.

The use of Planning ADES enables meaningful quantitative affinities to be determined through an exhaustive survey of the entire staff at a given facility. Each employee receives a questionnaire asking for the frequency with which his work requires him to travel to all other departments in the facility (Figure 1). The answers are keypunched and entered into the computer along with the salary of each person. From this information, Planning ADES calculates the expected annual "cost

This questionnaire is for gathering information about the traveling you do within the Bank building.

Please indicate the number of trips you make during the average work week to all the work areas listed below:

| NO. | BANK OFFICERS | COMP.# | TRIPS/ WEEKLY | RELATIVE IMPORT. |
|---|---|---|---|---|
| 100. | Office of Chairman | 1.00 | 01 | |
| 101. | President's Office | 1.01 | 13 | |
| 102. | First Vice President | 1.02 | 05 | |
| 103. | Senior Vice President | 1.03 | 02 | |

**Figure 1. Trip Frequency Questionnaire**

The diagrams below indicate possible work station configurations. Select the type which best suits the work you do:

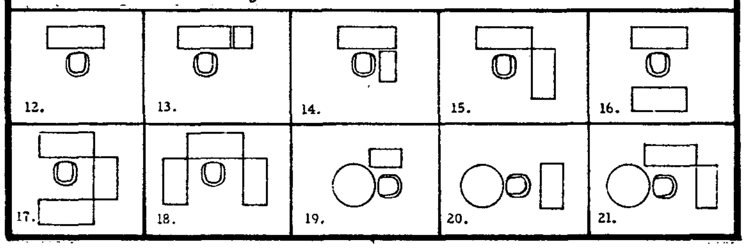


Figure 2. Area Requirement Questionnaire

per foot of walking distance" ("cpf") between all pairs of departments surveyed. The cpf is expressed in "dollars per foot per year". It is an objective quantitative measure of the circulation overhead costs to be incurred in the placement of departments in plan. The cpf value can also be adapted to account for the expected cost of electrical and mechanical runs between departments when special costs arise.

The resulting matrix of department-to-department cpf values provides a valid and useful basis for automating the design and evaluation processes which follow. In addition, it allows for the establishment of quantitative measures to be used in these processes. This is a fundamental requirement for their automation.

Areas. The manual determination of area requirements suffers from deficiencies similar to those encountered in the determination of affinities. A few individuals are asked for estimates of spatial needs in terms of quantity and type of work stations. Their responses are tabulated to produce the net spatial needs. The addition of increments for circulation and construction spaces yields a gross figure.

The process is prone to several forms of error. The estimates tend to be sketchy and inaccurate. The tabulations are subject to computational error. Time and effort must be spent to verify all calculations and reconcile all differences.

The process is further limited by its lack of flexibility. A proposed change in work station sizes or the contemplated introduction of a more efficient filing and storage technique requires at least partial recalculation of areas and reintroduces the possibility of human error.

With Planning ADES, the area requirements, like affinities, can be based on exhaustive analysis. Through questionnaires distributed to all employees, precise measures of current space and equipment needs can be made (Figure 2). By utilizing the computer, these computations are executed quickly and accurately. The facility with which data is entered and modified and the calculations performed permit the consideration of a wide range of work station sizes or equipment configurations before beginning the design. The impact of each change on total area needs is known almost immediately. In this manner, an efficient "design to cost" strategy can be developed for the allocation of a fixed cost quantity of space and equipment.

## Design

The design process aims to transform the affinities and areas into a functionally optimal set of floor plans. Functionally related departments are grouped onto floors, or "stacked", and layouts produced for each floor.

In the traditional process, no criteria for optimality exists, nor is the mechanism of the transformation specified. As a result, it is an entirely intuitive and ill-defined process which produces results that only

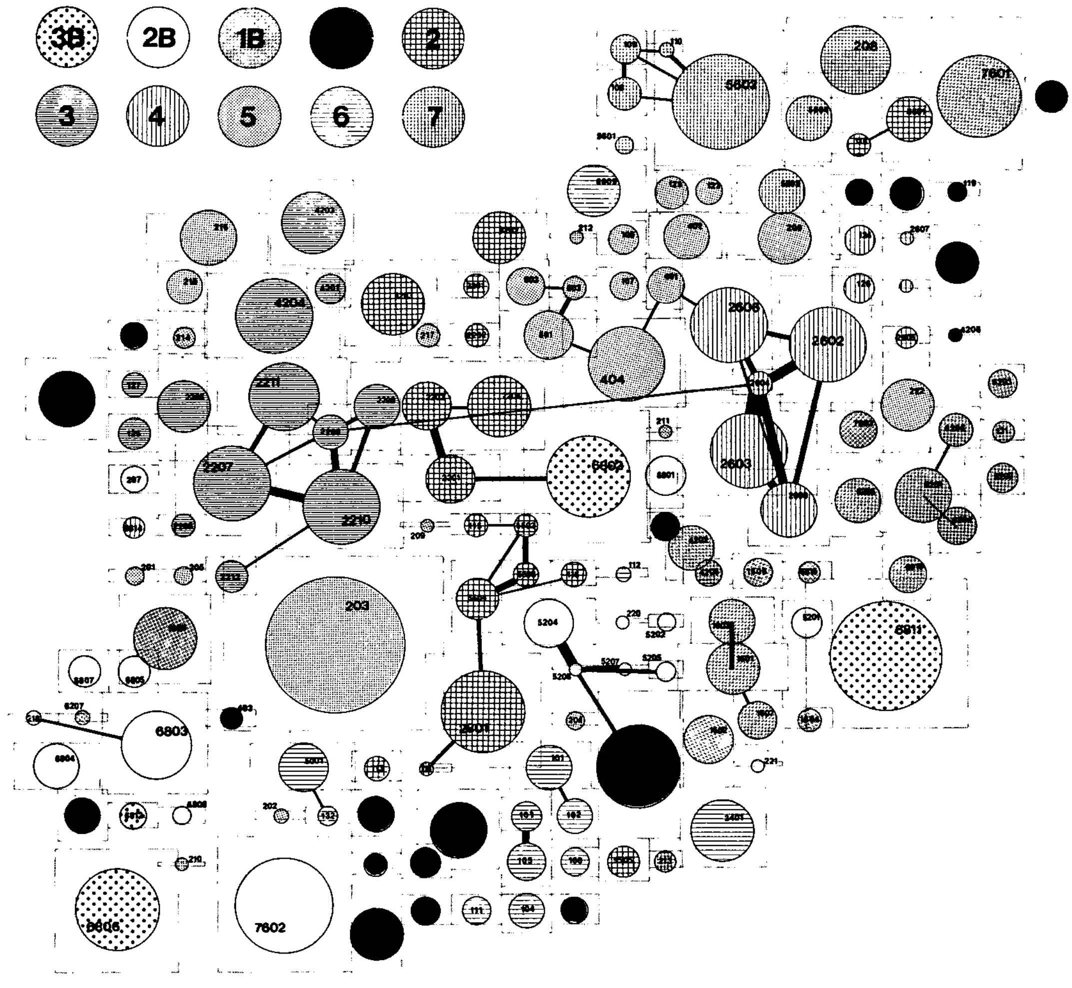


Figure 3. Schematic Plan With Floor Assignments

"seem" acceptable. In practice, it is customary for a designer to produce several alternative schemes and to defer to the client the selection of the one to be implemented.

With Planning ADES, the availability of cpf values allows criteria for optimality to be established. The assignment of departments to floors should minimize the interfloor circulation. Similarly, the layout of each floor should minimize circulation within the floor.

Utilizing heuristic assignment algorithms, Planning ADES can "stack" many departments over several floors and generate schematic bubble diagrams for each. Although the solutions produced are technically sub-optimal, they have been shown to be superior to manually derived solutions. While a man might require several weeks to "stack" and plan 150 departments over 10 floors, Planning ADES can perform this task in less than 5 minutes. Unlike the manual designer, it can also justify its decisions with quantitative measures of efficiency and functionality.

Figures 3 and 4 show sample floor assignment and schematic bubble diagrams. In figure 3, each department is represented by a circle whose size is proportional to its area. The dark lines between circles represent the relative affinities between the corresponding departments. Of the 1000 affinities, only the strongest affinities are shown. The shading patterns indicate the floor assignments selected by the system. It can readily be seen that functionally related departments are assigned to the same floors.

Implications. The speed with which Planning ADES produces floor assignments and bubble diagrams provides a unique tool for achieving efficient cost effective space planning. Within hours, the spatial implications of a dozen different planning strategies may be evaluated. The relative effects on functionality of horizontal and vertical planning can be evaluated. In cases of expansion, the question of whether to expand upwards or outwards can be answered. Where offices must be divided into separate facilities, Planning ADES can propose an assignment of departments

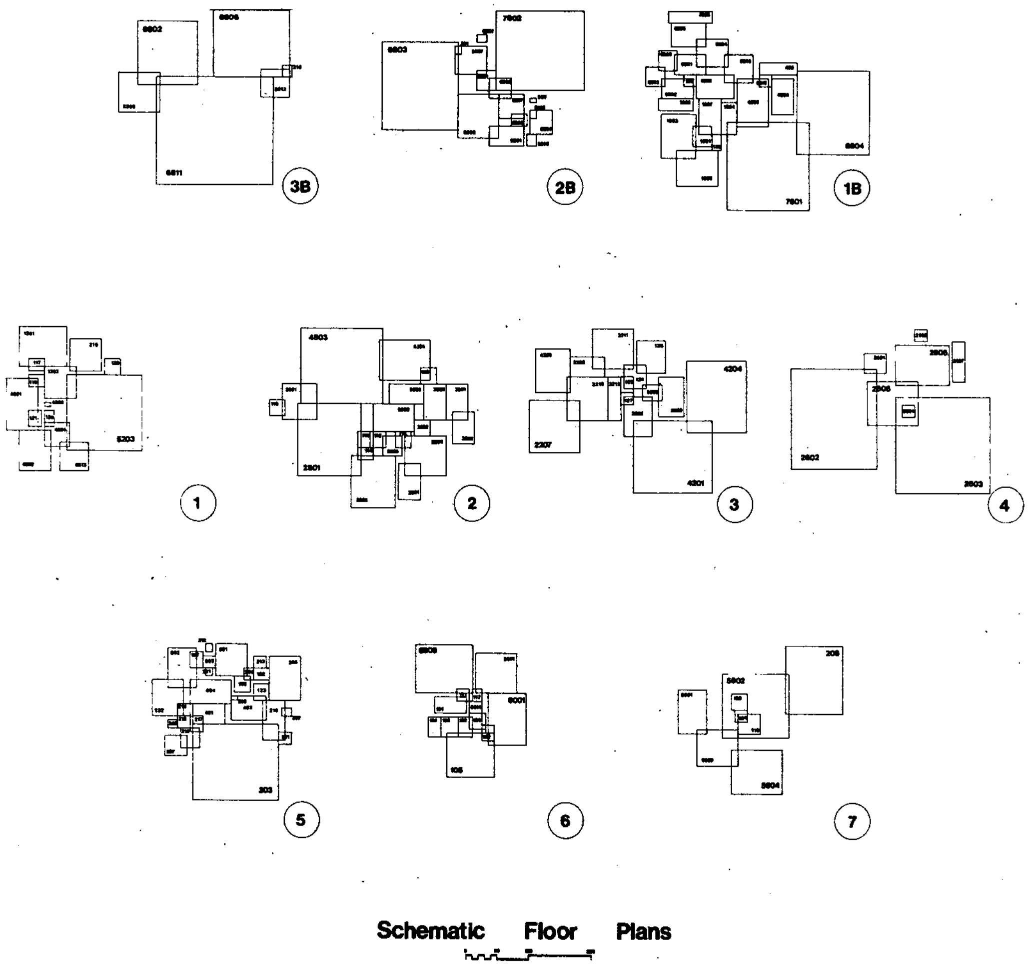


Figure 4. Schematic Plans

to facilities as well as evaluate suggested assignments.

Combined with the ability of the system to manipulate and analyze area requirements and affinities, this "design" capability provides a radically new flexibility in space programming and planning. The ease and speed with which it produces schematic diagrams and evaluates alternative space allocation strategies invites the continuous re-evaluation and revision of the most fundamental design decisions.

Evaluation

The evaluation process verifies the functionality of a proposed set of plans. Strengths and weaknesses of a proposal are determined. The process results in either the acceptance of a plan for implementation or in the initiation of re-design to improve it.

Traditional evaluation is as ill-defined and intuitive as traditional design. Again, the lack of explicit criteria for evaluation leads to the selection of a plan which "seems" good. Though different plans and proposals have relative strengths and weaknesses, they can not be measured or compared. Flaws can be missed.

Once a specific proposal for space utilization is made, Planning ADES can measure the functionality of the proposal. Utilizing the cpf values and the proposed layout as input, it simulates the circulation and measures the resulting overhead costs. Mathematically, it "walks" the corridors, "rides" the elevators, and "climbs" the stairs. This simulation yields an estimate of the total annual circulation cost of the proposed layout. Components of this total cost are printed, including a summary of the longest and costliest trips (Figure 5). This information allows different layouts to be compared and is a basis for specific improvements in them.

Implications. The evaluation capability of Planning ADES allows a measurably efficient plan to be selected. The detailed breakdowns of costs suggest specific improvements in any

SUMMARY OF MOST SIGNIFICANT OPERATING UNIT RELATIONSHIPS

EXTREMES AS MEASURED BY DISTANCE

| DIST RANK | COST RANK | FROM (OP. UNIT) | TO (OP. UNIT) | DIST (FT) | TRIPS (/WK) | HOURS (/YR) | COST (/YR) |
|---|---|---|---|---|---|---|---|
| 1 | **** | 5603 R/S.PUB | 6806 PRINT | 613 | **** | **** | $ 613. |
| 2 | 34 | 404 GEN.BKS | 2204 DCPC.RET | 565 | **** | **** | $ 1130. |
| 3 | 41 | 404 GEN.BKS | 2201 CHK.CORR | 545 | **** | **** | $ 1090. |
| 4 | **** | 404 GEN.BKS | 2202 DATA.MGT | 533 | **** | **** | $ 533. |
| 5 | 17 | 119 BK.RL.OF | 1202 TEC.ASST | 522 | **** | **** | $ 1566. |
| 6 | **** | 203 LUNCH | 6804 CUSTODL | 521 | **** | **** | $ 521. |
| 7 | **** | 119 BK.RL.OF | 206 OFF.DINE | 519 | **** | **** | $ 519. |
| 8 | **** | 119 BK.RL.OF | 204 COFFEE | 519 | **** | **** | $ 519. |
| 9 | 49 | 203 LUNCH | 2201 CHK.CORR | 506 | **** | **** | $ 1012. |
| 10 | **** | 203 LUNCH | 6805 FURN.EQ | 501 | **** | **** | $ 501. |
| 11 | 18 | 203 LUNCH | 6806 PRINT | 499 | **** | **** | $ 1497. |
| 12 | 19 | 203 LUNCH | 6803 BLDG.O/M | 497 | **** | **** | $ 1491. |

EXTREMES AS MEASURED BY ANNUAL COST

| COST RANK | DIST RANK | FROM (OP. UNIT) | TO (OP. UNIT) | DIST (FT) | TRIPS (/WK) | COST (/YR) |
|---|---|---|---|---|---|---|
| 1 | **** | 2201 CHK.CORR | 6802 ARCHIVE | 361 | **** | $ 4332. |
| 2 | **** | 204 COFFEE | 2801 EXAMIN | 205 | **** | $ 4305. |
| 3 | **** | 203 LUNCH | 2801 EXAMIN | 245 | **** | $ 2940. |
| 4 | **** | 2602 ANL.PRG | 2604 COMP.PU | 84 | **** | $ 2772. |
| 5 | **** | 2603 CP.OP.CM | 2604 COMP.PU | 40 | **** | $ 2680. |
| 6 | **** | 218 FREIGHT | 6803 BLDG.O/M | 274 | **** | $ 2466. |
| 7 | **** | 204 COFFEE | 2602 ANL.PRG | 193 | **** | $ 2316. |
| 8 | 30 | 204 COFFEE | 2204 DCPC.RET | 438 | **** | $ 2190. |
| 9 | **** | 2602 ANL.PRG | 2606 DATA.SER | 176 | **** | $ 2112. |
| 10 | **** | 2604 COMP.PU | 2606 DATA.SER | 116 | **** | $ 2088. |
| 11 | **** | 2201 CHK.CORR | 2205 DCPC.ADM | 384 | **** | $ 1920. |
| 12 | **** | 2207 RCDC.PRO | 2211 RCDC.SPC | 140 | **** | $ 1820. |

Figure 5. Longest/Costliest Trips

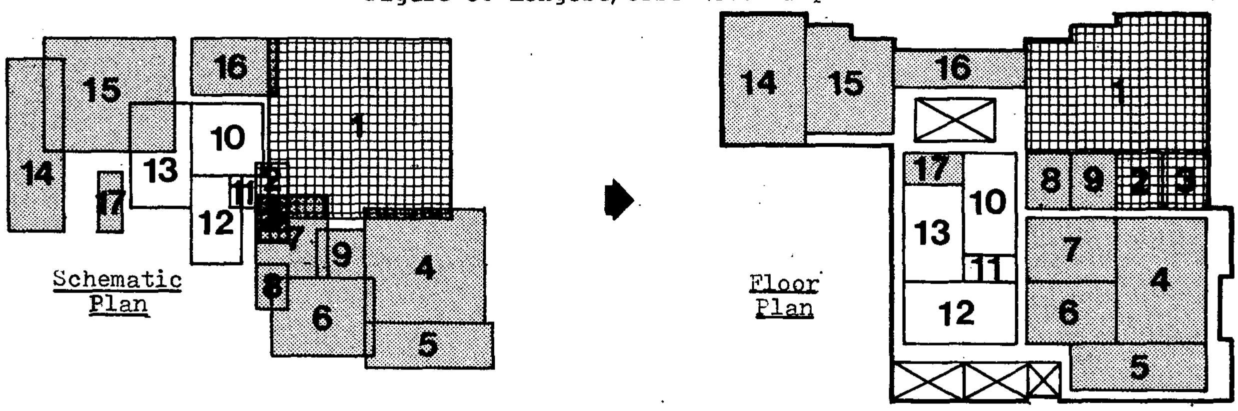


Figure 6. Layout Generation From Schematic Plan.

plan. In addition, the system provides a means of evaluating the cost effectiveness of such items as escalators and mechanical conveyances. By simulating the circulation of plans with and without such systems, equipment costs can be measured against the savings they produce in circulation costs.

## A Methodology for Computer-Assisted Planning

Planning ADES is a system for computer-assisted, not computerized design. Its benefits depend not simply on its use, but largely on how it is used. A brief summary of the use of Planning ADES in the context of the overall design process follows.

### Analysis

Orientation. Computer assisted space planning begins in a manner identical to the start of traditional planning, with the orientation of the design team. The design team meets with the client to become familiar with the purpose, goals, and operation of his organization. Through building tours and staff meetings, the design team develops an understanding of the client's organizational and operational structure. Discussions with key personnel reveal the client's particular spatial needs and objectives.

With this information, the design team develops a set of general design goals and a framework of understanding with which to pursue subsequent phases of activity. During those phases, the results of intermediate analysis and design are constantly validated against this background framework.

The conceptual understanding gained during orientation serves as a basis for the continuous validation of all information generated by the computer in subsequent activities.

Affinities. Beginning with the client's own organizational chart, the design team prepares an initial list of operating units. Each department on the list is considered a unit. The team scans the list for departments whose population is too large or too small to be used meaningfully in the data collection and design processes. In consultation with the client, large ones may be conceptually separated into smaller ones. Similarly, small ones may be grouped into large ones. Special equipment to be in fixed locations, such as xerox machines, may be included as units if it is desired to measure the circulation to them. Ultimately, a final list of operating units is prepared.

The final list of operating units is used to construct the trip frequency questionnaire (Figure 1). The questionnaires are distributed, answered, returned, and processed, ultimately producing a list of inter-unit affinities, or cpf values.

The design team compares the operational implications of the affinities with the intuitive understanding developed during orientation. When discrepancies arise, the original questionnaire responses of the individuals in the associated units are scrutinized. If this reveals no sign of misinterpretation by any respondent, then discussions are held with the appropriate managerial personnel in order to resolve the conflict. Occasionally, the weight of the data causes the client to reinterpret his own understanding of his organization. This process continues until all discrepancies are resolved, insuring the design team that it has valid data with which to begin the design process. Within this process, cpf values may be added where appropriate, to represent the costs of special mechanical runs.

Areas. Area requirements are determined in a similar manner. The design team compiles a list of existing work station and equipment types. From this list, a questionnaire of work station assignments is produced and distributed to all employees. (Figure 2). The results are input to Planning ADES for tabulation. The output totals are verified with the client before proceeding to the design process.

## Design

The design process is begun immediately after completion of the analysis.

Stacking. The assignment of units to floors, or "stacking", initiates the design process. Using the affinity and area data as input, along with a specification of the building size (in terms of floors and areas), Planning ADES generates a stacking diagram for the building (Figure 3).

The computer generated floor assignments are validated by the design team and verified with the client. Changes in assignments can be made.

Layout. Once the floor assignments are finalized, Planning ADES generates bubble diagrams for each floor (Figure 4). The design team then converts these diagrams into block layouts (Figure 6). This can be accomplished at the rate of one block layout per man per hour.

## Evaluation

Before submitting a set of plans to the client for approval, the design team utilizes Planning ADES to evaluate the plans and to suggest improvements.

The proposed plans are input to the system, along with the affinity data. The system produces a detailed listing of all circulation costs between units. These costs are indexed by operating unit, magnitude, and route. Figure 5 shows a sample listing of longest and costliest trips in a plan.

Redesign. The results of such a quantitative evaluation permit the design team to accurately evaluate a given layout and determine the need for redesign. For any plan, the strengths and weaknesses may be known and measured. This provides adequate information for the redesign of a plan.

Additionally, special attention may be given to the need for multiple locations of special types of facilities, such as xerox machines, vending machines, or mail chutes. The cost of duplicating these facilities may be compared against the savings in circulation produced by the duplication.

The evaluation may also cause the client to re-evaluate seemingly arbitrary design decisions imposed on the plan. The cost information may show that operating units which the client assumed operate together may in fact not.

Through several iterations of design and evaluation, the design team and client will arrive at a proposal that is functional and satisfactory to the client.

## Man/Machine Interaction

It is important to stress the structure of the design team interaction with the computer. The computer is used repeatedly to structure, order, and quantify the organization of the client's operation. After each such use, the design team compares the computer's output with its own conceptual understanding gained during orientation and throughout the continuing activities.

When computer generated data conflicts with the designer's conceptualizations, both are questioned and changed until the conflicts are resolved. When the computer and the designer agree, the quantitative measures of the computer enhance the designers understanding of the structure of the problem with which he is dealing.

## Implementation Experience

The planning ADES system is an operational computer system. It has been used in the space planning of two large office facilities, each with nearly 1000 employees and over 250,000 square feet of space.

Client response to the use of the system has been favorable. The plans produced have been accepted and are being implemented. In addition, the clients were particularly receptive to the "cost per foot" concept and the use of "circulation cost overhead" as a measure of plan functionality.

In both projects, Planning ADES was used to plan offices which designers using traditional methods were unable to plan. Using the system, the work was completed successfully in three to four months and at 60-75% of the cost of the unsuccessful manual efforts.

## Programs

Planning ADES consists of five FORTRAN programs, totalling approximately 4000 statements. Table 1 summarizes the functions and features of these programs.

| Program | Primary Algorithm | Statements | Words | Sample Time* |
|---|---|---|---|---|
| 1. Affinity Calculation | Arithmetic | 500 | 130K | 1 min. |
| 2. Area Tabulation | Arithmetic | 500 | 130K | 30 sec. |
| 3. "Stacking" Generator (Partitioning) | Sub-optimal Heuristic | 400 | 130K | 2 min. |
| 4. Layout Generator (Assignment) | Sub-optimal Heuristic | 600 | 130K | 1 min. |
| 5. Evaluation | Branch and Bound Shortest Path | 1500 | 250K | 3 min. |

Table 1 - Program Data

*"Sample Time" is based on a project involving 1000 persons, 150 departments, and 10 floors. Programs were run on an IBM 370/168.

The system was developed in a large-scale IBM 360/370 environment. Its concepts and algorithms represent the cumulative result of nearly four years of independent research by the authors. The assignment algorithm is a heuristic based on the work of Spillers, al-Banna, and Weidlinger (12, 13). The partitioning algorithm is a heuristic developed by the principal author.

## Summary

The Planning ADES system represents the successful application of CAD technology to the problem of space planning and design. Actual experience with the system has shown it to produce successful results at a lower design cost and with greater reliability than traditional manual methods. Additionally, the authors believe it to be capable of producing significantly better and more functionally and spatially efficient space planning than traditional methods.

## Acknowledgements

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