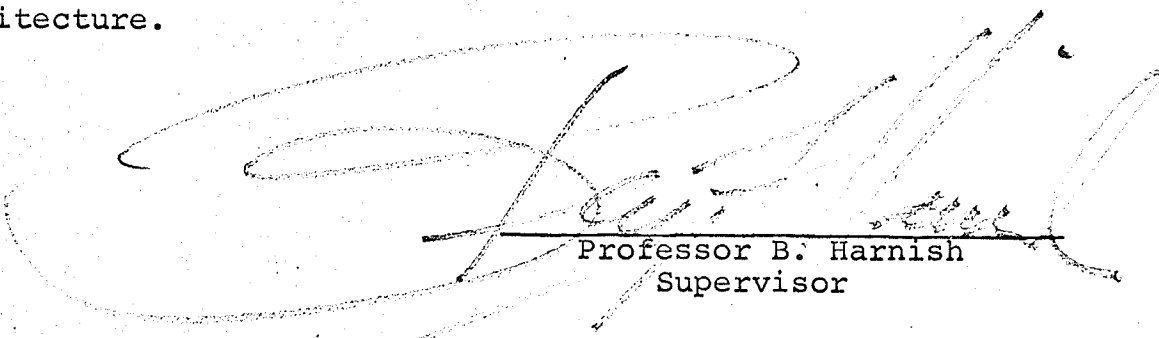
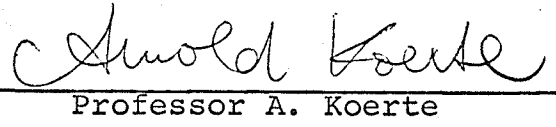


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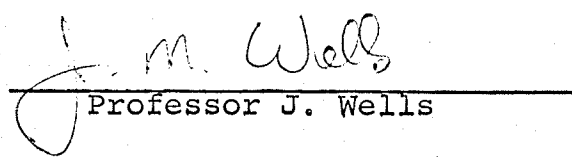
The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "A Precision Approach to Architectural Planning," submitted by Mr. Hussein Mohamed Tawfik in partial fulfillment of the requirements for the degree of Master of Architecture.



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THE UNIVERSITY OF MANITOBA

A PRECISION APPROACH TO ARCHITECTURAL PLANNING

by

Hussein M. Tawfik

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF ARCHITECTURE

Department of Architecture

Winnipeg, Manitoba

May, 1971

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ACKNOWLEDGEMENTS

The author wishes to express his sincere thanks to Professor Ben Harnish, Faculty of Architecture, University of Manitoba for his able guidance and encouragement during the course of this work.

Acknowledgement is also due to Professor A. Koerte, Faculty of Architecture and Professor J. Wells, Department of Computer Science, Faculty of Science for their valuable assistance and interest.

Also the author would like to thank Mr. E. Hillman, Director of Campus Planning, University of Manitoba, Mr. R. DeCuyper, Associate Registrar, Mr. D. Thompson, Assistant Registrar, Mr. G. Phillips, Senior Accountant, Professor J. Gray, Department of Economics and the staff members of the Registrar's Office for their cooperation and assistance. Acknowledgement is also due to the faculty and colleagues in the Department of Architecture for their valuable criticisms and encouragement.

ABSTRACT

This study illustrates a method of architectural planning by use of a digital computer. The computer uses as input data relating to the performance of an existing building similar to that under design. These data include interactions between different activities, time and motion study of personnel, salaries and cost of operation, fire requirements and site limitations.

The computer output is a scale plan of the required project that insures optimum performance for a minimum running cost. The study allows the user to place restrictions in the plan such as pre-located stairwells, outside configurations., etc. It can be applied either for the planning of a new building, or re-allocation of facilities within an existing building.

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INTRODUCTION

The creative act in architecture occurs throughout the design process. The architect is an artist whose brain serves as the ultimate computer, programmed by years of experience and sensitivity to visual phenomena. This means that the planning process is largely influenced by the experience, imagination and talents of the individual designer, rather than by solid facts. Programming of facilities for a certain project may be interpreted differently according to particulars of the architect involved. Various interpretations result in wide varieties of concepts regarding the same project. The basis of comparison are often quite arbitrary. These facts expose architectural work to casual criticism from any individual who can derive his own concepts. This is not the case in engineering discipline, where rigid facts and rules of procedure can protect the scientific work from any unqualified criticism.

Previous efforts have been made to emphasize the impact of 'facts' on architectural planning, rather than individual judgement. These 'facts' were interpreted mathematically to form the pattern of relative interactions between various components of the project. The final integration of these components were based upon the computed pattern of interactions.

The purpose of this study is to expand the approach to computer aided design and to investigate the prospects of its practical applications.

The interactions between different components of the project will be evaluated in terms of costs involved and time consumed etc. in order to determine their optimum locations. Components with relatively dense patterns of interactions will be located closer to each other than to those with lighter patterns. Because of the complexity of differentiating various patterns of interactions with respect to all locations available to those components, a digital computer is utilized to generate the required plan by optimizing proximities of its components according to their relative interactions. The economical merits of this approach will be evaluated to investigate the prospects of its practical applications.

CHAPTER I

METHODOLOGY

1.1 Architectural Concept

The pattern of interactions between different components of a project will have to be expressed in digital forms before a computed integration of these components can take place. Such interactions may be of any type and would be adjusted to any scale to suit the problem considered. For example, the micro interactions considered when evaluating the relative locations of furniture or equipment within a limited space, can be expanded to handle allocation of facilities in a large city.

The following are a few suggestions of various forms of these interactions:

- A. Quantitative evaluation of density of movements between different components.
- B. Qualitative categorization of movements based on functions or cost involved in these movements.
- C. Particulars of materials to be handled, such as unit weight and size, nature and function, frequency and cost of handling or storing.
- D. Mixed patterns of physical communications between activities. For example, if a belt conveyor is the means of communication between two activities, and if the objective

is to minimize the cost of communications, then these two activities would have to be brought close to each other. But if a third activity communicates with the first activity through a pneumatic system and with the second by personal contacts, then a system of compound pattern of interactions has to be used. The running cost per linear foot of the pneumatic system should be compared to that of the belt conveyor and the movement of personnel. The relative locations would be determined to minimize the over-all running cost of communication.

E. Cost of relative locations with respect to rent rates, vacancies, assessment of taxes, etc. The optimum plan should satisfy assumptions based upon any of these factors.

The previous presentation of forms of physical interactions has not accounted for the spiritual aspects which, in many cases, may be of primary importance. The impact of cultural and sociological considerations on the planning process would be evident when comparing two buildings of the same function, built in two different places, or built in two different time periods within the same locality.

Such spiritual considerations have to be assigned physical values before they can enter into a computational process.

1.2 Economical Merits

The approach of founding the planning process on daily interactions between different activities not only

optimizes the performance of the building, but also could result in substantial savings with respect to the building economics. The fixed cost of a project, in terms of site value and erection expenses is usually taken as the prime factor to consider when studying the economics of the project. The annual running, or operating cost, including lighting, heating, maintenance, taxes, insurance and salaries of personnel working in the building is usually a secondary consideration. This should not be so, as preliminary studies showed that the annual running cost of any building could be many times the amortized capital cost of construction.

1.2.1 Comparison between original and running cost

Taking the University of Manitoba Administration building as a sample for a comparison between the running and original costs:

A. It was found that the original fixed cost at the time of erection (1914) was \$271,400. Then assuming this cost was paid through a mortgage of 60 years length, with an interest rate of 7%, we find the annual equivalent cost by using the formula:

$$r = V_0 \times \frac{i(1+i)^n}{(1+i)^n - 1} \quad *$$

where:

* Reginald D. Forbes, 'Forestry Handbook', Ronald Press Comp., New York, 1955, Section 15, 16.

r : annual equivalent cost
 Vo: original fixed cost
 i : interest rate
 n : building life or length of mortgage

Then the annual equivalent cost of the building

$$= \frac{271,400 \times .07 (1.07)^{60}}{(1.07)^{60} - 1}$$

$$= \$19,300 \text{ approx.}$$

B. As for the annual running cost of the building, the data obtained from the accounting department of the University of Manitoba, concerning the annual running cost of the Administration building, shows that the total annual salary costs of employees working in the building is \$1,458,615, and the operating and maintenance costs are equal to \$43,443. This brings the total running cost of the building to \$1,502,058. The ratio between the annual running cost to the annual equivalent rate of the fixed cost would be 1,502,058:19,300 or 77:1. This ratio may be exceptionally high for special reasons related to this specific building. Applying any reasonable tolerance as a factor of safety, we still find that the ratio of the annual running cost to the annual equivalent rate of the original cost is large.

The previous analysis suggests that any small percentage reduction of a building's annual running cost would be much more significant than if the same percentage was saved of its original fixed cost. This would justify any

effort meant to reduce the running cost of the building.

The summary of the cost figures on the University of Manitoba Administration building demonstrates that the major part of the annual running cost is consolidated in staff salaries; and, therefore, the effort to minimize the running cost should be focused on this area. A considerable saving might be achieved by optimizing the performance of personnel.

1.2.2 The impact of efficiency of performance

An appropriate allocation of facilities will have an immediate saving by minimizing the time spent on movements between different locations. This would allow the same number of activities to be carried out by a fewer number of personnel or widening the range of activities that may be carried out by the present number. These savings may be surpassed by gains from optimizing the efficiency of performance of staff members. The physical interactions of an individual reflect on his mental potential. While a reasonable amount of physical effort may stimulate his mental energy, an excessive amount of movement can lead to exhaustion and drop of efficiency. Mental duties assigned to each individual have to be considered in the light of the physical effort involved. Adjusting the pattern of physical and mental duties of each individual to fall within the zone of optimum performance, Figure (1), will optimize his capability and consequently the performance of the whole plant.

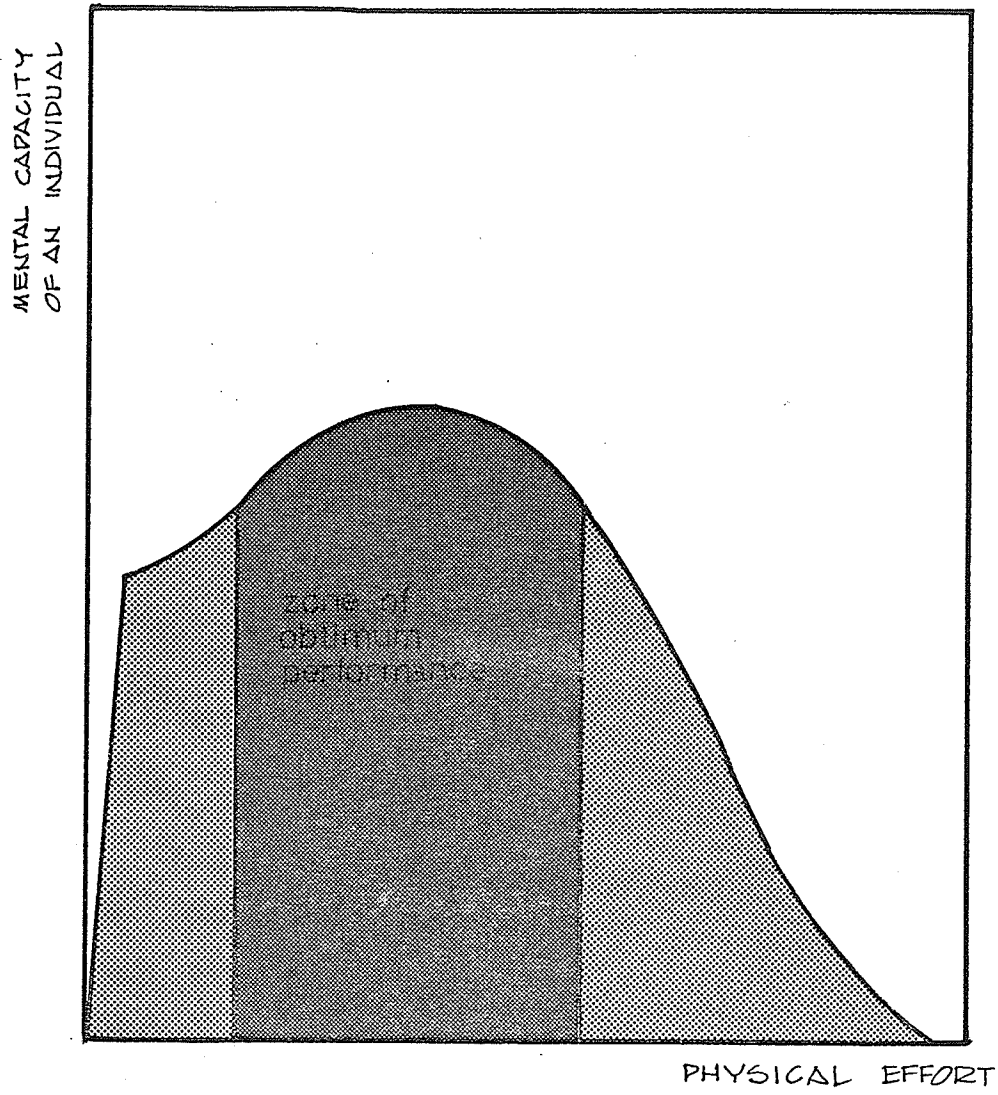


FIGURE 1 Boundary of human potentials

1.3 Methodology of Planning

As optimizing the efficiency of performance can minimize the running cost of the building, it will be used to formalize a precision approach to the planning process. The performance of an existing building of similar functions will be analysed to determine the space requirements and the pattern of interactions expected to take place in the building to be designed. Efficiency of performance of a building may be expressed analytically in terms of running expenses involved, time consumed, quality and quantity of output. Several factors may affect such performance. A brief outline of some of the main factors:

- A. Specialization and training of personnel.
- B. Systems analysis of the sequence of operations and network analysis and/or simulation to optimize productivity and eliminate slacks or contradictions.
- C. Quantity and quality of equipment available. Sufficient amounts of modern equipment will speed processing, while inadequate, or old fashioned equipment may cause drastic "bottle necks".
- D. Space requirements. An overcrowded space may reduce efficiency of performance as an oversized space might.
- E. Relative allocations of facilities. Proper distribution of locations may minimize intermediate movements and save time and cost spent on such interactions.

As is evident from the previous outline, a

comprehensive analysis of all factors affecting efficiency of performance may lead to areas beyond the scope of this study. This study shall confine its concern to the physical aspects of space requirements and a two dimensional arrangement of facilities. Particulars pertaining to other factors are assumed to be adjusted to perfection before the start of our procedure.

1.3.1 Procedure of practical application

The actual merits and limitations of this approach may be more evident through an illustration of its practical applications.

The University of Manitoba's existing Administration building will serve, in this example, as the source of data required for design of a new modern administration building. The procedure adopted for the planning process may be divided into two main phases:

A. Establishing the criteria of design: This will be accomplished by evaluating the present performance with respect to daily interactions and space allocations. A sample of field study will take place at the registrar's general office. The pattern of movements of different personnel will be recorded and the cost of these movements, in terms of salaries of the individuals involved, will be computed. Space allocated to different activities will be checked to evaluate its impact on the present performance.

The data collected from this survey will be modified to present the specific requirements of the new building. Space allocations will be represented by a number of space modular elements, and the predicted pattern of interactions will be prepared from the data available.

B. Computation stage: The interactions determined from the previous study will be used to arrange the modular space elements allocated to different activities in a way that would minimize the cost of their communication. This procedure will be explained in detail in the following chapters.

1.3.2 Growth and change

The computed plan should be as flexible as the rate of change of activities accommodated within it. An updating process should be performed periodically to any plan to insure a particular level of performance. This updating depends largely on the degree of flexibility maintained in the plan. Flexibility may be measured in two ways:

- A. The cost and time consumed for alterations of space allocations.
- B. The number of alternative allocations of facilities that can be accommodated within the same space.

The degree of desired flexibility depends largely on the type of building considered, while the functions of some buildings are hardly changeable, other buildings may require a high degree of flexibility. The factors governing

flexibility are:

- A. Structural systems with respect to live loads and clear spans. It should not only answer the present needs, but also be capable of accommodating any predictable changes of present activities.
- B. Means of vertical and horizontal circulations, and the number of alternative arrangements of facilities that could be served by these means.
- C. Allowances through the mechanical system that can be switched to locations with changing needs.
- D. The boundaries of space allocated to different facilities. This includes structural walls, partitions systems, built in furniture or equipment.

The updating process should check not only the relative locations, but also the space allocations to insure the capability of accommodating the short term growth of different activities. Some activities have to be provided with spaces substantially larger than the actual needs to serve as an overflow for other growing activities. However, a substantial expansion of many activities will necessitate an over-all expansion of the space available.

CHAPTER II

CRITERIA OF DESIGN

2.1 Collection of Data

The data to be collected for this study are required to cover three main items:

- A. Activities, including procedures and involvements of each activity, space allocations and cycles of change, if any.
- B. Personnel, including categorization, changes in numbers, and interactions between different individuals.
- C. Any special considerations affecting the present image, that have to be eliminated or manipulated during the planning process.

These data have to be collected over a representative lapse of time to insure a valid image of the existing performance. It should be noticed that the final design would be as good as the degree of accuracy maintained in establishing its criteria. Three main sources of information will be considered for the preparation of the required data:

- A. Documents: For any confidential informations pertaining to personnel. (i.e., salaries, administrative status, or different cost estimations).
- B. Interviewing: For the outline of sequence of performance, duties involved, and the output of different activities

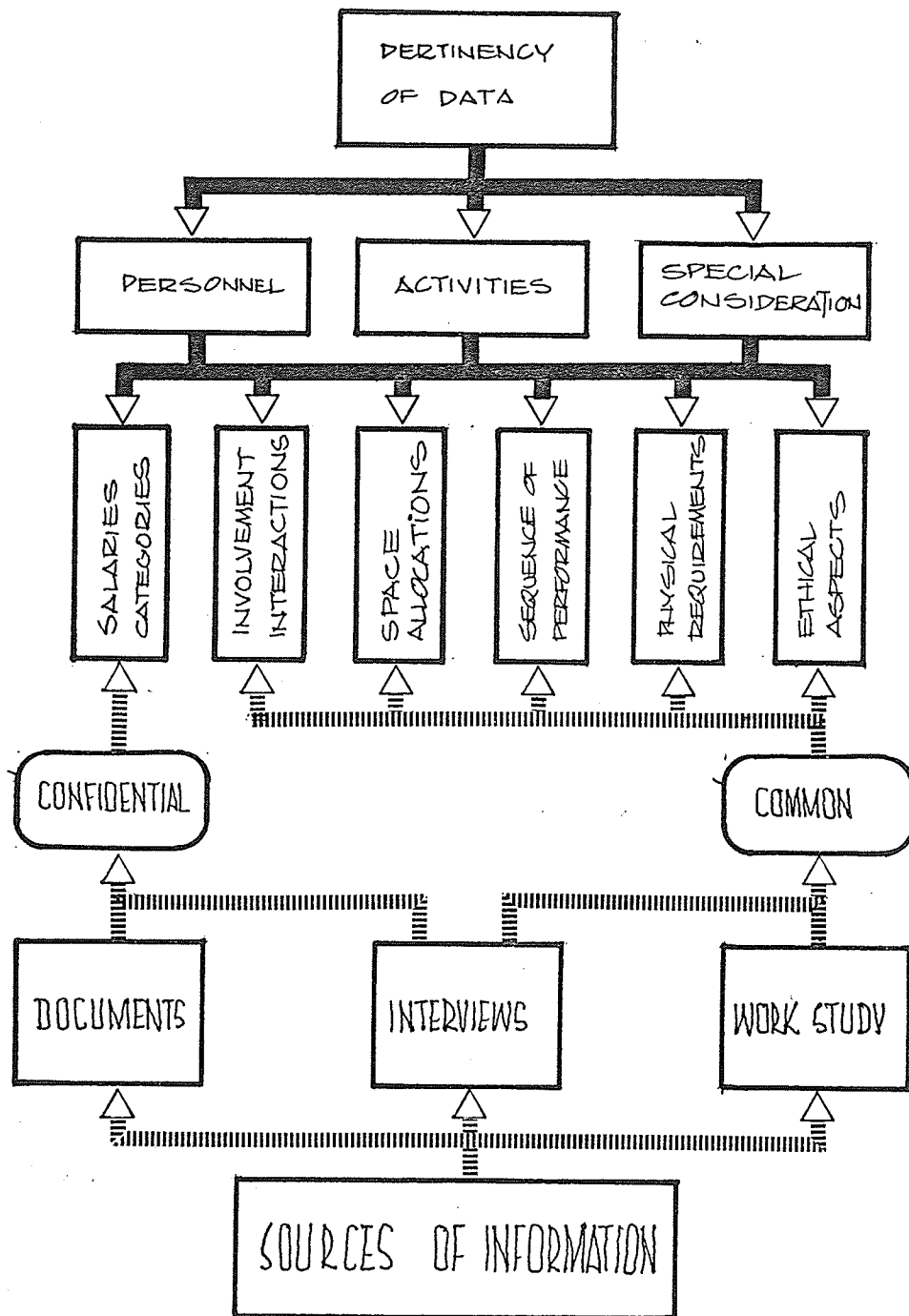


FIGURE 2 Collection of data

and personnel.

C. Observations and work study, using time and motion recording techniques in preparing a detailed pattern of interactions between different individuals and activities.

A summary of particulars of the required data and the corresponding sources of information is presented in Figure (2).

2.1.1 Activities analysis

The registrar's general office considered for this study occupies an area of about 3600 square feet, in the south side of the third floor of the U. of M. Administration building. One of the main architectural features of this classical building is the central hall accommodating the main staircase and connecting the four wings of the building. The disadvantage of this plan form became evident as related activities taking place in one wing grew larger and had to be allocated extra space in other wings or other floors of the building. This compulsory allocation of space results in a considerable drop of efficiency and causes inconvenience to personnel involved in daily communications between separated departments.

From the various sources of information discussed previously, particulars pertaining to each activity were collected. A concise summary of these particulars is as follows:

Activity # 1: Examinations & I.D. Cards

Allocated an area of 220 square feet, and performed by one staff member classified as examinations assistant. Duties include preparation of I.D. cards for the university community and preparatory arrangements for examinations seating. The interactions of this activity are seasonal and largely expanded during the examination periods and the start of the academic year. The normal load of work necessitates some visits to the I.D. center in the Fletcher Argue building and other locations outside the Administration building. Movements within the area are mainly to the reception counter to answer any students inquiries pertaining to I.D. cards or examination seating. In the peak periods, extra personnel are hired to help in clearing the excess load of work. A space for those extra personnel is provided within the area, but it is considered idle in the normal load period.

Activity # 2: General Files

Allocated an area of 520 square feet, and attended by two filing clerks. Duties other than filing, include mail distribution and periodical relief of the telephone operator. The students files are kept in this room for a period of five years before they are transferred downstairs to the microfilm department. The general files act as a nucleus to all other activities within the registrar's

office. Staff members located in different parts of the building contact the filing room for any information pertaining to students.

Activity # 3: Associate Registrar

Allocated a space of 275 square feet, which provides for a private office for the associate registrar and a work station for his secretary. Duties include communications with departments located in other parts of the building. The internal interactions within the area are mainly with the registrar and the records supervisor. Inconvenience to visitors are caused by the lack of waiting space, and the twisted route, through crammed desks, they have to take to reach this office.

Activity # 4: Records Supervision

Allocated a private office for the records supervisor and a working station for his secretary, a total area of 220 square feet. Duties involved in this activity include communications with departments located in the other side of the building, other floors, and with various faculties on campus. The internal interactions are mainly with the associate registrar and the general files.

Activity # 5: Convocations

This activity is performed by a staff member

classified as convocation coordinator and an assistant. Their duties include arrangements for convocations, and therefore a substantial amount of the activity communications involves with places outside the administration building. The space allocated to this activity is about 260 square feet.

Activity # 6: Check of Records

This activity is performed by one person classified as records examiner. The duties include visits to the microfilm department, one floor below. The space allocated to this activity is about 70 square feet.

Activity # 7: Fees

This is one of the busiest activities in the registrar's office. It is performed by a chief fee clerk and two assistants. Space allocated is about 170 square feet. It has relatively dense interactions with the reception counter. A small number of visits are made to the upper floor. The load of work and density of interactions depends upon the season of the year. In the peak periods, extra space and personnel may be required to handle the extra load.

Activity # 8: Control

This is performed by a control clerk and an assistant.

The area allocated is about 120 square feet, with a space for sorting students forms and keeping other relevant materials. The daily communications include visits to the data processing center across the stair hall, and to the current files located in the upper floor.

Activity # 9: Transcripts

The main functions of this activity are to receive the students applications for transcripts, check their courses and grades with different departments and finally prepare a laminated photo copy of the student's history. This activity is carried out by two staff members. Their internal interactions are mainly with the control department, and the vault. A few visits are made to the comptroller's office in a lower floor. The space allocated to this activity is about 120 square feet including the area required for both the Xerox and laminating machines. This activity passes through peak periods during which extra space, and sometimes personnel, are required to carry the excess load of work.

Activity # 10: Education and Graduate Studies

Performed by a senior personnel and two assistants. Their interactions within the area are mainly with the reception desk and the general files. The daily work necessitates a number of visits to the admissions department

located in the north end of the building, and to the upper floor. A few visits may be made periodically to the faculties of Education and Graduate Studies. The area allocated to this activity is about 120 square feet.

Activity # 11: The Registrar

Allocated a space of 275 square feet which provides for a private office for the registrar and a small reception area and work station for his secretary. Duties involve communications with the associate registrar, and a substantial number of visits to other departments within and without the Administration building.

Activity # 12: Mature Student Adviser

This activity is performed by one staff member. The daily interactions are mainly with offices outside the area considered with the exception of a few visits to the registrar's office. The area allocated to this activity is about 120 square feet. Its location next to the stair hall is not justified by the few interactions made to the outside departments.

Activity # 13: The Reception

Allocated a space of 350 square feet which provides for a small waiting area, a reception counter and a dummy waiter for delivery of materials it is attended by a

receptionist who operates the switchboard and is responsible for addressing students inquiries to different departments.

Activity # 14: The Vault

This activity involves the safe keeping of the academic documents of the University. It has been allocated an area of 160 square feet. Special measures were taken for protection against fire and to secure documents from theft or destruction. Filing duties within this activity are attended by the staff of the general files. Its internal interactions are mainly with the transcripts department.

Activity # 15: The Stairhall

An area of 300 square feet located in the southern side of the stairhall represents the access to the registrar's general office. A very dense pattern of interactions between this access and the reception desk is formed by students. Staff members from most activities pass through this area during their daily interactions with external activities.

2.1.2 Categorization of Personnel

A consistent way of evaluating the interactions between different individuals is by categorizing these interactions with respect to any chosen datum. The form of interactions considered for this study is the physical movements of persons. The datum considered is the cost of

these movements in terms of time consumed and salaries of persons involved. To minimize complications when dealing with large numbers of persons and wide variety of salaries, a system of grouping will be adopted. Staff members will be classified in a number of categories according to their salaries and administrative status. The range of each category, illustrated in Figure (3), will be represented by a number of salary strata. The following considerations are suggested to determine the number of strata in each category:

- A. The salary range of lower categories should be narrower than those of higher categories, as the number of persons in the lower salary strata are usually high, and therefore, even a narrow range would include a substantial number of persons.
- B. Within the range of a category, the number of persons in its central strata could be slightly higher than in its border strata. This expresses the fact that most of the new comers to any category would progress to its central strata and a lesser number are promoted to its higher strata.
- C. A significant sudden drop in number of staff at any stratum would suggest the starting of a new category. Figure (4) illustrates graphically the boundaries of different categories according to the previous considerations. We shall apply these criteria to determine the number and range of different categories of personnel in the registrar's

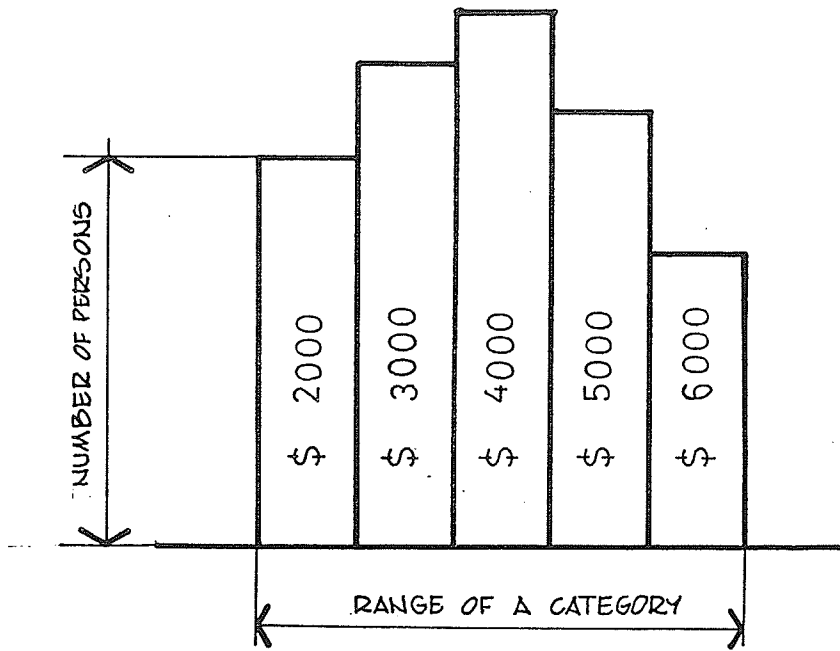


FIGURE 3 SALARY STRATA WITHIN A CATEGORY

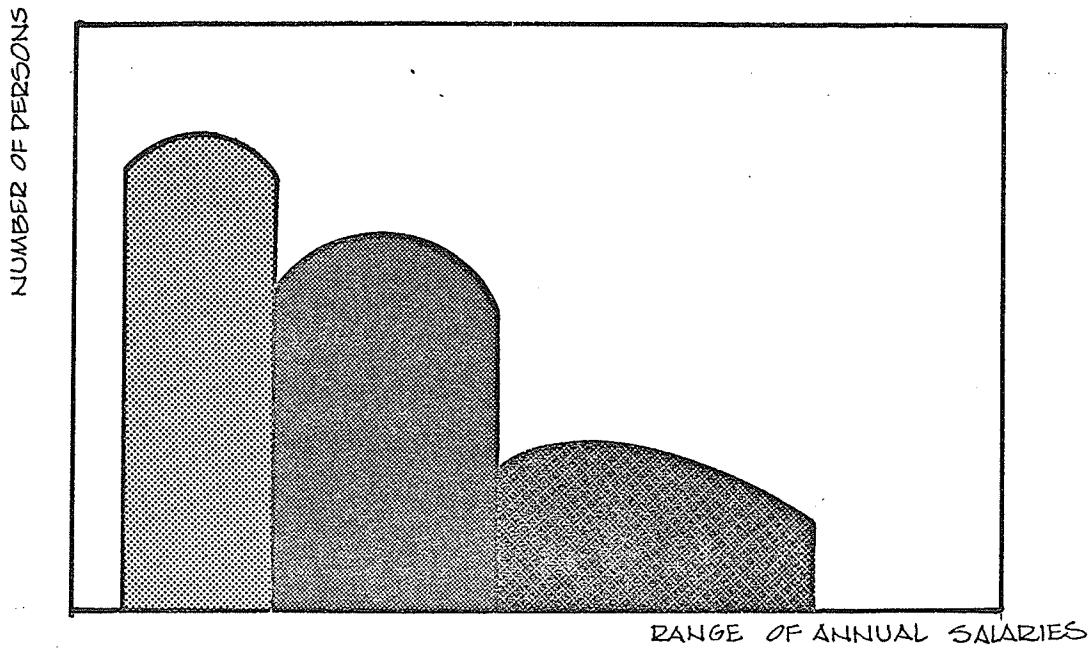


FIGURE 4 CATEGORIZATION

office.

From the payroll authorization report the staff members were grouped according to their annual salaries in \$1000 intervals. The number of persons in each stratum are shown in Table (1).

The different strata were plotted graphically. Applying the previous criteria, it became evident that personnel can be grouped into three categories as illustrated in Figure (5). The mean salary of each category was calculated according to the number of persons in each strata in the following way:

CATEGORY (1): The salaries of persons in this category ranges from \$9,500 to \$17,500. The staff within this range are the three top executives. The average annual salary for a person in this category = $\frac{10,000 + 13,000 + 17,000}{3} =$ \$13,300.

CATEGORY (2): Under this category 13 senior staff members are considered. Their salaries range from \$5,500 to \$9,500. The average annual salary for personnel in this category = $\frac{(3 \times 6000) + (4 \times 7000) + (3 \times 8000) + (3 \times 9000)}{13} =$ \$7,400.

CATEGORY (3): The bulk of the tasks in the registrar's office are performed by the 21 persons under this category. The annual starting salary is \$2,500 and its upper bracket

TABLE 1

Number of Persons in Different Salary Strata

| Strata of Annual Salary | From \$ 2500 | From \$ 3500 | From \$ 4500 | From \$ 5500 | From \$ 6500 | From \$ 7500 | From \$ 8500 | From \$ 9500 | From \$ 12500 | From \$ 16500 |
|-------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|---------------|---------------|
| Number of persons | 5 | 9 | 7 | 3 | 4 | 3 | 3 | 1 | 1 | 1 |

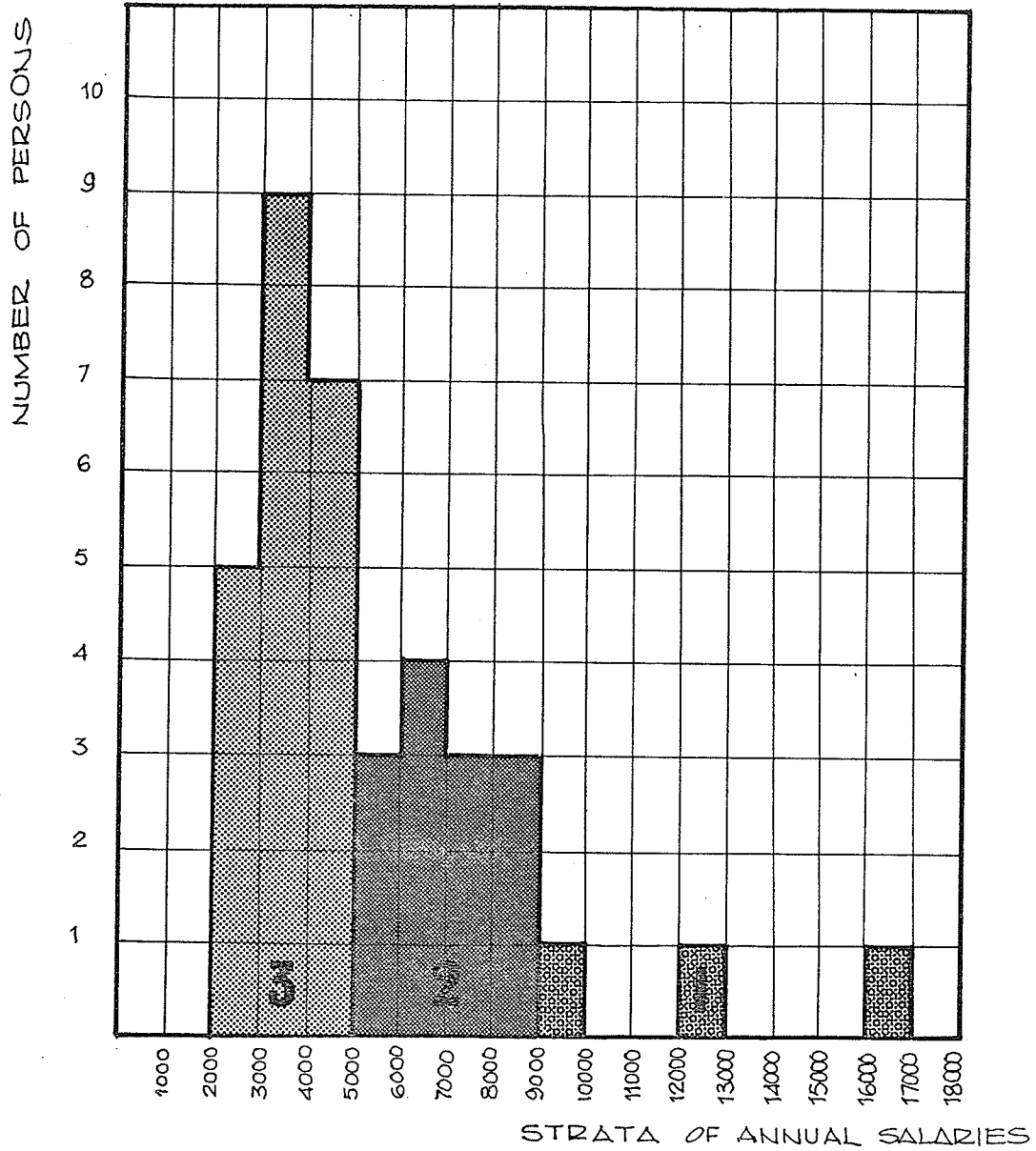


FIGURE 5 Categories of personnel

is \$5,500 per year.

$$\begin{aligned} & \text{Then the annual average salary of category 3} \\ & = \frac{(5 \times 3000) + (9 \times 4000) + (7 \times 5000)}{21} \\ & = \$4,000. \end{aligned}$$

2.1.3 Summary of Activities

After categorization of personnel each staff member was assigned a number as a form of identification during the computation process. The number and category of each person and an outline of his involvement with external activities are summarized in Table (2). Figure (6) shows the working stations of different personnel.

2.2 Time and Motion Study

The previous summary of activities' involvements with locations outside the area, is complementary information to the precise pattern of their interrelationships. This will be determined through a detailed time and motion study of personnel. Such a study must be made over a representative period of time, as the nature and quantity of work handled in the registrar's office varies over different seasons of the academic year. Even the number of personnel performing different activities and the pattern of their interactions may vary from time to time. For example, an activity with normally very few interactions at the start of the academic year may double its interactions during the

TABLE 2

Summary of Existing Activities

| Room No. | Number | Activity | | Persons | | | Involvement with External Locations | | | |
|----------|--------|---------------------|---------------|---------|---------------------|----------|-------------------------------------|----------|-------------|----------------------|
| | | Description | Area (Sq.Ft.) | Number | Classification | Category | North side | Upstairs | Down-stairs | Outside the Building |
| 303 | 1 | Examinations & I.D. | 220 | 1 | Exam. Assistant | 2 | | | | frequent |
| 305 | 2 | General Files | 520 | 2 | Sen. Filing Clerk | 3 | frequent | limited | limited | |
| | | | | 3 | Filing Clerk | 3 | frequent | limited | limited | |
| 306A | 3 | Associate Registrar | 275 | 4 | Associate Registrar | 1 | frequent | limited | | |
| | | | | 5 | Secretary | 3 | frequent | frequent | limited | |
| 306B | 4 | Records Supervisor | 220 | 6 | Records Supervisor | 2 | frequent | frequent | | limited |
| | | | | 7 | Secretary | 3 | | | | |
| 306C | 5 | Convocations | 260 | 8 | Conv. Coordinator | 2 | | | | frequent |
| | | | | 9 | Conv. Assistant | 3 | | | | |
| 306 | 6 | Check of Records | 70 | 10 | Record Examiner | 3 | | | limited | |
| 306 | 7 | Fees | 170 | 11 | Chief Fee Clerk | 2 | frequent | limited | | limited |
| | | | | 12 | Fee Clerk | 3 | frequent | frequent | | limited |
| | | | | 13 | Fee Clerk | 3 | | | | |
| 306 | 8 | Control | 120 | 14 | Control Clerk | 3 | frequent | frequent | | |
| | | | | 15 | Control Clerk | 3 | | | | |

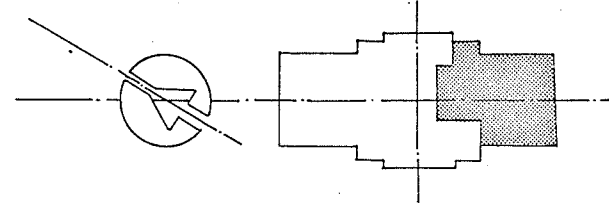
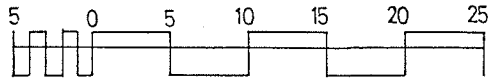
TABLE 2 (Continued)

| Room No. | Activity Number | Activity Description | Area (Sq.Ft.) | Persons | | | Involvement with External Locations | | | |
|----------|-----------------|----------------------|---------------|---------|---------------------|----------|-------------------------------------|----------|------------|----------------------|
| | | | | Number | Classification | Category | North side | Upstairs | Downstairs | Outside the Building |
| 306 | 9 | Transcripts | 120 | 16 | Transcript Clerk | 3 | | | | |
| | | | | 17 | Transcript Clerk | 3 | | | | |
| 306 | 10 | Educ. & Grad. Stud. | 120 | 18 | Sen. Grd. St. Clerk | 2 | frequent | limited | | limited |
| | | | | 19 | Education Clerk | 3 | frequent | frequent | | limited |
| | | | | 20 | Clerk | 3 | | | | |
| 307 | 11 | The Registrar | 300 | 21 | Registrar | 1 | limited | limited | limited | limited |
| 308A | | | | 22 | Secretary | 3 | limited | | | |
| 308 | 12 | Mature St. Adv. | 120 | 23 | Student Advisor | 2 | | | | frequent |
| 309 | 13 | Reception* | 350 | 24 | Receptionist | 3 | | | | |
| 304 | 14 | Vault* | 160 | -- | | -- | | | | |
| 300 | 15 | Stairhall* | 300 | -- | | -- | | | | |

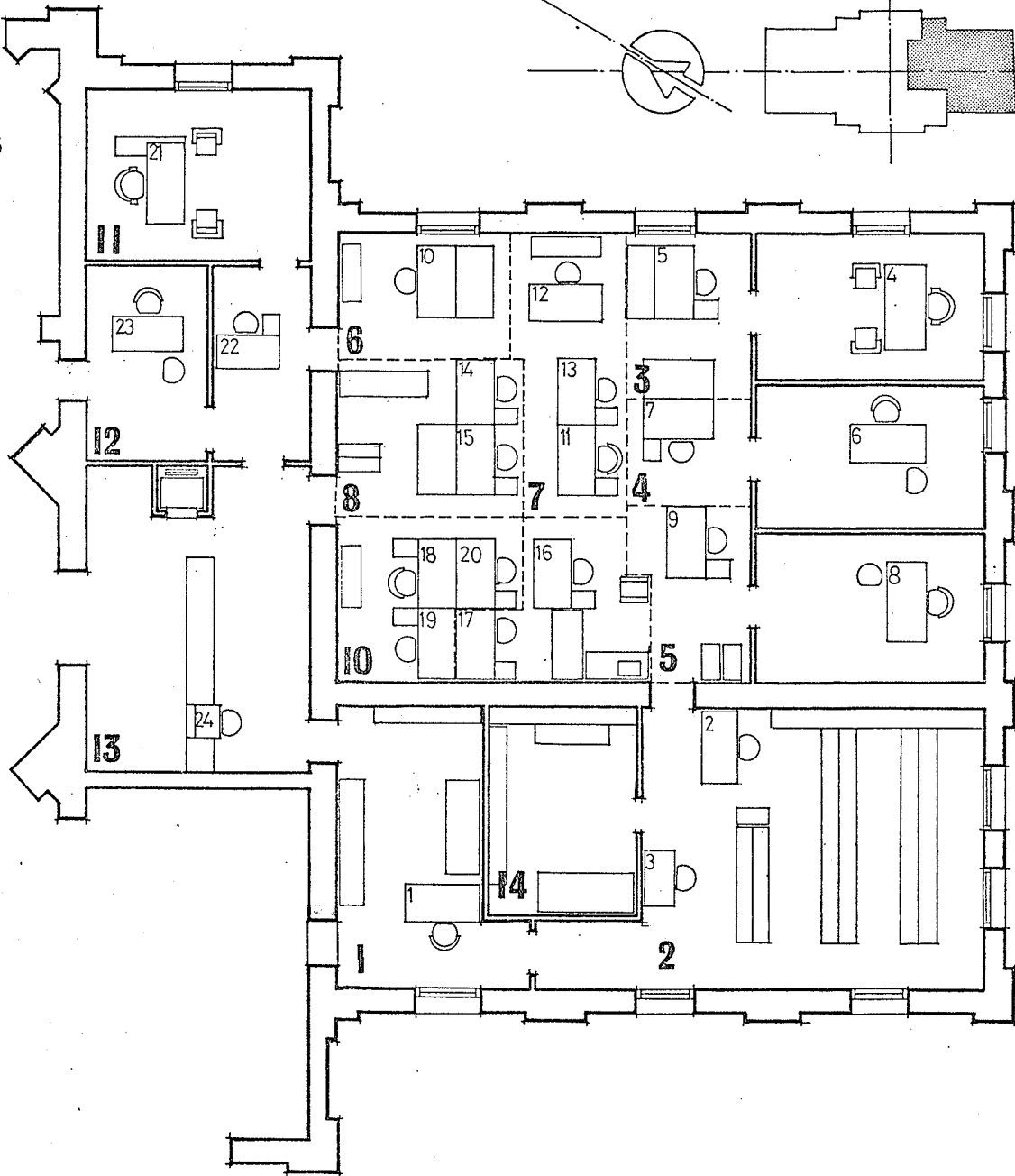
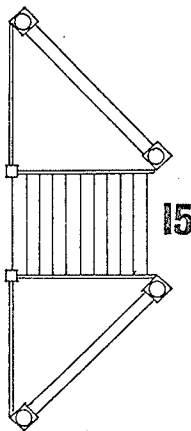
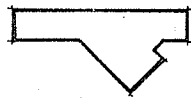
*Interactions of this activity are confined to receiving visits from other activities.

UNIVERSITY OF MANITOBA

REGISTRAR'S OFFICE



- ① EXAM. & I.D.
- ② GENERAL FILES
- ③ ASSOC. REGISTRAR
- ④ SUPERVISION
- ⑤ CONVOCATIONS
- ⑥ RECORDS
- ⑦ FEES
- ⑧ CONTROL
- ⑨ TRANSCRIPTS
- ⑩ EDUC. & GRAD. STUD.
- ⑪ REGISTRAR
- ⑫ MATURE STUD. ADV.
- ⑬ RECEPTION
- ⑭ VAULT
- ⑮ STAIRS



existing lay out

- Staff member of category 1
- Staff member of category 2
- Staff member of category 3

FIGURE 6

examinations season.

However, this study was carried out over a relatively short period of time. Other sources of information helped in adjusting the collected data to present the years activity.

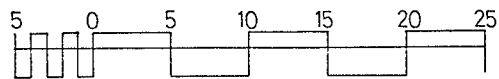
2.2.1. Preparatory procedures

Preparatory steps made before starting the time and motion study:

A. Definition of boundaries: The boundary of each activity has been determined according to the number and size of working stations allocated to persons and equipment performing this activity. A person from another activity has to cross these boundaries physically or verbally in order to count a qualified visit to this activity. Unqualified visits are those made for reasons other than work, however such visits were neglected and have not been recorded. Verbal visits, i.e. those made without physical interception with the activity boundaries were included, as they are quite common when dealing with large areas accommodating adjacent activities.

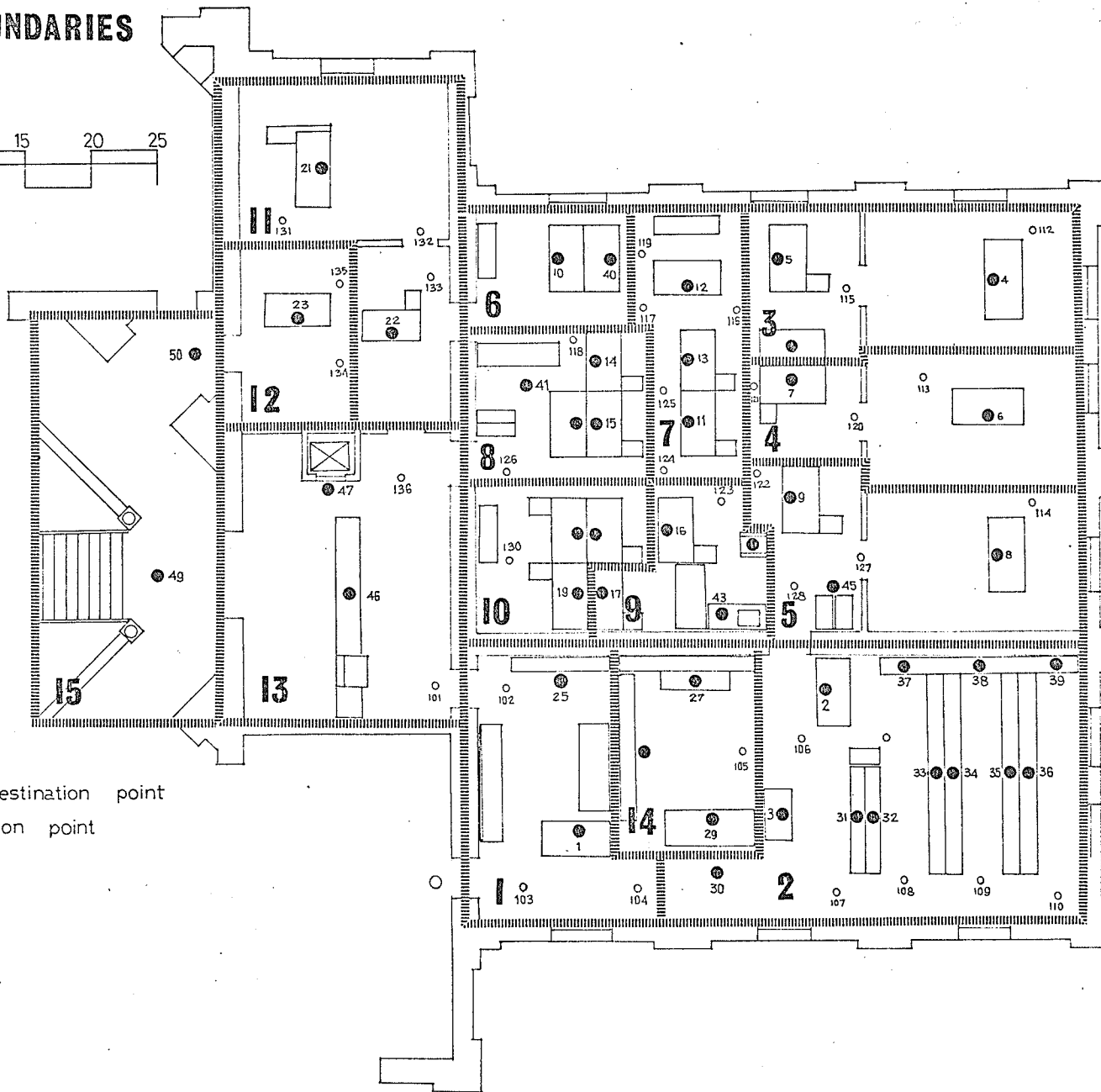
B. Destination points: Within the space allocated to each activity there are focal points that receive the visits made to this activity. These points are either work stations or locations of specific equipment or furniture. Each of those destination points had been assigned an identification

ACTIVITIES BOUNDARIES



- Work station or destination point
- Change of direction point

FIGURE 7



number. This number will be needed in case of desire to relocate the working stations within each activity according to internal interactions between them.

C. Guide points of communication routes: The locations of doors and the arrangement of desks and other pieces of furniture or equipment governs the routes connecting different destination points. In order to locate a particular route on plan, serial numbers have been assigned to various points in plan where a change of direction may take place. For example a typical route called (14-117-118-41) will be interpreted as a visit originated from the work station number 14 to the destination point number 41 passing by the points 117 and 118.

A plan of the area considered was prepared to a reasonable scale ($1/4" = 1'0"$, and all the previous preparatory stages were located on it (Figure (7)).

2.2.2 Motion recording technique

In dealing with activities where the patterns of movements for different members of the activity are identical, it is practical to record the movements of one person as a representative for each group, and multiply the number of visits made to different destinations by the total number of persons in the group. Considering the registrar's office it was found rather difficult to determine such a representative for each group, and because the number of

persons involved was relatively small, it was found more feasible to record the movements of each individual. This was accomplished by observing each person during different times of the day and over a number of days to insure that the movement pattern is not influenced by some personal reasons or arbitrary coincidences. The movements were recorded using the number of destination points, and change of direction points to locate the flow of movements within the area considered. Table (3) represents a sample of motion study recorded for person number (1) during four working hours. A complete set of tables recording the motion pattern of the other personnel is presented at Appendix C. Using these tables a string diagram was prepared to present physically the movement pattern of each individual during a typical working day. The number of strings connecting the original work station to any destination point represents the number of visits made to, and the number of returns from this destination point. This is illustrated in Figure (8). The easy preparation of the string diagram and the advantage of having a visual illustration of interactions within and without each activity, make it an efficient tool in the manual decision making process concerning the relations between activities. However, even if these relations would be determined through computations, the string diagram may be retained and compared later with a string diagram prepared for the final

TABLE (3) TIME AND MOTION STUDY OF PERSONNEL

Activity: 1
 Person: 1
 Category: 2

Activity: Continue
 Person: Same
 Category: Same

| Destination Point | Change of Direction Points |
|---|----------------------------|
| Date: October 22, 1970 Starting Time: 11:15a.m. | |
| * | (own working station) |
| 4 | 103-107-128 |
| * | 115-128-104 |
| 14 | 102-136-126 |
| * | 126-136-102 |
| 46 | 103-102 |
| * | 101-102 |
| 46 | 103-102 |
| * | 101-102 |
| 6 | 104-107-127 |
| * | 128-106-104 |
| 46 | 103-102 |
| * | 102-103 |
| End at: 12:00 noon Time recorded: <u>.45</u> minutes | |

| Destination Point | Change of Direction Points |
|---|----------------------------|
| Date: Same Starting Time: 1:00 p.m. | |
| * | (own working station) |
| 46 | 103-102 |
| * | 102-103 |
| 46 | 103-102 |
| * | 102-103 |
| 46 | 103-102 |
| * | 102-103 |
| 46 | 103-102 |
| * | 102-103 |
| 46 | 103-102 |
| * | 102-103 |
| 46 | 103-102 |
| * | 102-103 |
| 46 | 103-102 |
| End at: continue Time recorded: incomplete | |

TABLE (3) (continued)

Activity: 1

Person: same

Category: same

Activity: continue

Person: same

Category: same

| Destination Point | Change of Direction Points |
|---|----------------------------|
| Date: same Starting Time: 1:00 p.m. | |
| | Continue |
| * | 102-103 |
| 6 | 104-107-127 |
| * | 128-106-104 |
| 46 | 103-102 |
| * | 102-103 |
| 46 | 103-102 |
| * | 102-103 |
| 46 | 103-102 |
| * | 102-103 |
| 46 | 103-102 |
| * | 102-103 |
| 4 | 103-107-128 |
| * | 115-116-128 |
| 46 | 103-102 |
| * | 102-103 |
| End at: continue Time recorded: incomplete | |

| Destination Point | Change of Direction Points |
|--|----------------------------|
| Date: same Starting Time: | |
| | Continue |
| 4 | 103-107-128 |
| * | 115-116-128 |
| 46 | 103-102 |
| End at: 3:15 p.m. Time recorded: 2.15 Hr. | |

TABLE (3) (Continued)

Activity: 1

Activity: continue

Person: same

Person: same

Category: same

Category: same

| Destination Point | Change of Direction Points |
|--|----------------------------|
| Date: November 2, 1970 Starting Time: 1:10 p.m. | |
| * | (own working station) |
| 46 | 103-102 |
| * | 102-103 |
| 4 | 103-107-128 |
| * | 128-107-103 |
| 4 | 103-107-128 |
| * | 128-107-103 |
| 46 | 103-102 |
| * | 102-103 |
| 46 | 103-102 |
| * | 102-103 |
| 46 | 103-102 |
| * | 102-103 |
| 4 | 103-107-128 |
| * | 128-107-103 |
| 46 | 103-102 |
| End at: continue Time recorded: incomplete | |

| Destination Point | Change of Direction Points |
|---|----------------------------|
| Date: Starting Time: | |
| * | 102-103 |
| 46 | 103-102 |
| * | 102-103 |
| End at: 2.10 p.m. Time recorded: <u>1.00</u> | |

MOTION STUDY

MOVEMENT PATTERN OF
THE PERSON no. 19 IN
FOUR HOURS

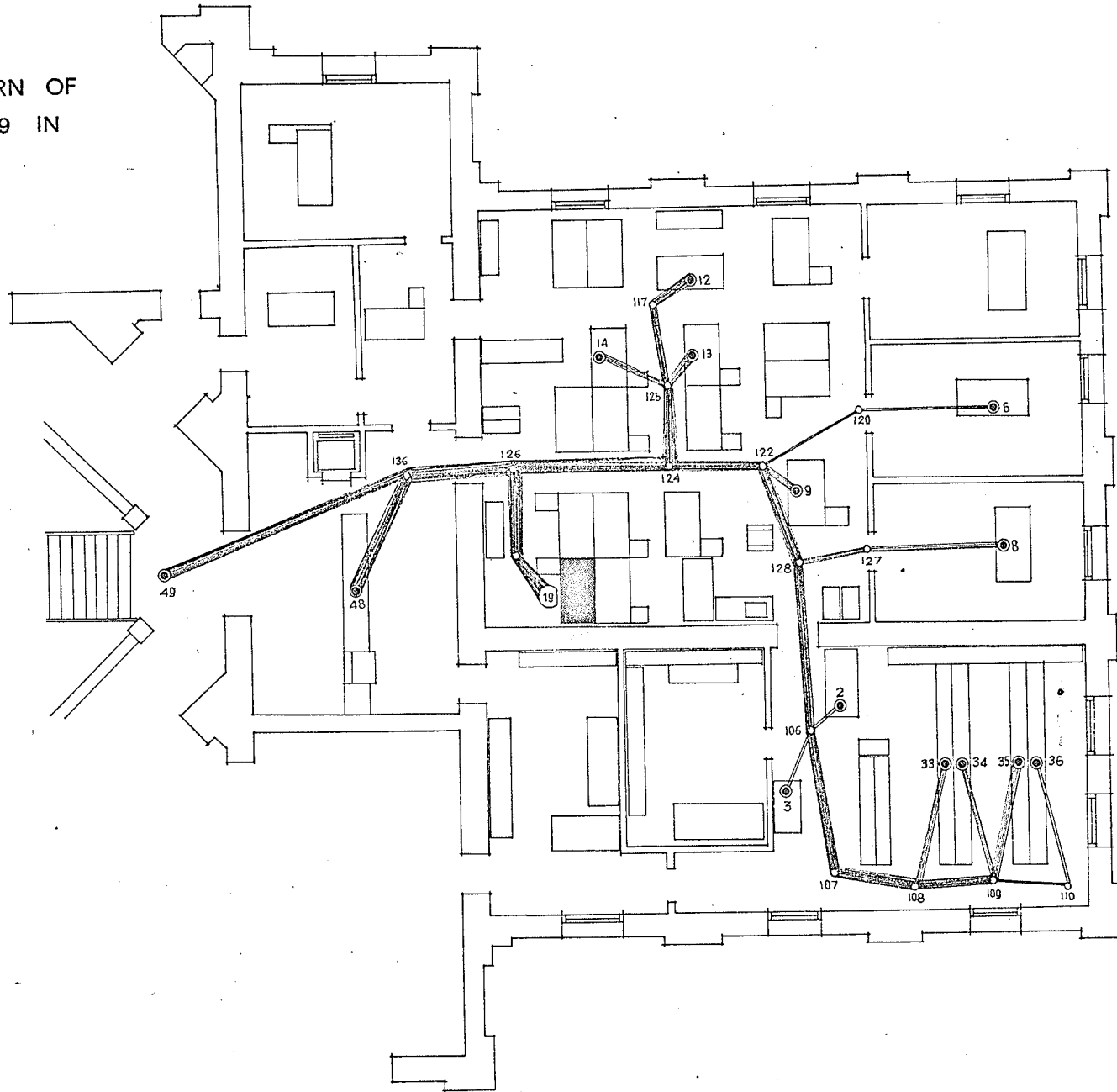


FIGURE 8

design. The total length of the string when unfolded would represent the total distance in feet, covered by the individuals concerned. A comparison between the total distances covered in the existing plan and that for the proposed design would make it possible to measure to a reasonable degree of accuracy the amount of time saved during the physical communications between activities.

The sum of visits received by various destination points within an activity will represent the total number of visits paid to this activity. Table (4) illustrates the summation process of visits received by different destination points from an individual during a specific time. This process is meant to find the interactions between all activities in terms of these visits. A complete set of tables of exchanged visits by all individuals appears in Appendix D.

The sum of visits paid to each activity has to be checked to insure that it represents a normal pattern of interactions, and that inconsistent reasons, such as the absence of some staff members or a particular equipment being out of order do not influence the output of the survey.

Other special factors have to be considered, as in case of interactions between the stairhall (activity 15) and other activities.. It had been noticed that visits made to the stairhall were often part of longer visits paid to

TABLE (4) INTERACTIONS BETWEEN ACTIVITIES

Visiting Activity: 1

Visiting Person: 1

Category: 2

| | | Receiving Activities | | | | | | | | | | | | | | | All |
|-----------------------------------|--|----------------------|----|---|---|---|---|---|---|---|----|----|----|----|----|----|-----|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | |
| Number of visits to each activity | | | | * | * | | | * | | | | | | * | | | |
| | | | * | * | | | | | | | | | | * | | | |
| | | | * | * | | | | | | | | | | * | | | |
| | | | * | * | | | | | | | | | | * | | | |
| Total visits in 4.00 hours | | | 6 | 2 | | | | 1 | | | | | | 23 | | | 32 |
| Total visits/day | | | 12 | 4 | | | | 2 | | | | | | 46 | | | 64 |
| Modified final interactions | | | 10 | 4 | | | | 2 | | | | | | 46 | | | 62 |

activities located in other parts of the building. This means that the number of such visits have to be modified to express the fact that the time consumed in communication is more than that spent to reach the stairhall.

Other special considerations were made for the interactions between activity # 2 and # 14. Visits made to the general files by members of other activities, in many cases were extended to the vault. This represents an essential proximity between the vault and the files although these visits are made by members of other activities. The final modified pattern of the present interactions is shown in Table (4).

2.3 Establishment of the Criteria of Design

The data collected from the previous analysis of activities, and time and motion study of personnel within the existing building will serve as a guide for establishing the criteria of the required building. Necessary modifications have to be made to the present pattern of interactions and space allocations to correspond with the new requirements. The procedure of establishing this criteria is illustrated in the following stages:

2.3.1 Space allocations

The space to be allocated to each activity must provide the minimum requirements for optimum performance. This

will be determined according to the number and size of work stations, and the pattern of internal interactions within the activity.

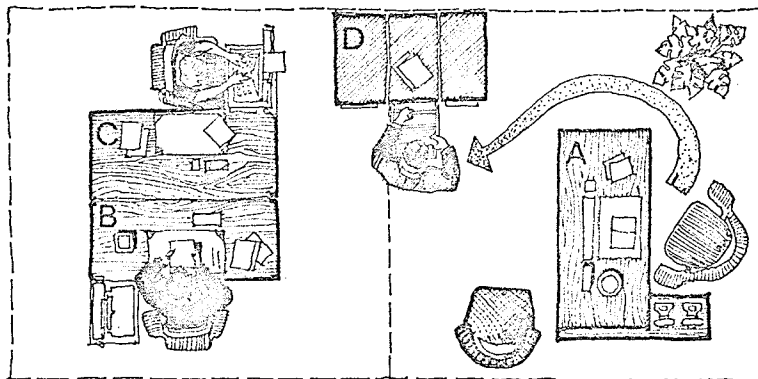
It has been noticed that some activities, such as those concerning senior executives are usually allocated larger spaces than is actually required for performance. It was also noticed that the arrangement of work stations within a certain space may be largely affected by ethical factors rather than efficiency of performance. Figures 9 and 10 illustrate an example of the impact of such ethical aspects. However such impacts have to be scrutinized as to the initial and running costs of the building.

Activities involving repetitive procedures, or special equipment with high running cost, have to be given special attention to insure that the space allocated is of the proper size.

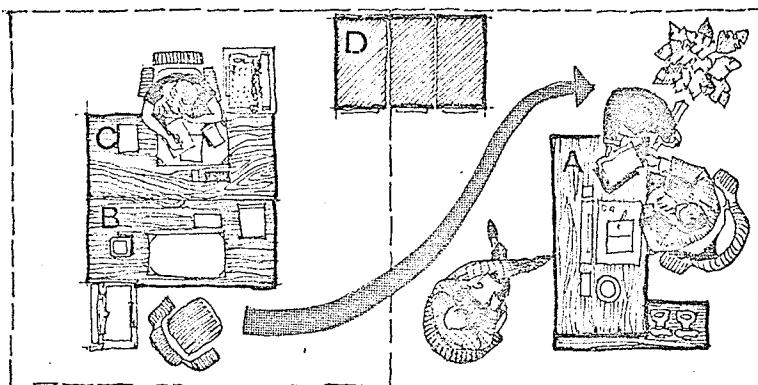
2.3.2 Modular presentation

The modular space element chosen for this particular example is 100 square feet. This is an appropriate size in office buildings, as it may accommodate an administrative work station with a reasonable space for circulation and accessories. Figure (11) illustrates the space analysis for an activity to determine its actual needs. According to this analysis, the area required for each activity was determined, and presented by a number of modular elements.

SPACE ALLOCATIONS

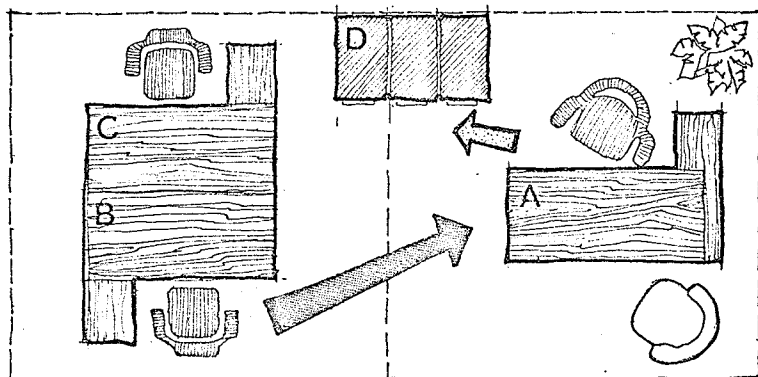


THE DOMINATING LOCATION OF THE WORK-STATION (A) NECESSITATE A RELATIVELY LONG TIME TO REACH STATION (D)



AND EVEN LONGER TIME WOULD BE CONSUMED TO COMMUNICATE WITH THE WORK STATION (B)

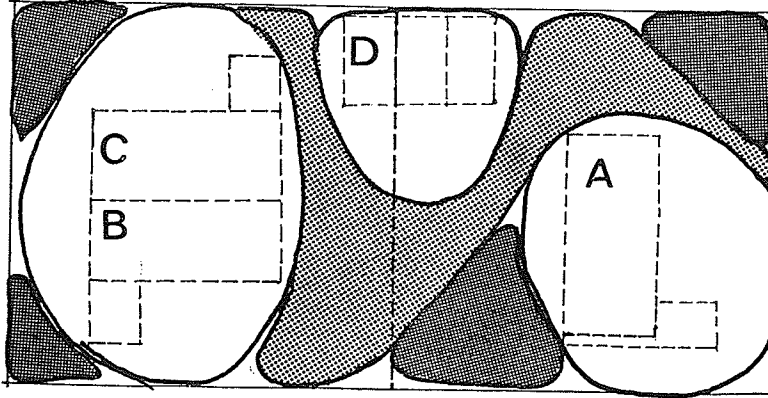
FIGURE 9



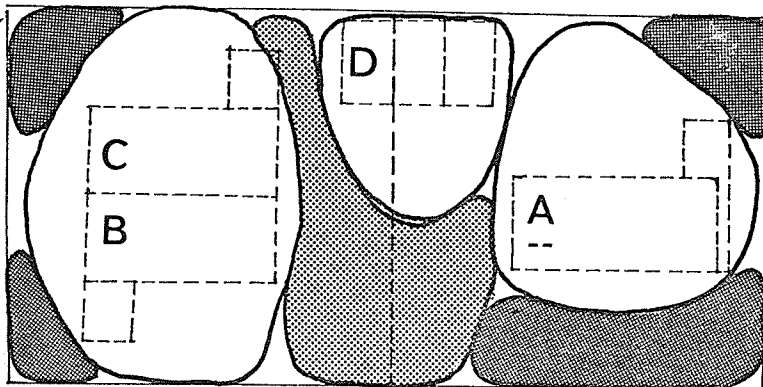
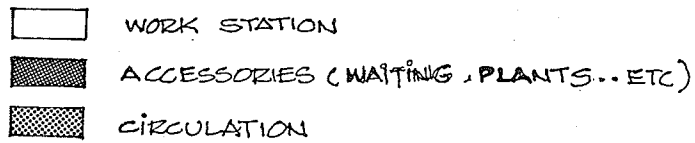
WHILE ACCEPTING A LESS DOMINATING LOCATION FOR THE WORK STATION (A), WOULD INCREASE THE EFFICIENCY OF PERFORMANCE AND MINIMIZE THE COMMUNICATIONS TIME.

FIGURE 10

SPACE ANALYSIS



EXTENDED CIRCULATION PATTERN



COMPACTED CIRCULATION PATTERN ALLOWS MORE SPACE FOR ACCESSORIES AND WORK STATIONS AND MINIMIZES COMMUNICATION TIME.

FIGURE 11

2.3.3 Final pattern of interactions

The data collected from the existing building will have to be modified to suit any anticipated growth or change of existing activities. These changes will be presented by a corresponding number of interactions within the activities involved. If more personnel will be accommodated in the new building, their pattern of movements will be based on the existing patterns of interactions of those activities they will be involved in. Table (5) illustrates the final pattern of interactions expected to take place in the new building.

TABLE 5

Daily Visits by Different Individuals

| Acti- vity | Visiting | | Receiving Activities | | | | | | | | | | | | | | |
|---------------|----------|---------------|----------------------|----|----|---|---|---|----|----|----|----|----|----|----|----|----|
| | Person | Cate- gory | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 1 | 1 | 2 | 0 | 0 | 10 | 4 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 46 | 0 | 0 |
| | 2 | 3 | 0 | 0 | 0 | 6 | 2 | 0 | 2 | 2 | 2 | 0 | 0 | 0 | 12 | 26 | 8 |
| 2 | 3 | 3 | 0 | 0 | 2 | 2 | 0 | 2 | 4 | 8 | 8 | 4 | 2 | 0 | 12 | 14 | 16 |
| | 4 | 1 | 2 | 1 | 0 | 4 | 0 | 1 | 1 | 0 | 1 | 1 | 3 | 0 | 3 | 0 | 11 |
| 3 | 5 | 3 | 3 | 5 | 0 | 4 | 1 | 0 | 1 | 0 | 0 | 0 | 3 | 0 | 3 | 0 | 12 |
| | 6 | 2 | 0 | 12 | 10 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 6 | 0 | 18 |
| 4 | 7 | 3 | 0 | 34 | 6 | 0 | 2 | 0 | 8 | 4 | 0 | 6 | 0 | 0 | 16 | 4 | 4 |
| | 8 | 2 | 0 | 6 | 6 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 2 | 0 | 8 | 0 | 22 |
| 5 | 9 | 3 | 0 | 32 | 4 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 1 | 2 |
| | 10 | 3 | 0 | 2 | 2 | 0 | 4 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 14 |
| 7 | 11 | 2 | 0 | 5 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 25 | 0 | 21 |
| | 12 | 3 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 2 | 0 | 0 | 35 | 0 | 6 |
| | 13 | 3 | 0 | 2 | 0 | 4 | 0 | 0 | 0 | 2 | 6 | 0 | 0 | 0 | 6 | 6 | 8 |
| 8 | 14 | 3 | 0 | 14 | 0 | 0 | 0 | 0 | 3 | 0 | 2 | 10 | 0 | 0 | 10 | 5 | 11 |
| | 15 | 3 | 0 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 14 | 2 | 9 |
| 9 | 16 | 3 | 0 | 12 | 0 | 2 | 0 | 0 | 28 | 26 | 0 | 8 | 2 | 0 | 16 | 16 | 0 |
| | 17 | 3 | 0 | 10 | 2 | 0 | 2 | 0 | 8 | 16 | 0 | 0 | 0 | 0 | 8 | 14 | 6 |

TABLE 5 (Continued)

| Acti- vity | Visiting | | Receiving Activities | | | | | | | | | | | | | | |
|---------------|----------|---------------|----------------------|----|---|---|----|---|----|---|---|----|----|----|-----|----|----|
| | Person | Cate- gory | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 10 | 18 | 2 | 0 | 8 | 1 | 0 | 5 | 0 | 8 | 8 | 6 | 0 | 0 | 0 | 10 | 0 | 9 |
| | 19 | 3 | 0 | 20 | 0 | 2 | 12 | 0 | 24 | 4 | 0 | 0 | 0 | 0 | 30 | 0 | 16 |
| | 20 | 3 | 0 | 8 | 2 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 6 | 0 | 6 |
| 11 | 21 | 1 | 2 | 0 | 4 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 18 |
| | 22 | 3 | 2 | 0 | 4 | 0 | 2 | 0 | 0 | 0 | 4 | 2 | 0 | 2 | 6 | 0 | 12 |
| 12 | 23 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 2 | 0 | 4 |
| 13 | 24 | 3 | 0 | 0 | 2 | 0 | 2 | 0 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 14 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | 0 |

CHAPTER III

THE PLANNING PROCESS

3.1 Definitions

It may be helpful at this stage to make a brief summary of terms used in this chapter to eliminate misinterpretations

1. Standard visit: a visit made by a staff member of category three to any point of destination beyond the boundaries of his own activity.
2. Relative cost of communications (RCC): the number of standard visits exchanged between two activities.
3. Cost of an activity: the sum of its relative costs of communications with all other activities.
4. Elemental force of attraction (EFA): obtained by dividing the relative cost of communication between two activities by the product of the numbers of their modular elements.
5. Cost of relative locations of two elements: the force of attraction multiplied by the number of modular sides separating them.
6. Cost of communications of an activity: the sum of costs of relative locations of its modular elements with respect to the elements of all other activities.
7. Cost of communications of plan: the sum of costs of communications of all activities.

This brief summary of terms will be explained in detail during the consecutive stages of the planning process.

In order to use the data derived from the previous analysis of activities in preparing the plan, a linear methodology will be adopted. A computer master programme and eleven subroutine programmes were developed to compute the given interactions and generate the required plan.

Different stages of computations will be explained in the following sections.

3.2 Standardization of Interactions

The speculated number of daily visits, to be made by different individuals, illustrated in Table (5) will serve to determine the pattern of interactions between different activities.

3.2.1 The multiplier

Evaluation of these interactions will be based upon the time spent in movements between considered locations, and the salaries of the persons involved. It is assumed that all personnel move with the same walking speed, and thus the time spent on movements between any two locations would be the same for all categories of personnel. This means that the relative evaluation of two trips of equal length made by two individuals will be based solely upon the ratio between their salaries. Thus if we consider a

visit made by a certain category of individuals as unity, then a multiplier is used to represent visits by other categories.

As the majority of personnel were of category (3), i.e., of \$4,000 average annual salary, the visits made by them were considered as a unit i.e., a 'standard visit'. A visit made by an individual of category (2), i.e., of \$7,400 average annual salary, would equal to $\frac{7400}{4000} = 1.8$ standard visit.

In the same way a visit made by an individual of category (1) would equal to $\frac{13300}{4000} = 3.3$ standard visit. Expressing the daily visits made by different categories of personnel in terms of standard visits facilitates the measurement of interactions between activities and makes it possible to establish a consistent proximity pattern for all activities.

3.2.2 The logic of computer subprogramme 'STNVST', (for standard visit)

A computer subroutine programme was developed, using the number of visits made by persons of different categories to prepare a matrix of predicted standard visits from each activity to all other individual activities. Figure (12) illustrates the multiplier action, while Figure (13) demonstrates the sequence of computing the sum of standard visits for an activity. Figure (14) illustrates the procedure of preparing the matrix of speculated standard visits

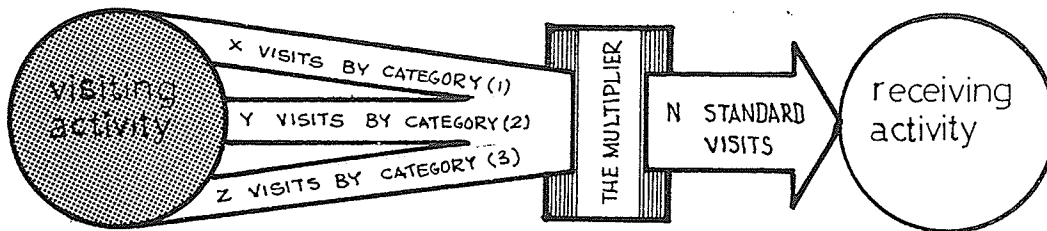


FIGURE 12. The multiplier

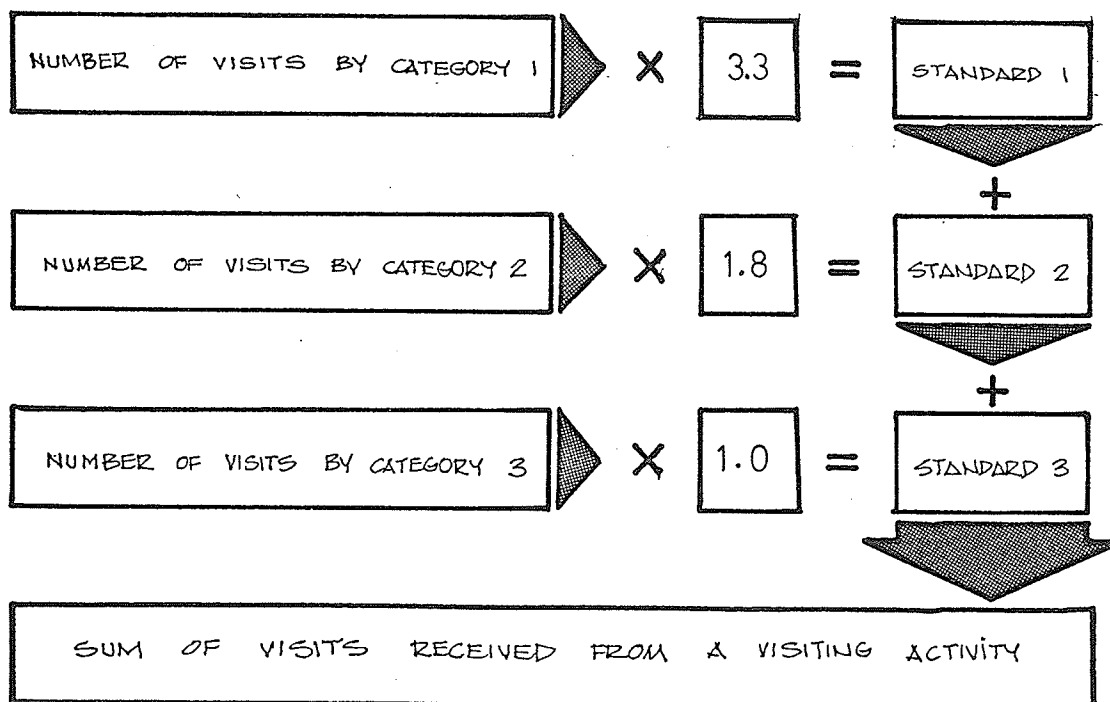
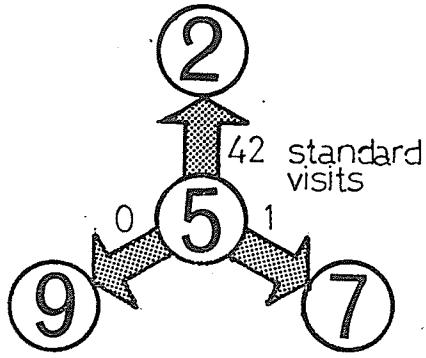
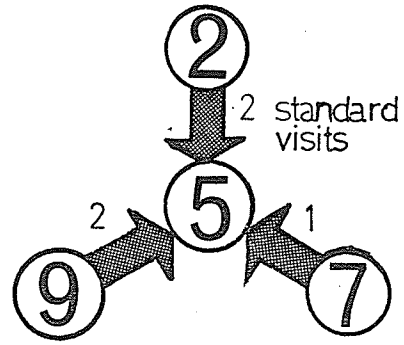


FIGURE 13 Sequence of standardization



ALL STANDARD VISITS MADE FROM ACTIVITY # 5 WILL BE LOCATED IN THE MATRIX OF STANDARD VISITS IN ROW # 5



ALL STANDARD VISITS RECEIVED BY ACTIVITY # 5 WILL BE LOCATED IN THE MATRIX OF STANDARD VISITS IN COLUMN # 5

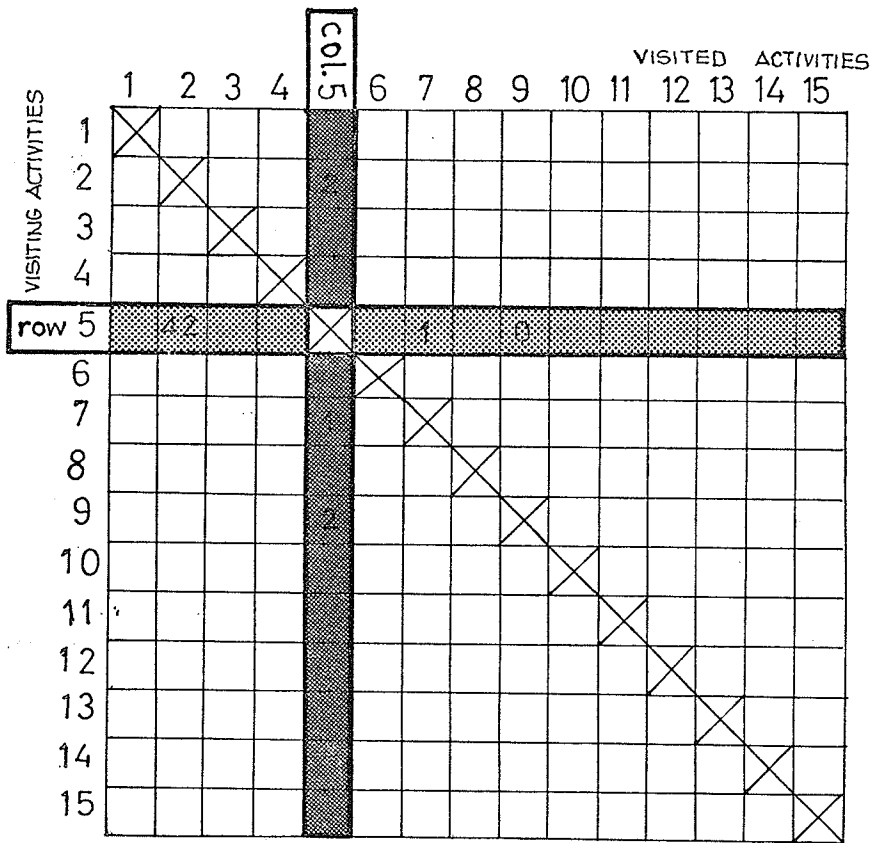


FIGURE 14 Matrix of standard visits

between all activities.

The computer programme was developed in a flexible way to standardize the movements of any number of persons from different categories using any range of multiplier.

3.3 Evaluation of Relative Cost of Communications

In order to find the final pattern of interactions between any pair of activities, the number of standard visits originated from any particular activity to another activity will be added to the number of standard visits received by this activity from the same other activity. The sum of these exchanged visits will be considered as the relative cost of communications between the two activities.

3.3.1 The logic of computer subprogrammes 'ACCOST' and 'SMCOST'

The computer subroutine programme 'ACCOST' (for activity cost) was developed using the matrix of estimated standard visits to prepare a matrix of relative cost of communications between activities. This matrix represents the actual pattern of interactions between activities and therefore will be considered as the main generator of the planning process. The final arrangement of locations of activities will be based upon their proximity values, as a function of the relative cost of communications. The subroutine programme 'SMCOST' (for sum of cost), was developed to compute the cost of each activity. This cost is considered

as the sum of relative cost of communications between the activity considered and all other activities. Figure (15) illustrates graphically the evaluation of cost of communications.

3.3.2 The logic of computer subprogramme 'SMSORT' (for sum of sorted activities)

The cost of activities will be sorted in a descending order starting with the most expensive activity. Sorting activities with respect to their cost will give an insight to their involvements and should be of interest in considering reassignment of space or personnel. Expensive activities have to be reexamined carefully to insure that their interactions are rational in compliance with the applied assumptions.

3.4 An Outline of the Linear Planning Sequence

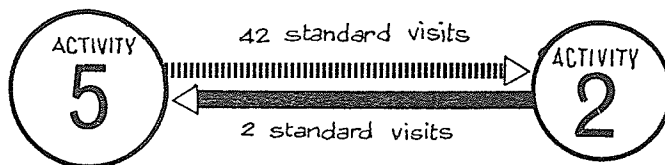
The planning process objective is to optimize the locations of activities by minimizing the distance between activities of highest relative cost of communications. This can be expressed as

$$\text{Minimize} \quad \sum_{i=1}^{n-1} \sum_{j=i+1}^n R_{ij} D_{ij}$$

where

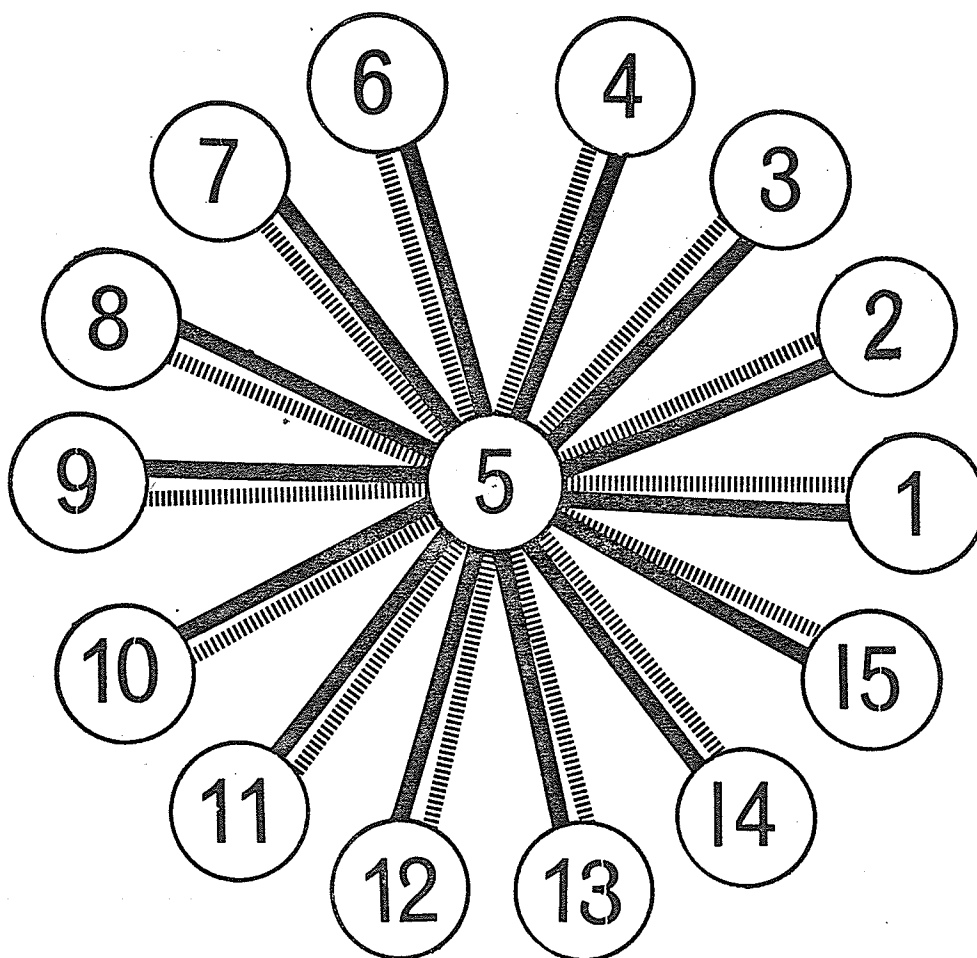
R_{ij} : relative cost of communication between activity i and activity j

D_{ij} : distance between the center of location of activity i and that of activity j .



RELATIVE COST OF COMMUNICATION BETWEEN ACTIVITY #5 & #2

$$RCC = 42 + 2 = 44 \text{ UNIT}$$



COST OF ACTIVITY #5 IS EQUAL TO THE
SUM OF RELATIVE COST OF COMMUNICATIONS
WITH ALL OTHER ACTIVITIES.

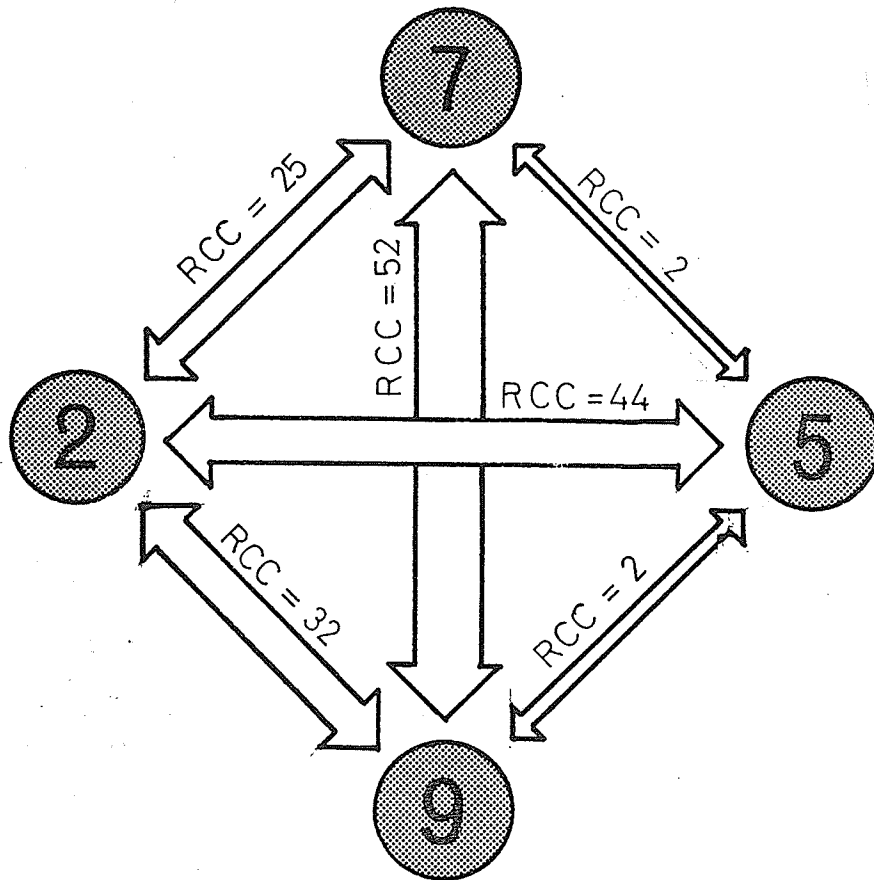
FIGURE 15 Cost of activity

A linear process will be applied in locating the space elements of each activity to fulfill this objective. The main difference between this approach and the trial and error method*, is that space elements will be located one at a time according to previously determined priorities. The precise location of each element should insure minimum overall cost of communications of plan.

3.4.1 The logic of computer subprogramme 'PRIORT',
(for priority of location)

The sequence of locating the space elements will be determined according to the relative cost of communications between activities. The first activity to be located in plan should be the most expensive one. The priority given to this activity is justified by the substantial cost involved in its interactions. The second activity will be located next to the most expensive one, and therefore it has to be the one with the highest relative cost of communications with it. The next activity will have the chance to occupy the closest location to both the first and second activity. Therefore the third activity to be chosen will be of the highest sum of relative cost of communications with both. In the same way, the fourth activity in the queue of priority will have a highest sum of R.C.C. with all previously located activities. A numerical example illustrated in

*Adopted in CRAFT program, IBM SHARE LIBRARY No. SDA 3391.



| | | | | |
|----------------------|---|--------------|---|-----|
| COST OF ACTIVITY # 2 | = | 25 + 44 + 32 | = | 101 |
| COST OF ACTIVITY # 5 | = | 2 + 44 + 2 | = | 48 |
| COST OF ACTIVITY # 7 | = | 25 + 52 + 2 | = | 79 |
| COST OF ACTIVITY # 9 | = | 32 + 52 + 2 | = | 86 |

- * **FIRST PRIORITY : ACTIVITY 2**
MOST EXPENSIVE
- * **SECOND PRIORITY : ACTIVITY 5**
HAS THE HIGHEST RCC WITH ACTIVITY # 2
- * **THIRD PRIORITY : ACTIVITY 9**
HAS THE HIGHEST SUM OF RCC WITH 2 & 5

FIGURE 16 Priority of locations

Figure (16) demonstrates the order in which activities will be located in plan. The computer subroutine programme 'PRIORT' was developed to apply this method.

3.4.2 The logic of computer subprogramme 'AKTLMN'

The process of locating different activities in a matrix representing the site is the main part of the planning procedure. Some processing is required before this process can start. As the space elements will be located, one at a time, according to the previously determined priorities of their activities, they have to be assigned serial numbers to determine the sequence of locating them in plan. The computer subroutine programme 'AKTLMN' (for activity elements) was developed to assign these numbers.

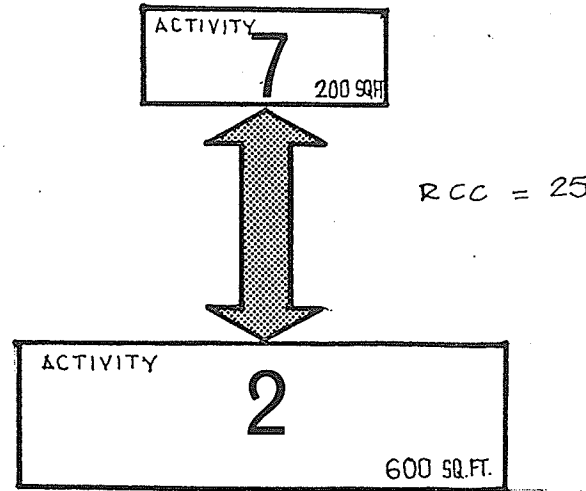
Considering the same example illustrated in Figure (16), where the priority of locating activities are: 2-5-9-7, and assuming that the number of elements allocated to those activities are 6, 3, 1 & 2 respectively, then the serial number assigned to each element to determine its locating priority will be as illustrated in Table (6).

| Elemental locating priority | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|-----------------------------|---|---|---|---|---|---|---|---|---|----|----|----|
| Activity number | | | 2 | | | | | 5 | | 9 | | 7 |

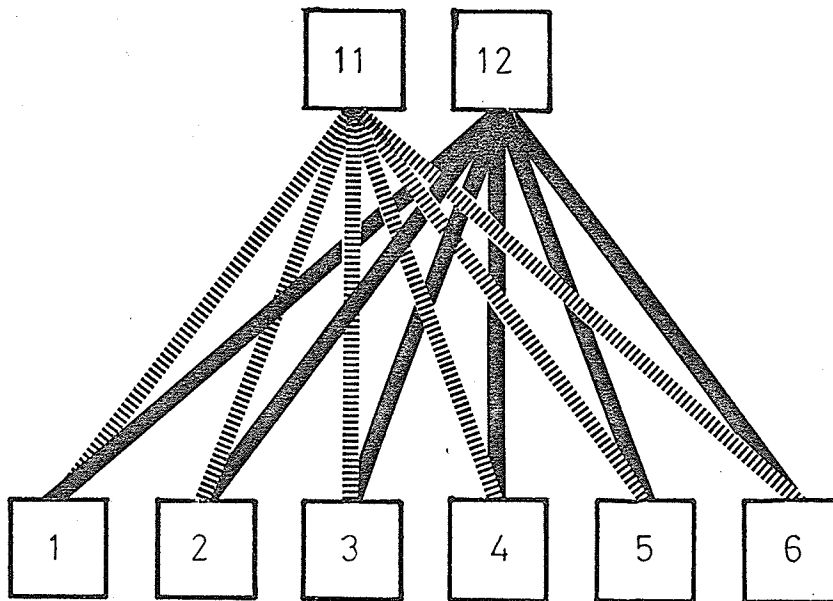
3.4.3 The logic of computer subprogramme 'ELMTRK'
(for elements attractions)

The next step is to establish a pattern of relations between the modular elements according to which their relative locations in plan will be determined. The relative cost of communication between activities will be manipulated to present this pattern. We may assume that the RCC between two activities generates forces of attraction between their modular elements, and the higher this RCC is, the closer they should be. Figure 17 illustrates that the Elemental Forces of Attraction (EFA) between elements from two activities is determined by dividing the RCC by the product of their numbers of modular elements. As the relative cost of communication between an activity and itself is considered to be zero, then a computed force of attraction between its elements would equal to zero. To overcome this irrational result and to insure that the elements representing any activity will be located next to each other, a very high force of attraction between the elements of the same activity is assigned.

A computer subroutine programme was developed to assign these high forces to the elements within any activity and to compute the EFA between elements from different activities, and finally prepare a matrix representing the forces of attraction between all the modular elements of the project.



RELATIVE COST OF COMMUNICATION BETWEEN ACTIVITY 2 & ACTIVITY 7 = 25



$$\text{ELEMENTAL FORCE OF ATTRACTION (E.F.A.)} = \frac{RCC}{N_2 \times N_7} = \frac{25}{6 \times 2} = 2$$

WHERE: N_2 = NUMBER OF MODULAR ELEMENTS IN ACTIVITY 2

N_7 = NUMBER OF MODULAR ELEMENTS IN ACTIVITY 7

FIGURE 17 Elemental force of attraction

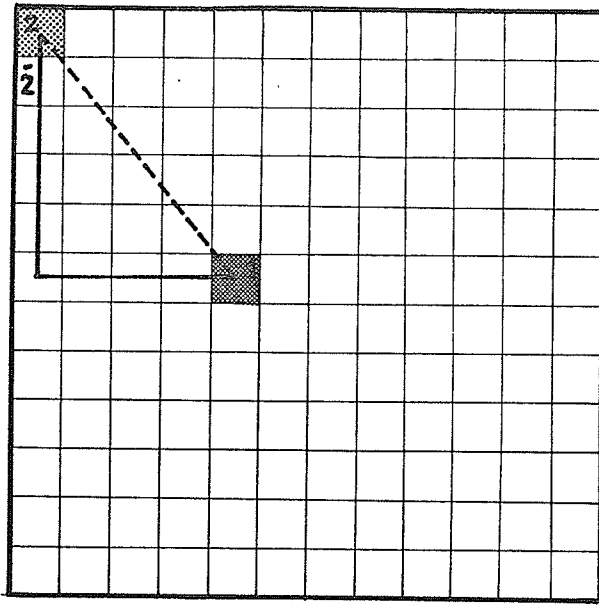
3.5 Optimum Arrangement of Modular Elements

Now the space modular elements are ready to be taken one at a time, and located in a matrix representing the site. The size of this matrix will be determined according to the total number of modular elements, and the expected shape of plan as whether it is rectangular or of almost equal proportions. An over estimated size of matrix may add millions of unnecessary operations to the computation process, while an under sized matrix may restrict the planning process by forcing the activities arrangement within a relatively small matrix. The established criteria and particulars of the site will switch the planning process at this stage, to either the free or restricted planning procedures.

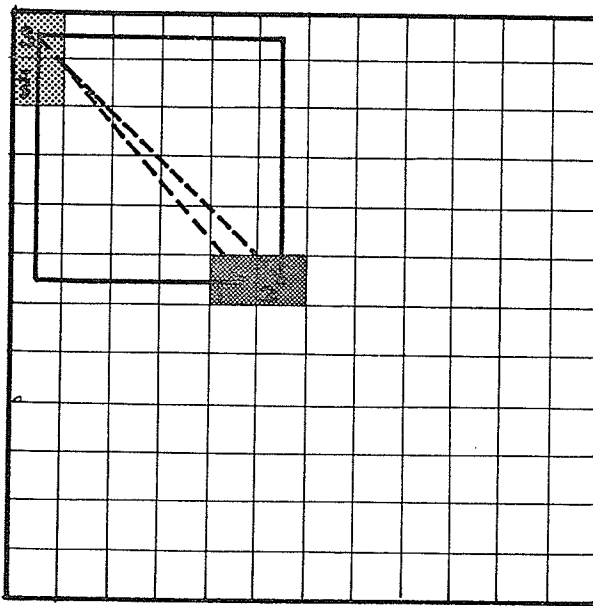
3.5.1 The free planning process

Free planning means that no conditions of any kind will be imposed on the process. It is assumed that the site is spacious enough to accommodate any plan regardless of its shape. It is also assumed that no activity is required to occupy any pre-determined location, and that the location of every activity will be determined solely through computations.

The procedure starts by placing the first element in a central location within the matrix representing the site. The second element will be placed at the upper left corner of this matrix, as illustrated in Figure (18). The cost of



ELEMENTAL FORCE OF ATTRACTION (EFA) BETWEEN
 ELEMENT #1 & ELEMENT #2 IS ASSUMED TO BE 3
 DISTANCE BETWEEN THEM = $4 + 5 = 9$ MODULAR SIDES
 COST OF RELATIVE LOCATION (CRL) = $3 \times 9 = 27$ UNIT
FIGURE 18 The matrix representing the site



$$CRL = EFA_{(3,1)} \times 9 + EFA_{(3,2)} \times 10$$

FIGURE 19 Cost of relative locations

the relative locations of these two elements according to this configuration is equal to the EFA between them multiplied by the number of modular sides separating their centers. Measuring the distance between the two elements in directions parallel to the modular sides rather than a short cut diagonal is meant to represent the actual routes of communication. These routes, because of the system of partitions or the arrangements of furniture and equipment, usually take this parallel pattern. If these two elements were of the same activity, then the assumed high elemental force of attraction between them, when multiplied by the separating distance, will result in a considerably expensive cost of these relative locations. Then element # 2 will be shifted downwards to the next location and a new cost of these new relative locations will be computed. This procedure will be repeated until all the vacant locations are tested and the cost of each location with respect to the first element is evaluated. Obviously the location with the cheapest cost will be the closest to the first element, and therefore such a location will be selected to accommodate the second element. The same procedure will be applied to the third element. The cost of each vacant location will be computed with respect to both the first and second elements as illustrated in Figure (19). The selected location will be that of a minimum sum of costs. The rest of the elements will be located, one at a time, applying

the same procedure by testing all the vacant locations before placing the element in the one with minimum cost.

As the cost of any chosen location is minimum, then this will result in a minimum over-all cost of the plan.

3.5.2 The restricted planning process

Actually in practical problems it is often necessary to impose some restrictions on the planning process. The following are a number of reasons that may call for such restrictions:

A. The site limitations: In the free planning process the borders of the computed plan will be determined after arranging the space elements in an optimum configuration. In some cases the site available for the project may not be spacious enough to accommodate the freely computed layout. The dimensions of the site or the code requirements may confine the computed plan to certain proportions, or restrict the allowable length of any side.

B. Orientation and landscape: The surrounding landscape or adjacent buildings may have their effect on the computed plan. A gracious landscape could be appreciated by certain activities more than by others. Those activities should be given priority to occupy locations enjoying such landscape. On the other hand activities that cannot tolerate the nuisance caused by the surrounding buildings or environment, such as smoke, noise, odors or ugly shapes, should not be

placed in exposed locations.

C. Fire regulations: The code requirements may fix the locations of certain activities such as those of vertical circulation or emergency exits, regardless of their actual pattern of interactions with other activities.

D. Availability of natural lighting: In certain projects, natural lighting may be required for more activities than could be located next to the outer walls. In such cases, internal courts would be provided, or the width of the building would be restricted.

E. Ethical and practical aspects: In many cases the interactions between related activities may be surpassed by their interactions with other activities. For example the communication between an executive and his secretary may not be frequent enough to insure adjacent locations in the computed plan, or, a rest room annexed to a president's office which might be visited only once a day.

F. Alteration of an existing building: In common practice, it is always noticed that the functions taking place in a building usually change from time to time. A building would be considered obsolete if its plan would not allow an efficient performance of the activities taking place in it. The alternative of having to move to a new building is to redistribute the developed activities within the existing premises after making the necessary alterations. In such cases the planning process would be restricted within the

contour of the existing plan. Certain activities such as those for vertical circulations or mechanical installations would be pre-located in plan before starting the computation process.

After this brief review of the factors that may necessitate imposing various restrictions upon the planning process, we shall go through the procedure adopted for such restricted planning.

3.5.3 The logic of computer subprogramme 'RSTRCT'

First, the various reasons for imposing restrictions would be interpreted in one of two ways:

- A. Restriction of space
- B. Pre-determined locations of activities.

The following is an outline of the procedure applied in each case.

A. Restriction of space: A restricted space means that the modular elements would not be allowed to occupy certain locations in the matrix. Such locations would be filled with dummy elements. During the linear operation of arranging elements, only the vacant locations would be considered. This procedure is applied when computed plan is required to retain specific borders, such as the case of redistributing activities within an existing building, or planning within a restricted site. In such cases the desired outline of plan will be surrounded by a number of dummy elements. The

vacant locations available for placing the modular elements as illustrated in Figure (20) will be confined to the area surrounded by these dummy elements.

B. Pre-determined locations of activities: There are cases where some activities are required to occupy specific locations in plan regardless of a computed decision. The reason could be physical, as in case of retaining the location of a staircase when relocating activities within an existing building, or ethical, as the case of locating a president's office in a corner enjoying a gracious view. In such cases, the modular elements of those activities will be placed in the desired locations as illustrated in Figure (21). The cost of these reserved locations will be computed before starting arrangement of the remaining modular elements. This arrangement will follow the same sequence adopted in the free planning process. Starting with the element of highest priority of location, all vacant locations will be tested, and it will be placed in the one with minimum cost with respect to all previously located elements. The total cost of plan will be the sum of costs of the predetermined and the computed locations.

3.5.4 The graphical output

A computer subroutine programme 'PLOTTER' was developed to express the final configuration of modular elements in a graphical form. The scale of the drawings is determined

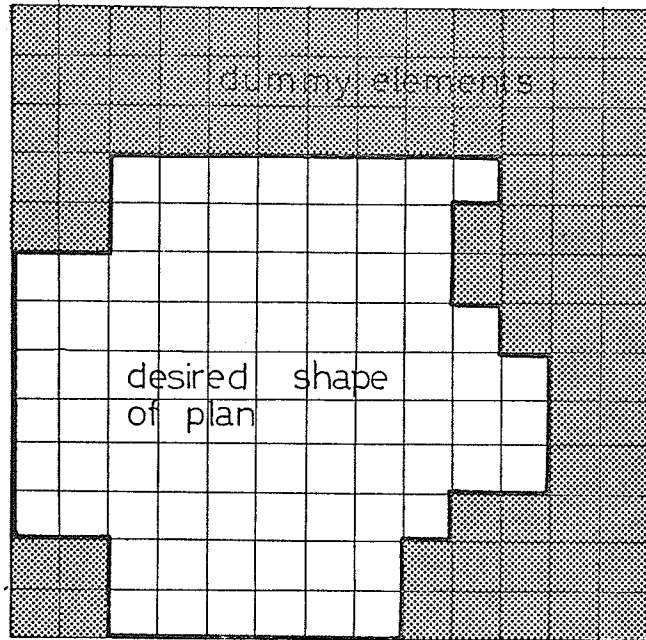


FIGURE 20 Restricted outline

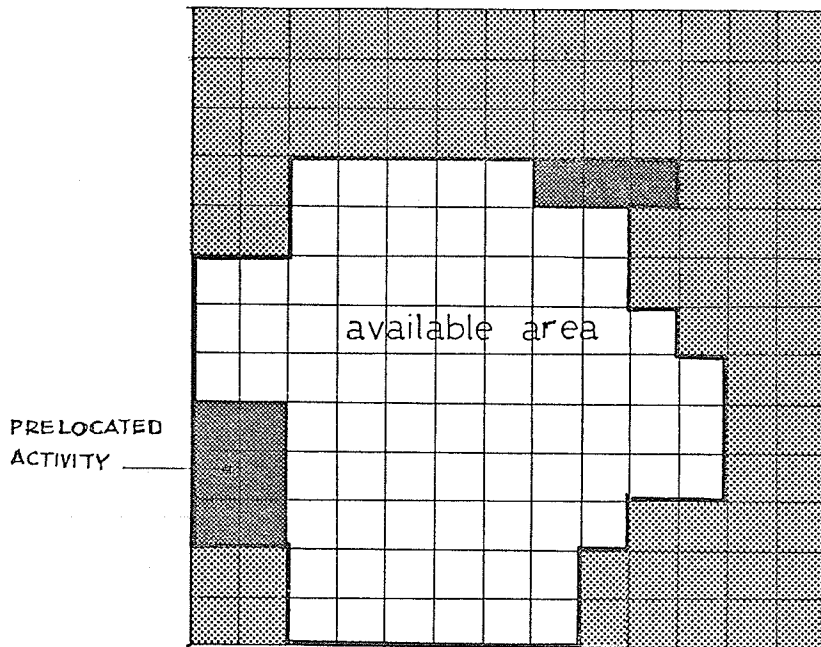


FIGURE 21 Pre determined locations

automatically according to the size of the generated plan. A flow chart of this program illustrating the stages of graphical formation is presented in Appendix A.

3.6 The Actual Cost of Communications

So far our use of the term cost was not expressed in terms of dollars. The previously determined cost of plan is represented by a number of modular sides covered daily by an individual of \$4,000 annual salary. Multiplying this number by the length of the modular side, i.e. 10 feet, gives the total distance covered daily. Applying an average walking speed of 5 feet/second it is possible to find the total time spent in the daily movements between different locations. The total time spent annually may be calculated by multiplying by the number of working days per year. The actual cost of communications of a plan can be obtained by multiplying the total time consumed in communications by the rate of pay of the standard individual. This cost when divided by the square footage of a plan yields the annual cost of communications per square foot of plan. This will be utilized as the bases of comparison between different plan forms.

The computer master programme and subroutine programmes explained in the previous sections appear in Appendix B.

CHAPTER IV

ANALOGY BETWEEN EXISTING AND COMPUTED PLANS

The previous procedures were applied in planning the registrars general office according to both the restricted and free planning techniques. Actually, it was found necessary to evaluate the performance of the existing plan, in terms of cost of communications, before starting the planning process.

4.1 Evaluation of Existing Plan

Evaluation of cost of communications according to the present plan is meant to establish some point of reference with which modified or new plans may be compared. The existing pattern of interactions and space allocations were used for evaluating this cost in the same way applied for restricted planning with the following modifications:

- A. All the forms of space allocated to different activities are already determined.
- B. The locations of 'all' activities are fixed.

A moulding process was applied to adjust the existing locations into forms that can be represented by a number of modular elements, as illustrated in Figure (22). These elements were located in a matrix representing the site in a configuration identical to the existing one. Then the cost of communication was computed as explained in the

MOULDING OF SPACE

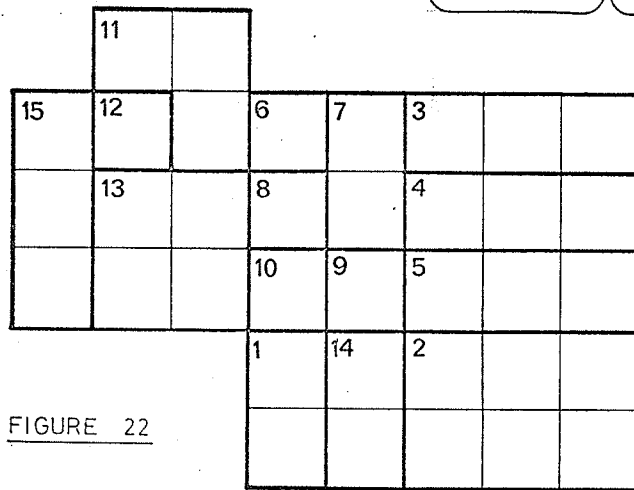
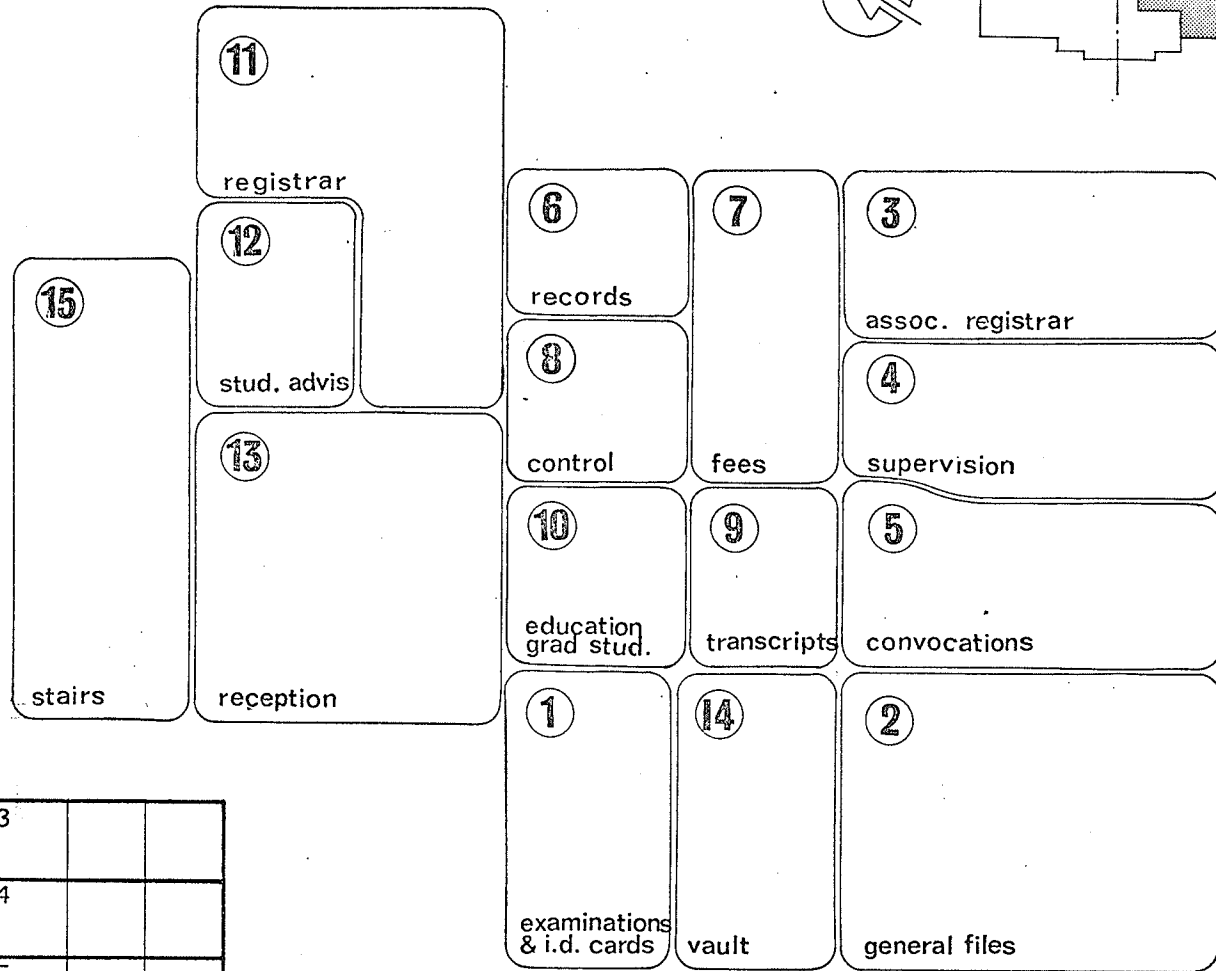
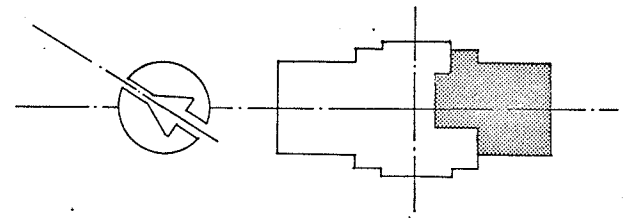


FIGURE 22

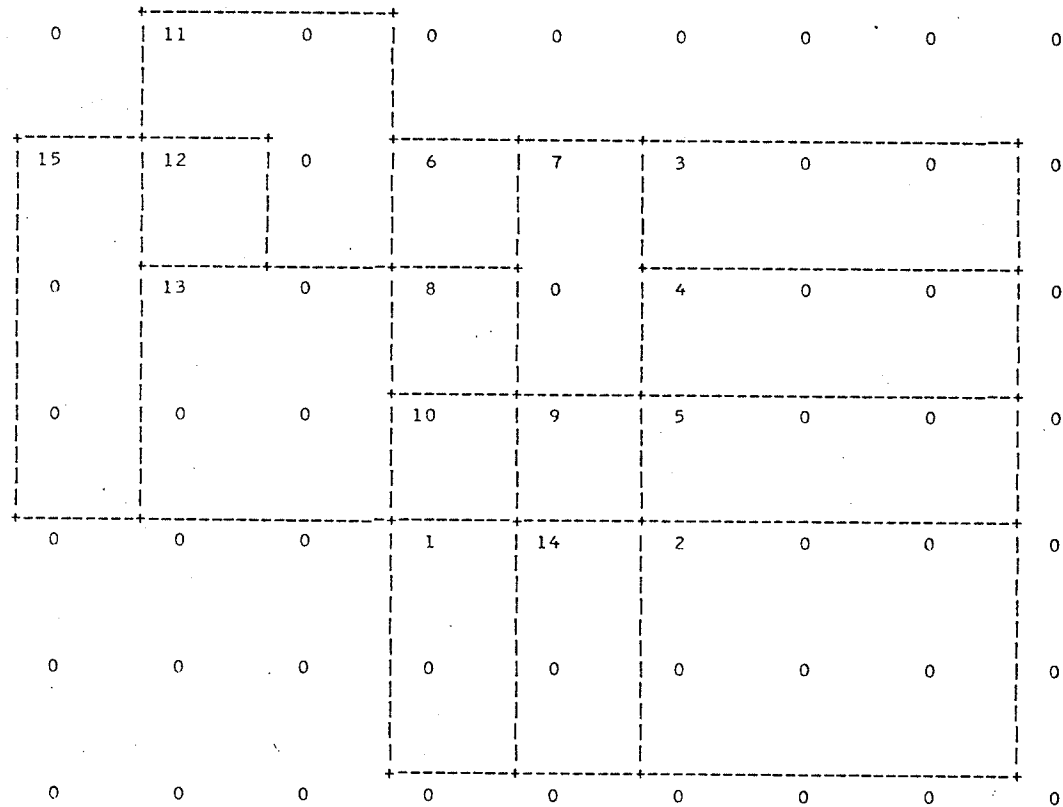
previous chapter.

The output of computations illustrated in Figure (23) shows that the annual cost of communications according to the present arrangement is equal to \$3,736. It also shows that the annual cost per square foot of plan is \$1.03. These figures will be referred to when evaluating the relative advantages of different computed plans.

4.2 Re-allocation of Facilities within the Existing Building

As activities taking place in a building are often subjected to cycles of growth and change that may not be long enough to justify moving to a new building, it is necessary to periodically update the existing layout by reallocation of facilities within the existing space. In some cases the cost of alterations may surpass the expected savings of running the modified layout. In such cases, a comparison has to be made between alternatives of modified plans. The second factor to be considered is space allocations. As the overall size of plan will remain the same, the extra space required for the growing activities will have to be provided internally i.e., from activities with little or non-expected growth, or activities allocated larger space than their actual need.

A study was carried out to re-allocate activities in the registrar's office within the present space. The first step was to re-allocate space to different activities according to their expected growth. This was accomplished by providing



SCALE : ONE INCH = 10 FEET

ANNUAL COST OF COMMUNICATION DUE TO PRE LOCATED ACTIVITIES = 3736 DOLLAR
 ANNUAL COST DUE TO COMPUTED ACTIVITIES = 0 DOLLAR
 ANNUAL TOTAL COST OF COMMUNICATION OF PLAN = 3736 DOLLAR
 ANNUAL COST PER SQUARE FOOT OF AREA CONSIDERED = 103 CENT

N.B. : THESE FIGURES DO NOT INCLUDE COST OF MOVEMENTS WITHIN EACH ACTIVITY

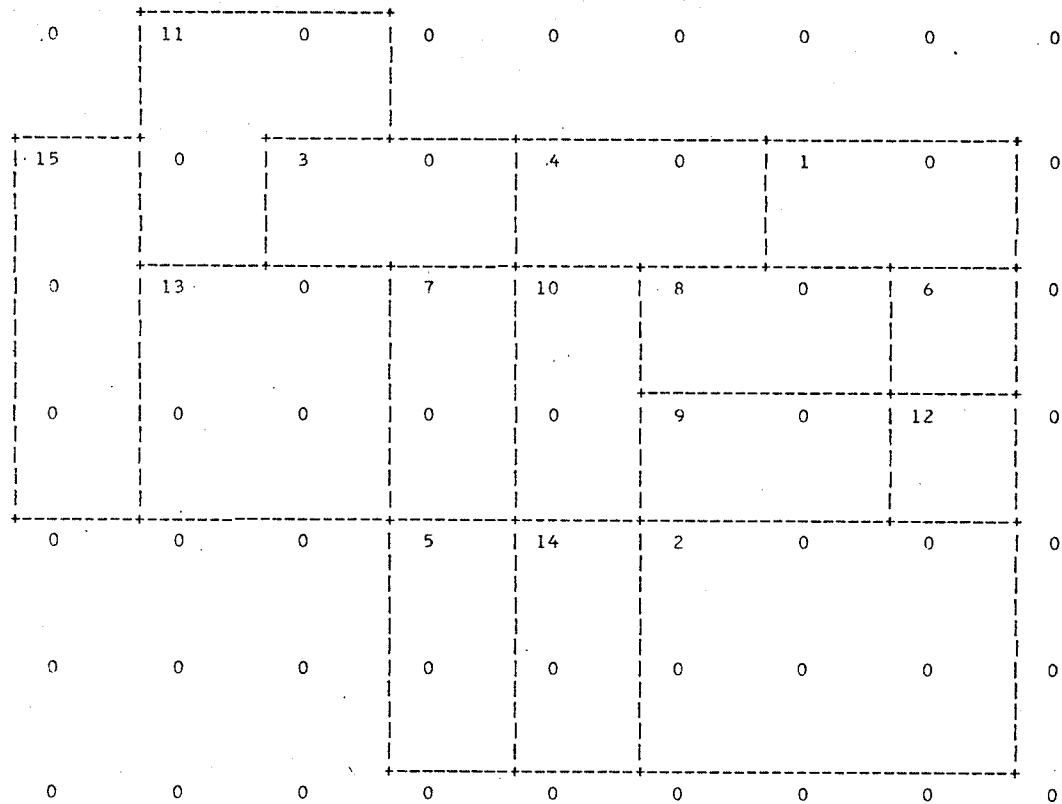
FIGURE 23 : COMPUTER OUTPUT , EXISTING PLAN

the activities # 8, 9 and 10 with 100 square feet each, taken from activities # 3, 4 and 5. The second step was to determine the fixed locations. The reception area and the stair hall (activities 13 and 15) were kept in their present locations. The locations of the general files and the vault were retained to eliminate the high cost of alterations because of their special construction for security and protection against fire.

Interactions between the remaining activities were computed and their locations determined as illustrated in Figure (24). The computed output was interpreted architecturally in Figure (25). From this output we notice that the new arrangement did not cause substantial reduction in the cost of communication. This may be for two reasons:

- A. The present arrangement is efficient with respect to the existing form of space provided.
- B. A number of activities were assigned the present locations before computations. This reduced substantially the number of space elements that were located through computations.

Another computer run was made on the assumption that more physical alterations can be made. This allowed the locations of the vault and general files to be determined through computations. The only two activities that were pre-located are the reception and the stairhall. Figure (26) illustrates that a considerable improvement was achieved when the number of computed locations was increased. An architectural



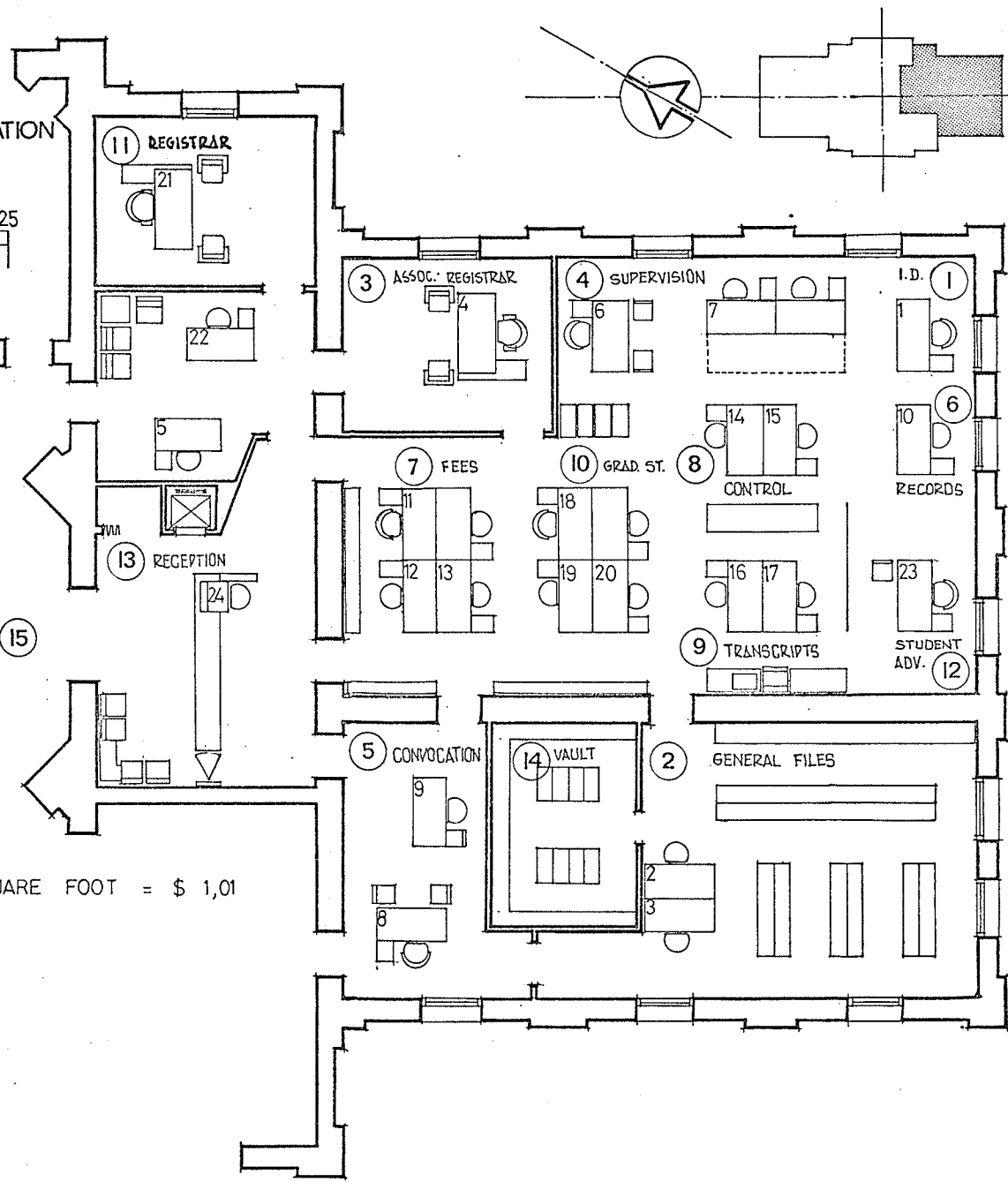
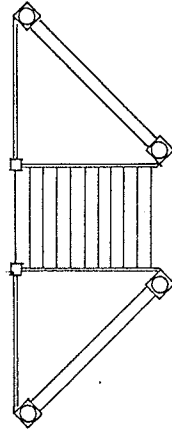
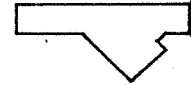
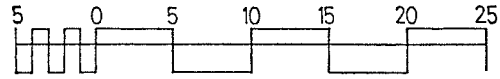
SCALE : ONE INCH = 10 FEET

ANNUAL COST OF COMMUNICATION DUE TO PRE LOCATED ACTIVITIES = 3652 DOLLAR
 ANNUAL COST DUE TO COMPUTED ACTIVITIES = 0 DOLLAR
 ANNUAL TOTAL COST OF COMMUNICATION OF PLAN = 3652 DOLLAR
 ANNUAL COST PER SQUARE FOOT OF AREA CONSIDERED = 101 CENT
 N.B. : THESE FIGURES DO NOT INCLUDE COST OF MOVEMENTS WITHIN EACH ACTIVITY

FIGURE 24: COMPUTER OUTPUT , MINIMUM MODIFICATIONS

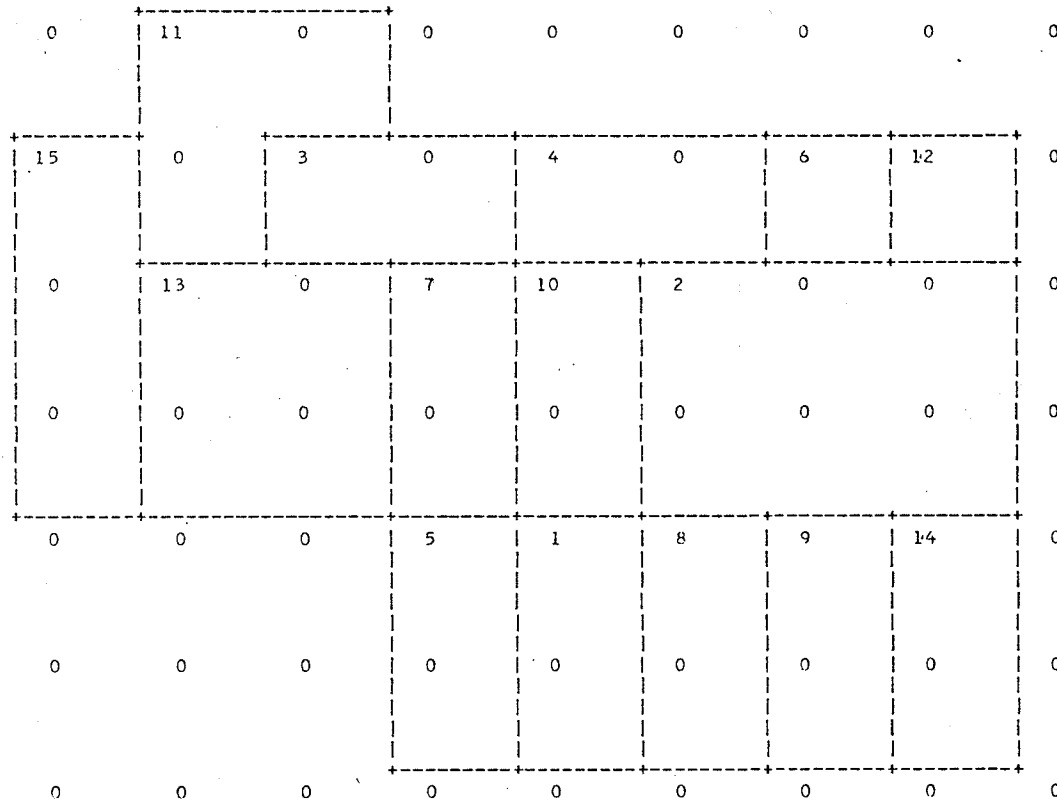
COMPUTED LAY OUT

EXISTING. WITH MINIMUM ALTERATION



COST OF COMMUNICATIONS PER SQUARE FOOT = \$ 1,01

FIGURE 25



SCALE : ONE INCH = 10 FEET

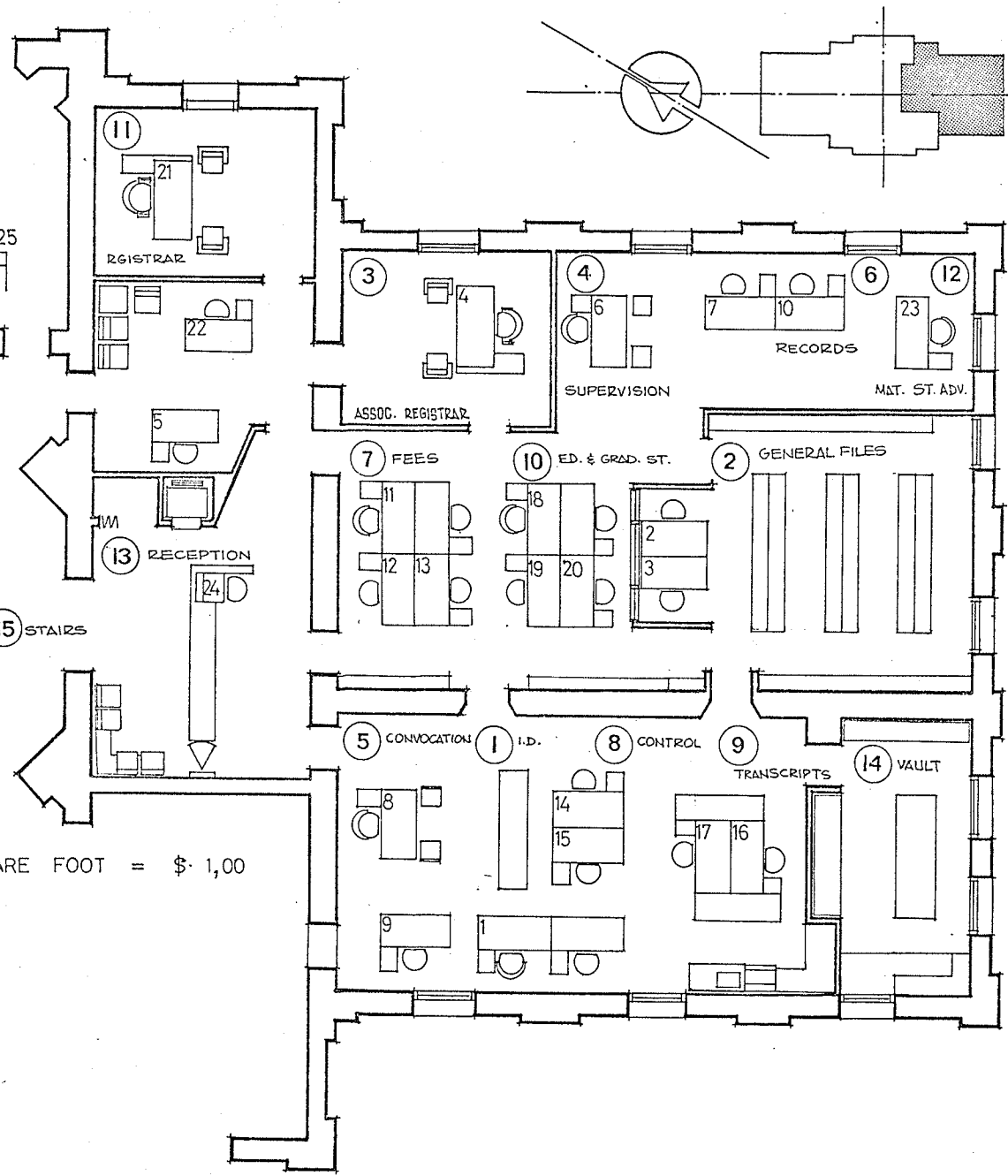
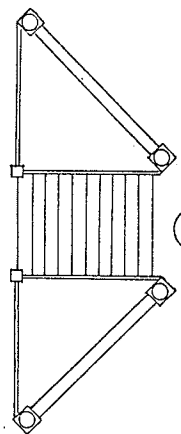
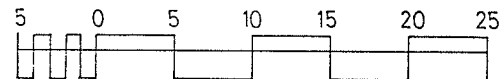
ANNUAL COST OF COMMUNICATION DUE TO PRE LOCATED ACTIVITIES = 3618 DOLLAR
 ANNUAL COST DUE TO COMPUTED ACTIVITIES = 0 DOLLAR
 ANNUAL TOTAL COST OF COMMUNICATION OF PLAN = 3618 DOLLAR
 ANNUAL COST PER SQUARE FOOT OF AREA CONSIDERED = 100 CENT

N.B. : THESE FIGURES DO NOT INCLUDE COST OF MOVEMENTS WITHIN EACH ACTIVITY

FIGURE 26: COMPUTER OUTPUT , MODIFIED PLAN

COMPUTED LAY OUT

ALTERATIONS OF
EXISTING PREMISES



COST OF COMMUNICATIONS PER SQUARE FOOT = \$ 1,00

FIGURE 27

interpretation of this output is illustrated in Figure (27).

4.3 Planning in a Non-restricted Site

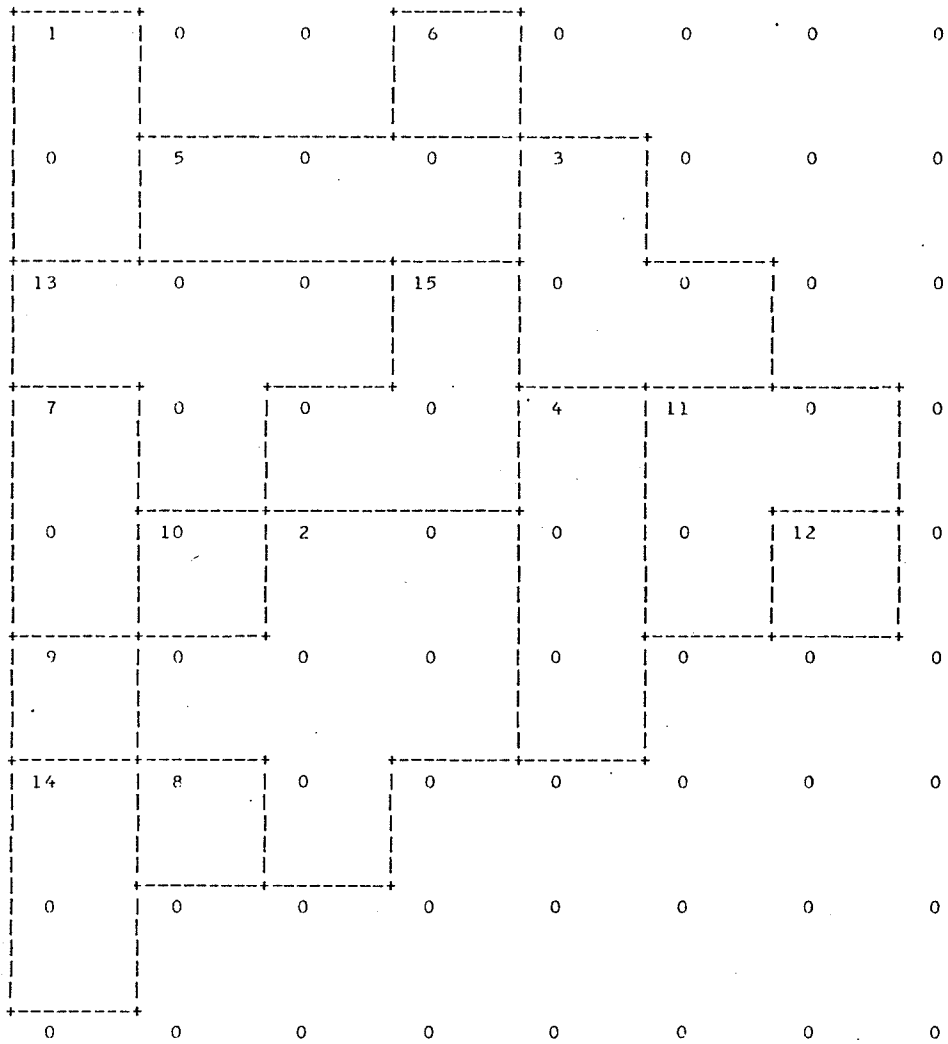
The interactions between different activities were used to compute a free plan. The only modification made is with respect to the stairhall.. Previous figures were originally modified to express the particular circumstances of the present layout, where different personnel pass through the stairhall on their way to related activities located outside the area. In planning a new building in a non-restricted site, it is assumed that all related activities are located in the same floor, and thus, visits to the stairhall are not treated as visits to a more distant activity.

The present space allocations were used to form a rational base for comparison.

The computed output illustrated in Figure (28) shows an impressive reduction in the annual cost of communications.

The present annual cost of communications was brought from \$1,03 down to \$44 per each square foot of plan. The final architectural treatment illustrated in Figure (29) shows that activities were grouped in three zones:

Zone A, for the administrative activities, which usually have larger interactions between themselves rather than with the public activities located in Zone B. Accessibility to the area is provided through its core (zone C), expressing the fact that the registrar's office is serving the campus



SCALE : ONE INCH = 10 FEET

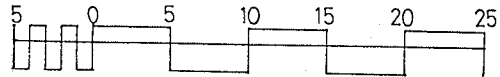
ANNUAL COST OF COMMUNICATION DUE TO PRE LOCATED ACTIVITIES = 0 DOLLAR
 ANNUAL COST DUE TO COMPUTED ACTIVITIES = 1619 DOLLAR
 ANNUAL TOTAL COST OF COMMUNICATION OF PLAN = 1619 DOLLAR
 ANNUAL COST PER SQUARE FOOT OF AREA CONSIDERED = 44 CENT

N.B. : THESE FIGURES DO NOT INCLUDE COST OF MOVEMENTS WITHIN EACH ACTIVITY

FIGURE 28 : COMPUTER OUTPUT, FREE PLAN

COMPUTED LAY OUT

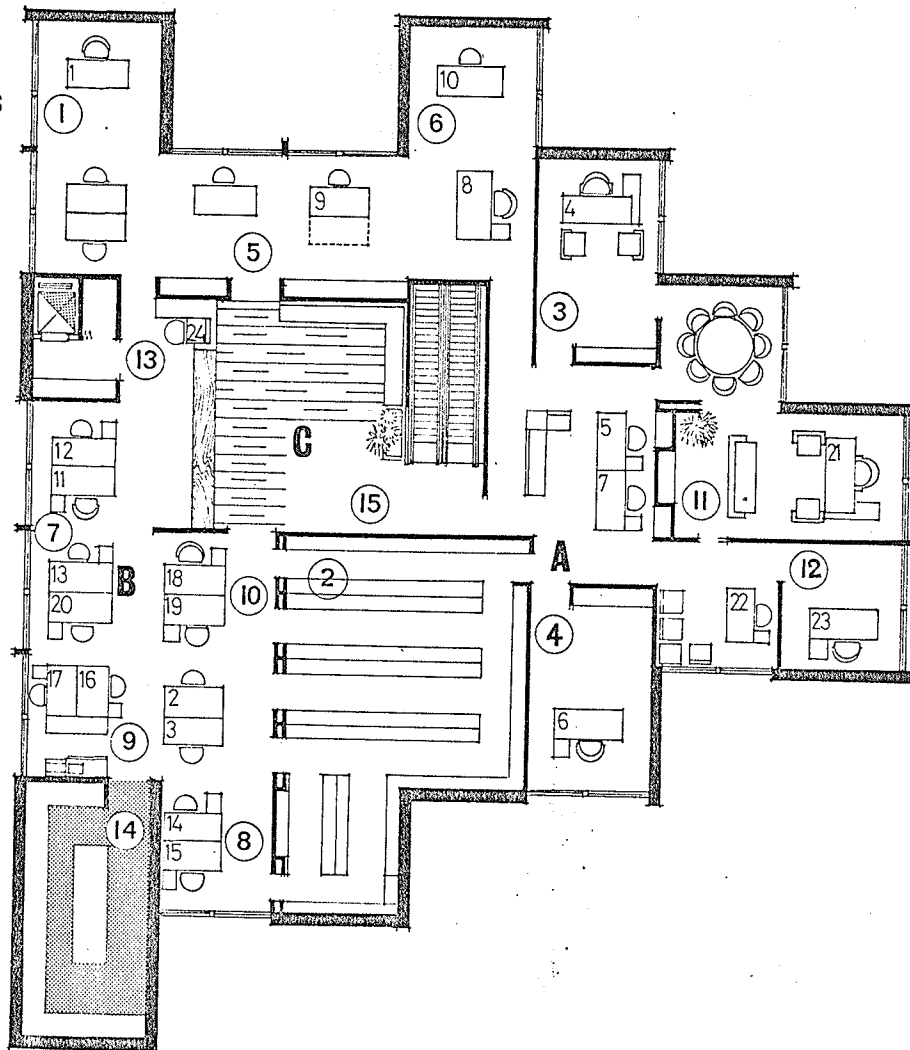
FREE PLANNING WITH NO RESTRICTIONS



- ① EXAM. & I. D.
- ② GENERAL FILES
- ③ ASSOC. REGISTRAR
- ④ SUPERVISION
- ⑤ CONVOCATIONS
- ⑥ RECORDS
- ⑦ FEES
- ⑧ CONTROL
- ⑨ TRANSCRIPTS
- ⑩ EDUC. & GRAD STUDIES
- ⑪ REGISTRAR
- ⑫ MATURE STUDENT ADVISER
- ⑬ RECEPTION
- ⑭ VAULT
- ⑮ STAIRS

ANNUAL COST OF COMMUNICATIONS PER
SQUARE FOOT = \$ 0,44

FIGURE 29



at large and its physical interactions with outside activities are vital for an efficient performance.

4.4 Analogy between free and Restricted Plans

From the previous illustration of free and restricted planning, we find that the free planning process has a considerable advantage with respect to cost of communication. The locations of different activities are determined solely through minimizing cost of communications. No restrictions that might have interfered with the selection of such locations are imposed. On the other hand, the restricted planning, while giving a higher cost of communications, has the advantage of controlling the output of computations. This facility is indispensable in planning within a specific given space. However, the two procedures can be used to help in the decision whether to move to a new building or simply rearrange activities within the same premises. The cost of necessary alterations and the resulting savings in annual cost of communications would be compared to the cost of a new building and its annual communication cost. The life of the building would be taken into account with other factors (i.e., mortgage rates, taxation, budget, etc.).

In the particular case considered we find that the annual cost of communication was brought from the present \$103 per square foot, down to \$44. This means an annual saving of about \$59 per square foot.

This cost of communication is based upon the present pattern of salaries. So, if we may consider that the annual increase in salaries is almost equal to the mortgage interest rate, then, we can hypothetically consider that the discounted present value of the cost of communication per square foot would be the same over the building life (mortgage length).

An annual saving of \$59 over a life span of 60 years, using this assumption, would amount to \$36 per square foot. This does not mean that activities will remain unchanged throughout such a long span of time, rather, emphasizes the fact that cost of communication may be a dominant factor affecting the economical components of the project.

CONCLUSIONS

The present role of the architect requires him to make functional decisions, discover visual relationships and express both in formal terms. It can be enhanced by using the computer for simultaneous analysis of many functional variables. Economic gains of such an approach may be surpassed by the convenience of optimum performance of the building.

However, these advantages may be largely expanded if future work overcomes the limitations of the present programme.

Limitations and Points of Interest for Future Investigation

The planning process optimizes the locations of different activities within any given area. The two dimensional arrangement does not take into account the impact of activities located in other floors. In the present procedure a manual decision has to be made as to which activities would be grouped on the same floor before optimizing their relative locations within this floor. Computing the interactions between different activities in three dimensions will distribute activities to various levels, determine various floor areas, and, consequently, the mass plan of the project.

B. Imposing restrictions on the planning process reduces the chances of attaining an optimum arrangement. In some cases, pre-located activities distort the computation process by attracting the elements of high priority of location regardless to a possible week pattern of interactions that would not justify such proximity.

Future work may investigate the possibility of introducing modification factors that can neutralize the distorting effect of pre-located activities to insure that locations next to them would be occupied by highly related activities.

C. Interactions between different activities are computed according to the assumption that the boundaries of any activity may be crossed at any side. In many cases, walls, furniture or equipment may interfere with this assumption, and divert the movements between two adjacent locations to longer routes. More realistic results would be obtained if locations of doors, dividing partitions etc., were introduced.

D. The present programme may handle a complex problem in two or more stages.

At the first stage activities of similar nature will be clustered in groups. The collective interactions between these groups will be computed to determine their relative locations. The second stage is to optimize the locations of activities within the space allocated to each group. As we

see, a considerable amount of manual decisions are involved, increasing the chances for inaccurate representation and sub-optimum results.

Such drawbacks can be overcome in a master programme that could make decisions, such as grouping of activities and the collective interactions between groups.

A multi-stage approach could greatly reduce the computation time, and provide a facility that could handle efficiently practical problems of substantial size.

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APPENDIXES

APPENDIX A

The sequence of computations illustrated in the previous chapters is applied to optimize the location of activities with respect to the cost of movements of persons involved. If the plan is required to be optimized with respect to any other given form of relations, the matrix of these relations would be provided, and all the preparatory computations of cost of movements would be omitted. Evaluation of different computed outputs will be in terms of the given relations. A chart illustrating the various stages of the computation process is shown in Figure (30).

A flow chart of subroutine programme 'PLOTTER' shown in Figure (31) illustrates the stages of graphical formation of the required plan.

COMPUTATIONS FLOW CHART

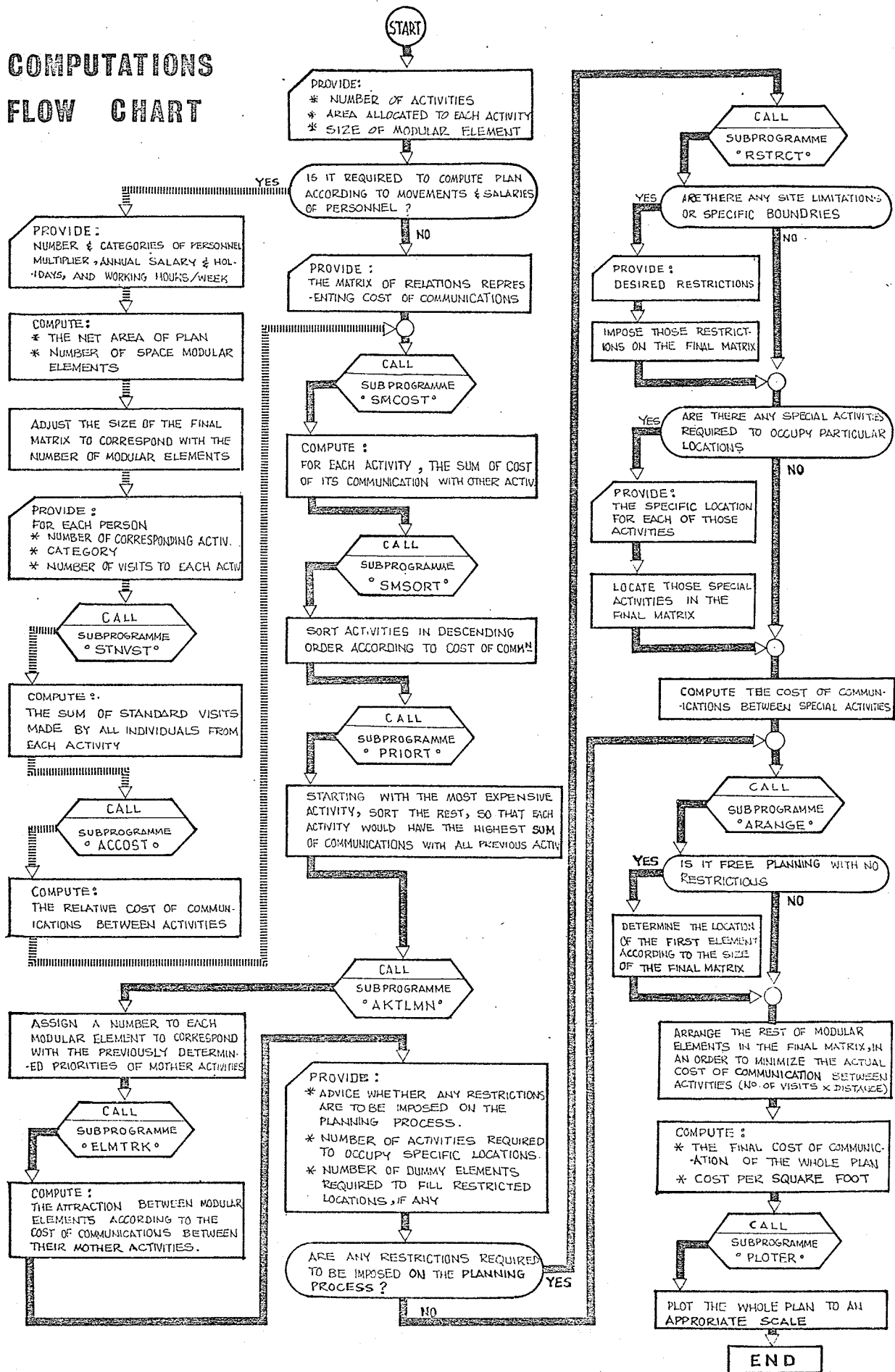


FIGURE 30

SUBPROGRAM PLOTTER

flow chart

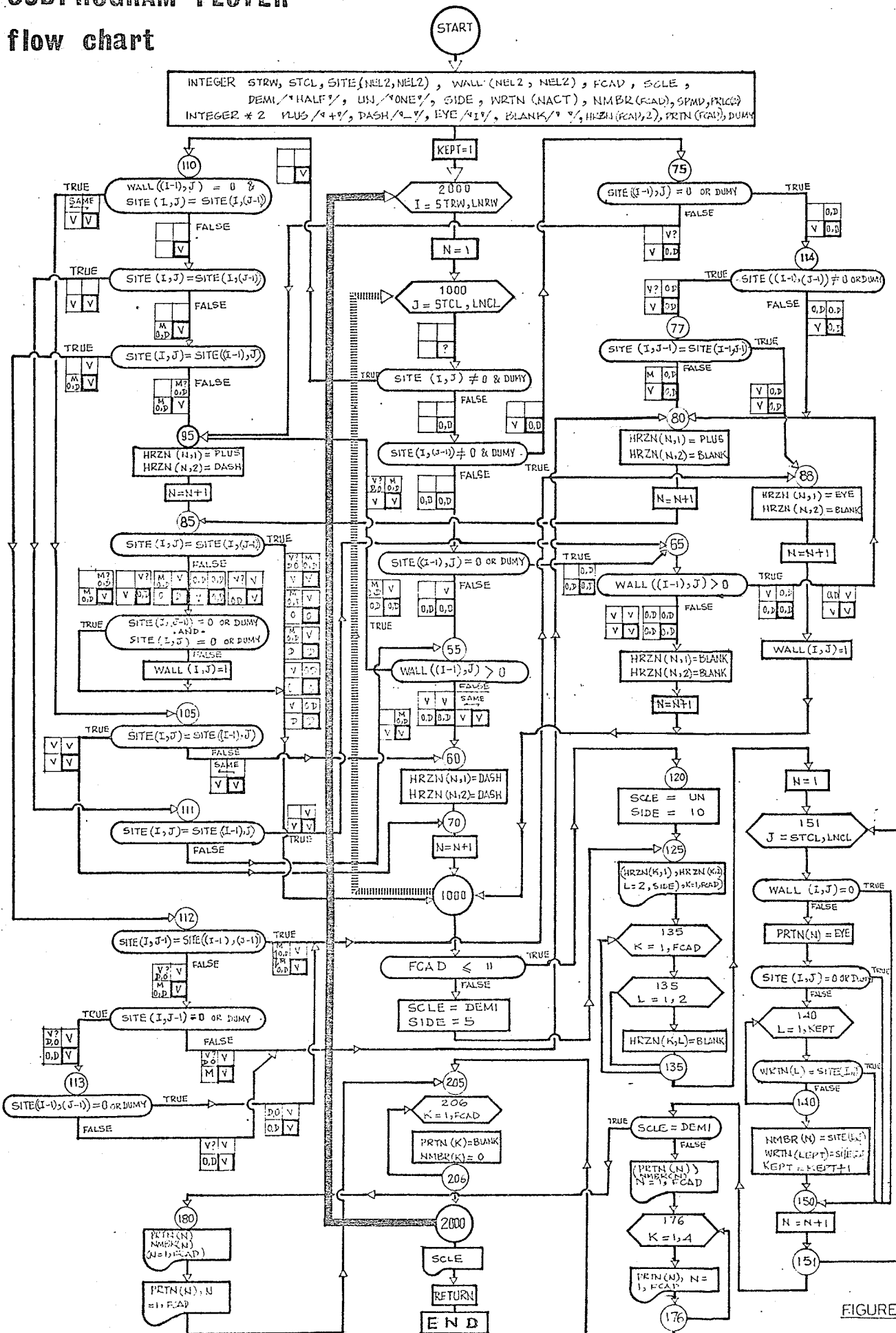


FIGURE 31

APPENDIX B

THE COMPUTER PROGRAMME

A copy of the complete computer programme is presented in the following pages. It should be noticed that the function of the master programme was confined to reservation of more than adequate memory for storing different arrays. The exact number of bites required for each array is determined through the subroutine programme 'MAINSB', after reading the particulars of activities considered. This makes the programme quite flexible and capable of handling problems of various sizes.

\$JOB WATFIV TAWFIK,KP=29,TIME=120,PAGES=30

C A PRECISION APPROACH TO ARCHITECTURAL PLANNING (P A T A P)
C THIS PROGRAMME GENERATES THE REQUIRED PLAN ACCORDING TO EITHER THE COST OF
C COMMUNICATION OR ANY GIVEN PATTERN OF INTERACTIONS BETWEEN ACTIVITIES.

C THE FOLLOWING TERMS ARE USED :

C CRYT : CRITERIA OF PLANNING
C NACT : TOTAL NUMBER OF ACTIVITIES
C SPMD : AREA OF SPACE MODULAR ELEMENT IN SQUARE FEET
C AREA(I) : AREA OF ACTIVITY (I) IN SQUARE FEET
C NCTG : TOTAL NUMBER OF CATEGORIES
C FACT(I) : THE MULTIPLIER OR FACTOR OF STANDARDIZATION
C SLRY : STANDARD ANNUAL SALARY
C HLDY : AVERAGE ANNUAL HOLIDAY IN WEEKS
C WKHR : AVERAGE WORKING HOURS PER WEEK
C ACTV : ACTIVITY'S NUMBER
C PRSN : PERSON'S NUMBER
C CATG : CATEGORY

C VIST(I) : NUMBER OF VISITS MADE BY CONSIDERED PERSON TO ACTIVITY (I)
C COST(I,J) : MATRIX OF INTERACTIONS BETWEEN ACTIVITIES
C RSTR : RESTRICTIONS IMPOSED ON THE PLANNING PROCESS
C NPRL : TOTAL NUMBER OF ACTIVITIES TO BE PRE LOCATED
C NDMY : NUMBER OF DUMMY ELEMENTS
C XRDN(I),YRDN(I) : HORIZONTAL AND VERTICAL ORDINATES OF DUMMY ELEMENT (I)
C PRLC(I) : PRE LOCATED ACTIVITY (I)
C ACSZ(I) : NUMBER OF MODULAR ELEMENTS ASSIGNED TO A PRE LOCATED ACTIVITY

C THE SEQUENCE OF DATA READ IS AS FOLLO :
C 1-'CRYT' (CRYT=1 ,IF COST IS COMPUTED ACCORDING TO MOVEMENTS AND SALARIES,
C (CRYT=0 ,IF OTHER MATRIX OF RELATIONS IS PROVIDED WITHOUT COMPUT.

C 2-'NACT,SPMD,(AREA(J),J=1,NACT) '
C THEN 3 , 4 ARE PROVIDED ONLY IF 'CRYT' = 1

C 3-'NCTG,(FACT(I),I=1,NCTG),SLRY,HLDY,WKHR'

C 4-'ACTV,PRSN,CATG,(VIST(I),I=1,NACT) '
C (THE CARD # 4 IS REPEATED ACCORDING TO THE NUMBER OF PERSONS)

C THEN 5 WILL BE PROVIDED ONLY IF 'CRYT' = 0

C 5-'(COST(I,J),J=1,NACT),I=1,NACT)
C (THIS MATRIX REPRESENTS ANY DESIRED RELATIONS BETWEEN ACTIVITIES)

C 6-'RSTR,NPRL,NDMY'
C ('RSTR' = 1 IF ANY DUMY OR ACTUAL ACTIVITIES ARE PRE LOCATED,OTHERWISE =0)

C ('NPRL' IS NUMBER OF ACTUAL ACTIVITIES TO BE PRE LOCATED)
C ('NDMY' IS NUMBER OF DUMMY ELEMENTS TO BE PRE LOCATED)

C THEN 7 IS PROVIDED ONLY IF 'RSTR' = 1 AND 'NDMY' GREATER THAN 0

C 7-(XRDN(I),YRDN(I),I=1,NDMY)

C THESE ARE THE ORDINATES IN THE MATRIX 'ARNG' WHERE DUMY ELEMENTS ARE PRE
C LOCATED.

C THEN 8 , 9 ARE PROVIDED ONLY IF 'NPRL' IS GREATER THAN 0

C 8-PRLC(1),ACSZ(1)

C (PRLC(1) IS THE NUMBER OF ACTIVITY TO BE PRE LOCATED FIRST)

C (ACSZ(1) IS THE NUMBER OF ELEMENTS REPRESENTING THIS ACTIVITY)

C 9-XRDN(1) , YRDN(1) , I=1,ACSZ(1)

C THEN 8 ,9 ARE REPEATED ACCORDING TO THE NUMBER OF PRE LOCATED ACTIVITIES 'NPRL

1 INTEGER ACTV , PRSN , CATG , STND(5,20)/100*0/ , SUM(20,20) , K/1/

1,ACST(20) /20*0/,COST(20,20) , SMCS(2,20)/40*0/ ,

1SIZE(20),AREA(20),SPMD,AKEL(2,100),A(25),PREV,P,R,OLDI,OLDJ,

1ATRK(100,100),SMSI,SMSJ,PLAN/0/,PRIR(20),SMPR(20),

1ARNG(33,33)/1089*0/,SITE(35,35)/1225*0/,WALL(35,35)/1225*0/

2 REAL FACT(5) , VIST(20)

3 READ,CRYT

4 READ,NACT,SPMD,(AREA(J),J= 1,NACT)

5 IF(CRYT.EQ.0)G3 TO 9

6 READ,NCTG,(FACT(I),I=1,NCTG),SLRY,HLDY,WKHR

```

7 9 DO 10 I = 1 , NACT
8 PLAN = PLAN + AREA (I)
9 10 CONTINUE
10 NELM = PLAN / SPMD
11 IF(NELM.LT.21) GO TO 12
12 NEL = NELM/3
13 GO TO 15
14 12 IF(NELM.LT.10) GO TO 13
15 NEL = NELM/2
16 GO TO 15
17 13 NEL = NELM-1
18 15 NEL1 = NEL+1
19 NEL2 = NEL+2
20 CALL MAINSB (STND , SUM , ACST , COST , SMCS , FACT , VIST
1, NACT , NCTG , ACTV , PRSN , CATG , K ,
1AREA,SPMD,SIZE,AKEL,A,PREV,NELM,M,L,P,R,OLDI,OLDJ,ATRK,
1N,PLAN,SMSI,SMSJ ,NROW,PRIR,SMPR,LARG,NEL,ARNG,SITE,WALL,
1NEL1,NEL2,CRYT,SLRY,HLDY,WKHR )
21 PRINT 1000
22 1000 FORMAT ('1')
23 STOP
24 END

25 SUBROUTINE MAINSB (STND , SUM,ACST,COST,SMCS,FACT,VIST
1, NACT , NCTG , ACTV , PRSN , CATG , K ,
1AREA,SPMD,SIZE,AKEL,A,PREV,NELM,M,L,P,R,OLDI,OLDJ,ATRK,
1N,PLAN,SMSI,SMSJ ,NROW,PRIR,SMPR,LARG,NEL,ARNG,SITE,WALL,
1NEL1,NEL2,CRYT,SLRY,HLDY,WKHR )
26 INTEGER STND(NCTG,NACT) , SUM(NACT,NACT) , ACST(NACT) ,PRCS,
1COST(NACT,NACT) , SMCS(2,NACT) ,ACTV , PRSN , CATG ,
1SIZE(NACT) ,AREA(NACT) ,SPMD,PLAN,AKEL(2,NEL1),A(25),PREV,P,R,
1OLDI,OLDJ,ATRK(NELM,NELM),SMSI,SMSJ,PRIR(NACT),SMPR(NACT),
1RSTR,PRLC(20),ARNG(NEL,NEL),TOTV,SITE(NEL2,NEL2),WALL(NEL2,NEL2),
1WRTV(20)/20*0/,NMBR(22)/22*0/,STCL,ENCL,STRW,ENRW,FCAD
27 INTEGER XRDN(90) , YRDN(90) , XPNS , PRXP , PRCE , FTPR
28 INTEGER*2 HRZN(22,2)/44*' ' /,PRTN(22)/22*' ' / ,DUMY/'X' /
29 REAL FACT(NCTG) , VIST(NACT)
30 PRINT 2,NACT,SPMD,NELM,PLAN
31 2 FORMAT('1',///20X,'NUMBER OF ACTIVITIES =',I6,///20X,'SPACE MODULE
1 =',I6,' SQUARE FEET',//20X,'NUMBER OF ELEMENTS =',I6,///
120X,'TOTAL AREA OF PLAN =',I6,' SQUARE FEET'///)
32 IF(CRYT.EQ.0) GO TO 276
33 PRINT,NCTG,{FACT(I),I=1,NCTG}
34 PRINT,(AREA(J),J=1,NACT)
35 3 READ , ACTV , PRSN , CATG , (VIST(I) , I= 1,NACT)
36 PRINT , ACTV , PRSN , CATG , AREA(ACTV)
37 PRINT ,(VIST(I) , I=1,NACT)
38 CALL STNVST (NACT , ACTV , NCTG , CATG , K , SUM , VIST , STND ,
1ACST , FACT )
39 IF ( ACTV .EQ.NACT ) GO TO 15
40 GO TO 3
41 15 DO 16 J = 1 , NACT
42 SUM(NACT,J) = ACST(J)
43 16 CONTINUE
44 PRINT201
45 201 FORMAT('1',///30X,'SUM OF VISITS FROM EACH ACTIVITY TO ANY OTHER
1ACTIVITY' ///50X,'VISITED ACTIVITIES'/'0' , 15X,'1' , 5X , '2' ,
15X , '3' , 5X , '4' , 5X , '5' , 5X , '6' , 5X , '7' , 5X , '8' ,
15X , '9' , 4X , '10' , 4X , '11' , 4X , '12' , 4X , '13' , 4X ,
1'14' , 4X , '15' , 4X , '16' , 4X , '17' , 4X , '18' , 4X , '19' ,

```

```

14X , '20' ///)
46 DO 250 I=1,NACT
47 PRINT 240,I,(SJM(I,J),J=1,NACT)
48 240 FORMAT('0','VISITOR',I3,(20I6,/10X))
49 250 CONTINUE
50 CALL ACCOST(COST,SUM,NACT)
51 PRINT 270
52 270 FORMAT('1',///35X,'RELATIVE COST OF COMMUNICATION BETWEEN ACTIVITI
IES '//0',30X,'REPRESENTED BY THE SUM OF VISITS MADE FROM AND RECEI
IVED BY'//0',37X,'EACH ACTIVITY TO AND FROM ANY OTHER ACTIVITY'
1//50X,
1 ' *****' /// 52X , 'NUMBER OF ACTIVITY'//0',
115X , '1' , 5X , '2' ,
15X , '3' , 5X , '4' , 5X , '5' , 5X , '6' , 5X , '7' , 5X , '8' ,
15X , '9' , 4X , '10' , 4X , '11' , 4X , '12' , 4X , '13' , 4X ,
1'14' , 4X , '15' , 4X , '16' , 4X , '17' , 4X , '18' , 4X , '19' ,
14X , '20' ///)
53 DO 275 I = 1,NACT
54 PRINT274,I,(COST(I,J),J=1,NACT)
55 274 FORMAT('0','ACTIVITY',I2,(20I6,/10X))
56 275 CONTINUE
57 GO TO 277
58 276 READ,((COST(I,J),J=1,NACT),I=1,NACT)
59 277 CALL SMCOST(COST,SMCS,NACT)
60 PRINT 280
61 280 FORMAT('1',///20X,'TOTAL SUM OF RELATIVE COST OF COMMUNICATION FO
R EACH ACTIVITY PRESENTED BY'//0',15X,'THE SUM OF VISITS MADE FRO
M AND RECEIVED BY ANY ACTIVITY TO AND FROM ALL OTHER ACTIVITIES '
1//50X,'*****'//)
62 PRINT 285 , ( SMCS (1,J) , J =1, NACT)
63 285 FORMAT('0','ACTIVITY ',(20I6,/10X))
64 PRINT286,(SMCS(2,J) , J=1,NACT)
65 286 FORMAT('0','COST SUM ',(20I6,/10X))
66 CALL SMSORT(SMCS , NACT)
67 PRINT 290
68 290 FORMAT('0',/////////35X,'ACTIVITIES ARRANGED IN A DESCENDING ORDER
1//25X,'ACCORDING TO THE SUM OF THEIR RELATIVE COST OF COMMUNICATIO
IN '//50X,'*****'//)
69 PRINT 295,(SMCS(1,J),J=1,NACT)
70 295 FORMAT('0','ACTIVITY ',(20I6,/10X))
71 PRINT 296 , (SMCS(2,J) , J=1, NACT)
72 296 FORMAT('0','COST SUM ',(20I6,/10X))
73 CALL PRIORT( NACT,NROW,PRIR,SMPR,LARG,COST,SMCS )
74 PRINT 300
75 300 FORMAT('1',///30X,'ARRANGEMENT OF ACTIVITIES ACCORDING TO PRIORITY
1 OF CONTACT'//45X,'*****'//)
76 PRINT310,(PRIR(J),J=1,NACT)
77 310 FORMAT('0',20I5////////)
78 CALL AKTLMN (SIZE,AREA,PRIR,SPMD,PREV,P,R,NACT,AKEL,NELM)
79 PRINT 425
80 425 FORMAT('0',/////,30X,'ARRANGEMENT OF SPACE ELEMENTS ACCORDING TO P
RIRORITY OF CONTACT'//50X,'*****'//)
81 PRINT 426, (AKEL(1,J),J=1,NELM)
82 426 FORMAT('0','ELEMENT',4X,(40I3,/6X))
83 PRINT427, (AKEL(2,J),J=1,NELM)
84 427 FORMAT('0','ACTIVITY',3X,(40I3,/6X))
85 CALL ELMTRK (P,R,OLDI,OLDJ,NACT,SIZE, ATRK,COST,NELM,SMSI,SMSJ
1,PRIR)
86 PRINT 550
87 550 FORMAT(////'1',10X,'MATRIX OF FORCE OF ATTRACTION BETWEEN ELEMENTS

```



```

1 , ARRANGED ACCORDING TO THE TOTAL COST OF ACTIVITIES')
88 DO 570 I = 1,NELM
89 PRINT 555,I,(ATRK(I,J),J=1,NELM)
90 555 FORMAT('0','ELMNT',I3,4X,(40I3,/7X))
91 570 CONTINUE
92 PRCS = 0
93 ME = 0
94 READ , RSTR,NPRL,NDMY
95 IF(RSTR.GT.0) CALL RSTRCT(NPRL,PRLC,ME,NELM,AKEL,ARNG,NEL,
1ATRK,PRCS,DUMY,NDMY,XRDN,YRDN)
96 PRINT 575 , RSTR,NPRL,NDMY
97 575 FORMAT('0',////20X,'RESTRICTIONS',23X,'=',I5,//20X,
1'NUMBER OF PRELOCATED ACTIVITIES ',3X,'=',I5,//20X,
1'NUMBER OF DUMMY ELEMENTS',11X,'=',I5,//20X,
1'PRELOCATED ACTIVITIES',14X,'=')
98 IF(NPRL.EQ.0) GO TO 581
99 PRINT 580,(PRLC(I),I=1,NPRL)
100 580 FORMAT('+',56X,20I3/)
101 GO TO 590
102 581 PRINT 585
103 585 FORMAT('+',59X,'0')
104 590 IF(ME.EQ.1000) GO TO 710
105 PRINT 700
106 700 FORMAT('0',20X,'THE COMPUTED PLAN IS BASED UPON THE FOLLOWING ASSU
IMPTIONS : '//30X,'1- NO SITE LIMITATIONS'/30X,'2- NO ACTIVITIES AR
IE REQUIRED TO OCCUPY SPECIFIC LOCATIONS'//20X,'PLEASE ADVISE IF AN
1Y NEW RESTRICTIONS ARE TO BE CONSIDERED'/////////)
107 710 CALL ARANGE(TOTV,NEL1,RSTR,NPRL,PRLC,AKEL,NEL,ARNG,ATRK,
1NEL1,NEL2,SITE,STRW,ENRW,STCL,ENCL,LSRW,LNRW,LSCL,LNCL,FCAD,DUMY)
108 PRINT 715
109 715 FORMAT('1',20X,'ARRANGEMENT OF MODULAR ELEMENTS THAT REPRESENTS TH
IE MINIMUM COST OF COMMUNICATION BETWEEN ACTIVITIES'//)
110 PRINT716,(J,J=1,NEL)
111 716 FORMAT('0',10X,40I3//)
112 DO 720 I = 1,NEL
113 PRINT717,I,(ARNG(I,J),J=1,NEL)
114 717 FORMAT('0',5X,I2,3X,(40I3,/11X))
115 720 CONTINUE
116 RATE = SLRY/((52-HLDY)*WKHR*3600)
117 TIME = .2*SQR(FLOAT(SPMD))
118 XPNS = TOTV*TIME*RATE*255
119 PRXP = PRCS*TIME*RATE*255
120 PRCE = XPNS+PRXP
121 FTPR = (PRCE*100)/(NEL1*SPMD)
122 730 CALL PLOTER(STRW,STCL,LNRW,LNCL,SITE,WALL,HRZN,FCAD,SPMD,
1NEL1,NEL2,PRTV,NACT,WRTN,NMBR,DUMY,PRLC,NPRL)
123 IF(CRYT.GT.0) GO TO 734
124 737 PRINT738,PRCS,TOTV,PRCS+TOTV
*EXTENSION* OTHER COMPILERS MAY NOT ALLOW EXPRESSIONS IN OUTPUT LISTS
125 738 FORMAT('0',/21X,'PREREQUISITE VALUE DUE TO PRELOCATED ACTIVITIES'
1,12X,'=',I10,' UNIT'//21X,'VALUE OF COMPUTED LOCATIONS OF NON RES
1TRICTED ACTIVITIES',3X,'=',I10,' UNIT'/84X,' _____'//21X,
1'TOTAL VALUE OF PLAN ACCORDING TO THIS ARRANGEMENT',10X,'=',I10,
1' UNIT')
126 RETURN
127 734 PRINT 735,PRXP,XPNS,PRCE,FTPR
128 735 FORMAT('0',//21X,'ANNUAL COST OF COMMUNICATION DUE TO PRE LOCATED
1ACTIVITIES =',I8,' DOLLAR'//21X,'ANNUAL COST DUE TO COMPUTED ACTI
1VITIES ',20X,'=',I8,' DOLLAR'//
183X,' _____'/21X,'ANNUAL TOTAL COST OF COMMUNICATION OF PLAN'

```

```

1,17X,'=',18,' DOLLAR'//21X,
1'ANNUAL COST PER SQUARE FOOT OF AREA CONSIDERED',13X,'=',18,
1' CENT'//21X,
1'N.B. : THESE FIGURES DO NOT INCLUDE COST OF MOVEMENTS WITHIN EACH
1 ACTIVITY')

```

```

129   RETJRN
130   END

```

```

131   SUBROUTINE STNVST ( NACT,ACTV,NCTG,CATG,K,SUM,VIST,STND,ACST,FACT)
132   INTEGER  SUM(NACT,NACT),STND(NCTG,NACT), ACST(NACT) , ACTV , CATG
133   REAL FACT (NCTG) , VIST(NACT)
134   IF (ACTV .EQ. < ) GO TO 7
135   DO 30 J = 1,NACT
136   SUM(K,J) = ACST(J)
137   30  CONTINUE
138   K = ACTV
139   DO 40 I = 1 ,NCTG
140   DO 40 J = 1 , NACT
141   ACST(J) = 0
142   STND (I,J) = 0
143   40  CONTINUE
144   7   DO 20 J = 1 , NACT
145   STND (CATG , J ) = FACT(CATG) * VIST(J)
146   ACST (J) = ACST (J) + STND (CATG , J)
147   20  CONTINUE
148   RETURN
149   END

```

```

150   SUBROUTINE ACCOST(COST,SUM,NACT)
151   INTEGER COST ( NACT , NACT ) , SUM(NACT,NACT)
152   DO 20 I = 1 , NACT
153   DO 20 J = 1 , NACT
154   COST (I,J) = SUM(I,J) + SUM(J,I)
155   COST(J,I) = COST(I,J)
156   20  CONTINUE
157   RETURN
158   END

```

```

159   SUBROUTINE SMCOST(COST,SMCS,NACT)
160   INTEGER COST(NACT,NACT),SMCS(2,NACT)
161   DO 30 J = 1,NACT
162   DO 30 I = 1,NACT
163   SMCS(2,J) = SMCS(2,J) + COST(I,J)
164   30  CONTINUE
165   DO 40 J = 1,NACT
166   SMCS(1,J) = J
167   40  CONTINUE
168   RETJRN
169   END

```

```

170   SUBROUTINE SMSORT (SMCS , NACT)
171   INTEGER SMCS ( 2 , NACT )
172   J = NACT - 1
173   9   IF ( J .LT. 1 ) RETURN
174   DO 10 K = 1 , J
175   IF ( SMCS(2,K) . GT. SMCS(2, K+1))GO TO 10
176   L = SMCS (1,K)
177   M = SMCS(2,K)
178   SMCS(1,K) = SMCS(1 ,K+1)
179   SMCS(2,K) = SMCS(2 ,K+1)

```

```

180          SMCS(1,K+1) = L
181          SMCS(2,K+1) = M
182 10       CONTINUE
183          J= J-1
184          GO TO 9
185          END

186          SUBROUTINE PRIORT ( NACT,NROW,PRIR,SMPR,LARG,COST,SMCS )
187          INTEGER PRIR(NACT),SMPR(NACT),COST(NACT,NACT),SMCS(2,NACT)
188          DO 350 J = 1,NACT
189             PRIR(J) = 0
190             SMPR(J) = 0
191 350       CONTINUE
192             PRIR(1) = SMCS(1,1)
193             DO 360 J = 1,NACT
194                LARG = 0
195                DO 370 I = 1,NACT
196                   SMPR(I) = SMPR(I) + COST(I,PRIR(J))
197                   IF(LARG .GT. SMPR(I)) GO TO 370
198                   DO 380 L = 1,J
199                      IF(I .EQ. PRIR(L)) GO TO 370
200 380       CONTINUE
201                LARG = SMPR(I)
202                NROW = I
203 370       CONTINUE
204             IF(J.EQ. NACT) RETURN
205             PRIR(J+1) = NROW
206 360       CONTINUE
207             RETJRN
208             END

209          SUBROUTINE AKTLMN ( SIZE,AREA,PRIR,SPMD,PREV,P,R,NACT,AKEL,NELM)
210          INTEGER SIZE(NACT),AREA(NACT), PRIR(NACT) ,SPMD,PREV,P,R,
211          IAKEL(2,NELM) ,A(25)
212          DO 400 J =1,NACT
213 400       SIZE(J) = AREA(PRIR(J))/SPMD
214             PREV = 0
215             P = 1
216             R = 1
217             DO 410 J = 1,NACT
218                N = SIZE (J)
219                DO 420 L = 1,N
220                   A(L) = PRIR(J)
221                   M = PREV + L
222                   AKEL(1,M) = M
223                   AKEL(2,M) = A(L)
224 420       CONTINUE
225             PREV = M
226 410       CONTINUE
227             RETJRN
228             END

229          SUBROUTINE ELMTRK(P,R,OLDI,OLDJ,NACT,SIZE,
230          IATRK,COST,NELM,SMSI,SMSJ,PRIR)
231          INTEGER P,R,OLDI,OLDJ,SIZE(NACT),SMSI,SMSJ, ATRK(NELM,NELM)
232          I,COST(NACT,NACT),PRIR(NACT)
233          OLDJ = 0
234          DO 500 J = 1,NACT
235             P = 1

```

```

234      OLDI = 0
235      SMSJ = OLDJ + SIZE(J)
236      DO 530 I = 1, NACT
237      SMSI = OLDI + SIZE(I)
238      DO 510 K = P, SMSI
239      DO 510 L = R, SMSJ
240      IF (P.EQ. R) GO TO 515
241      ATRK(K,L)=COST(PRIR(I),PRIR(J))/(SIZE(I)*SIZE(J))
242      GO TO 510
243      515 ATRK(K,L) = 999
244      510 CONTINUE
245      P = SMSI + 1
246      OLDI = SMSI
247      530 CONTINUE
248      R = SMSJ + 1
249      OLDJ = SMSJ
250      500 CONTINUE
251      RETJRN
252      END

253      SUBROUTINE RSTRCT(NPRL,PRLC,ME,NELM,AKEL,ARNG,NEL,ATRK,PRCS,
IDUMY,NDMY,XRDN,YRDN)
254      INTEGER PRLC(20),ACSZ(90),AKEL(2,NELM),XRDN(90),YRDN(90),ARNG(NEL,
INEL),PRCS,ATRK(NELM,NELM)
255      INTEGER*2 DUMY
256      IF(NDMY.EQ.0) GO TO 651
257      READ,(XRDN(I),YRDN(I),I=1,NDMY)
258      DO 649 I = 1,NDMY
259      ARNG(XRDN(I),YRDN(I)) = DUMY
260      649 CONTINUE
261      651 IF(NPRL.EQ.0) GO TO 696
262      PRINT 650
263      650 FORMAT('1',12X,'ACTIVITIES TO BE PRE LOCATED IN PLAN TO COMPLY WIT
IH SITE LIMITATIONS AND CLIENT REQUIREMENTS.'/20X,'PRE LOCATED ACTI
IVITY',20X,'NUMBER OF ELEMENTS',20X,'RESERVED LOCATION')
264      DO 580 L = 1,NPRL
265      READ,PRLC(L),ACSZ(L)
266      PRINT 655,PRLC(L),ACSZ(L)
267      655 FORMAT('0',20X,I10,27X,I10)
268      DO 670 J = 1,NELM
269      IF(PRLC(L).NE.AKEL(2,J))GO TO 670
270      N = ACSZ(L)
271      READ,(XRDN(I),YRDN(I),I=1,N)
272      DO 661 I = 1,N
273      PRINT 660,XRDN(I),YRDN(I)
274      660 FORMAT(' ',100X,'ARNG(',I3,',',I3,')')
275      661 CONTINUE
276      DO 665 I =1,N
277      ARNG(XRDN(I),YRDN(I)) = AKEL(1,(J-1+I))
278      665 CONTINUE
279      GO TO 680
280      CONTINUE
281      680 CONTINUE
C THEN IT WILL COMPUTE THE COST OF COMMUNICATIONS BETWEEN PRE LOCATED ACTIVITIES
282      DO 695 L=1,NEL
283      DO 695 K=1,NEL
284      IF((ARNG(K,L).EQ.0).OR.(ARNG(K,L).EQ.DUMY)) GO TO 695
285      DO 685 J = 1,NELM
286      IF(ARNG(K,L).EQ.AKEL(1,J)) GO TO 686
287      685 CONTINUE

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288      GO TO 687
289      686  NAK = AKEL(2,J)
290      687  DO 590 N = 1,NEL
291          DO 590 M = 1,NEL
292          IF((ARNG(M,N).EQ.0).OR.(ARNG(M,N).EQ.DUMY)) GO TO 690
293          IF(AKEL(2,ARNG(M,N)).EQ.NAK) GO TO 690
294          PRCS=PRCS+ATRK(ARNG(K,L),ARNG(M,N))*IFIX(ABS(FLOAT(K-M))+
        IABS(FLOAT(L-N)))
295      690  CONTINUE
296      695  CONTINUE
297          PRCS = PRCS/2
298      696  ME = 1000
299          RETURN
300          END

301      SUBROUTINE ARANGE(TOTV,NELM,RSTR,NPRL,PRLC,AKEL,NEL,ARNG,ATRK,
302      INEL1,NEL2,SITE,STRW,ENRW,STCL,ENCL,LSRW,LNRW,LSCL,LNCL,FCAD,DUMY)
        INTEGER VALU,TOTV,RSTR,PRLC( 20 ),AKEL(2,NELM),ARNG(NEL,NEL),
        IATRK(NELM,NELM),ROW,COL,CNTR,SITE(NEL2,NEL2),STCL,ENCL,STRW,ENRW,
        IFCAD
303      INTEGER*2 DUMY
304      TOTV = 0
305      IF(NEL.LT.12) GO TO 752
306      CNTR = (NEL/2) - 2
307      GO TO 753
308      752  CNTR = NEL/2
309      753  DO 790 J= 1,NELM
310          MNVL = 1000000
311          IF(NPRL.EQ.0) GO TO 757
312          DO 755 N = 1,NPRL
313          IF(AKEL(2,J).EQ.PRLC(N)) GO TO 790
314      755  CONTINUE
315          GO TO 760
316      757  IF(J.NE.1) GO TO 760
317          ARNG(CNTR,CNTR)=AKEL(1,J)
318          GO TO 790
319      760  DO 780 L = 1,NEL
320          DO 780 K = 1,NEL
321          IF(ARNG(K,L) .NE. 0) GO TO 780
322          ARNG(K,L) = AKEL(1,J)
323          NAK = AKEL(2,J)
324          VALU = 0
325          NTVL = 0
326          DO 770 N=1,NEL
327          DO 770 M=1,NEL
328          IF((ARNG(M,N).EQ.0).OR.(ARNG(M,N).EQ.DUMY)) GO TO 770
329          VALU=VALU +ATRK(ARNG(K,L),ARNG(M,N))*IFIX(ABS(FLOAT(K-M))+
        IABS(FLOAT(L-N)))
        IF(AKEL(2,ARNG(M,N)).EQ.NAK) GO TO 770
        NTVL=NTVL+ATRK(ARNG(K,L),ARNG(M,N))*IFIX(ABS(FLOAT(K-M))+
        IABS(FLOAT(L-N)))
330      770  CONTINUE
331          IF(VALU .GT. MNVL) GO TO 775
332          MNVL = VALU
333          ROW = K
334          COL = L
335          NET = NTVL
336      775  ARNG(K,L) = 0
337      780  CONTINUE
338          ARNG(ROW,COL) = AKEL(1,J)
339
340

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341      TOTV = TOTV + NET
342      790 CONTINUE
      C THEN IT WILL LOCATE ACTIVITIES NUMBERS IN THE LARGER MATRIX "SITE"
343      DO 3 I = 1,NEL
344      DO 8 J = 1,NEL
345      IF(ARNG(I,J).EQ.0) GO TO 8
346      IF(ARNG(I,J).NE.DUMY) GO TO 3
347      SITE((I+1),(J+1)) = DUMY
348      GO TO 8
349      3 DO 4 K = 1,NELM
350      IF(ARNG(I,J).EQ.AKEL(1,K)) GO TO 6
351      4 CONTINUE
352      6 SITE((I+1),(J+1)) = AKEL(2,K)
353      8 CONTINUE
      C THEN IT WILL TRIM THE MATRIX "SITE" ACCORDING TO CONTOUR OF LOCATED ELEMENTS
354      DO 10 J = 2,NEL1
355      DO 10 I = 2,NEL1
356      IF((SITE(I,J).EQ.0).OR.(SITE(I,J).EQ.DUMY)) GO TO 10
357      STCL = J
358      GO TO 15
359      10 CONTINUE
360      15 DO 20 J = 2,NEL1
361      DO 20 I = 2,NEL1
362      IF((SITE(I,(NEL2-J+1)).EQ.0).OR.(SITE(I,(NEL2-J+1)).EQ.DUMY)) GO
      ITO 20
363      ENCL = NEL2 - J + 1
364      GO TO 25
365      20 CONTINUE
366      25 DO 30 I = 2,NEL1
367      DO 30 J = 2,NEL1
368      IF((SITE(I,J).EQ.0).OR.(SITE(I,J).EQ.DUMY)) GO TO 30
369      STRW = I
370      GO TO 35
371      30 CONTINUE
372      35 DO 40 I = 2,NEL1
373      DO 40 J = 2,NEL1
374      IF((SITE((NEL2-I+1),J).EQ.0).OR.(SITE((NEL2-I+1),J).EQ.DUMY)) GO
      ITO 40
375      ENRW = NEL2 - I + 1
376      GO TO 41
377      40 CONTINUE
378      41 LSCL = STCL - 1
379      LNCL = ENCL+1
380      LSRW = STRW-1
381      LNRW = ENRW+1
382      FCAD = LNCL - STCL +1
383      DO 42 J = 1,NEL
384      DO 42 I = 1,NEL
385      IF(ARNG(I,J).EQ.DUMY) ARNG(I,J) = 0
386      42 CONTINUE
387      RETURN
388      END

389      SUBROUTINE PLOTTER(STRW,STCL,LNRW,LNCL,SITE,WALL,HRZN,FCAD,SPMD,
INEL1,NEL2,PRTN,NACT,WRTN,NMBR,DUMY,PRLC,NPRL)
390      INTEGER STRW,STCL,SITE(NEL2,NEL2),WALL(NEL2,NEL2),FCAD,SCLE,
1DEMI/'HALF'/,UN/'ONE'/,SIDE,WRTN(NACT),NMBR(FCAD),SPMD,PRLC(20)
391      INTEGER*2 PLUS/'+'/,DASH/'-'/,EYE/'|'/,BLANK/' '/,HRZN(FCAD,2),
1PRTN(FCAD),DUMY
392      PRINT 50

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393 50  FORMAT('1')
394      KEPT = 1
395      DO 2000 I = STRW , LNRW
396      N = 1
397      DO 1000 J = STCL , LNCL
398      IF((SITE(I,J).NE.0).AND.(SITE(I,J).NE.DUMY)) GO TO 110
399      IF((SITE(I,(J-1)).NE.0).AND.(SITE(I,(J-1)).NE.DUMY)) GO TO 75
400      IF((SITE((I-1),J).EQ.0).OR.(SITE((I-1),J).EQ.DUMY)) GO TO 65
401 55  IF(WALL((I-1),J).GT.0) GO TO 95
402 60  HRZN(N,1) = DASH
403      HRZN(N,2) = DASH
404      N = N+1
405      GO TO 1000
406 65  IF(WALL((I-1),J).GT.0) GO TO 80
407      HRZN(N,1) = BLANK
408      HRZN(N,2) = BLANK
409 70  N = N+1
410      GO TO 1000
411 75  IF((SITE((I-1),J).EQ.0).OR.(SITE((I-1),J).EQ.DUMY)) GO TO 114
412      GO TO 95
413 77  IF(SITE(I,(J-1)).EQ.SITE((I-1),(J-1))) GO TO 88
414 80  HRZN(N,1) = PLUS
415      HRZN(N,2) = BLANK
416      N = N+1
417 85  IF(SITE(I,J).EQ.SITE(I,(J-1))) GO TO 1000
418      IF(((SITE(I,(J-1)).EQ.0).OR.(SITE(I,(J-1)).EQ.DUMY)).AND.
1((SITE(I,J).EQ.0).OR.(SITE(I,J).EQ.DUMY))) GO TO 1000
419      WALL(I,J) = 1
420      GO TO 1000
421 88  HRZN(N,1) = EYE
422      HRZN(N,2) = BLANK
423      N = N+1
424      WALL(I,J) = 1
425      GO TO 1000
426 95  HRZN(N,1) = PLUS
427      HRZN(N,2) = DASH
428      N = N+1
429      GO TO 85
430 105 IF(SITE(I,J).EQ.SITE((I-1),J)) GO TO 70
431      GO TO 60
432 110 IF((WALL((I-1),J).EQ.0).AND.(SITE(I,J).EQ.SITE(I,(J-1)))) GO TO
1105
433      IF(SITE(I,J).EQ.SITE(I,(J-1))) GO TO 111
434      IF(SITE(I,J).EQ.SITE((I-1),J)) GO TO 112
435      GO TO 95
436 111 IF(SITE(I,J).EQ.SITE((I-1),J)) GO TO 65
437      GO TO 55
438 112 IF(SITE(I,(J-1)).EQ.SITE((I-1),(J-1))) GO TO 88
439      IF((SITE(I,(J-1)).EQ.0).OR.(SITE(I,(J-1)).EQ.DUMY)) GO TO 113
440      GO TO 80
441 113 IF((SITE((I-1),(J-1)).EQ.0).OR.(SITE((I-1),(J-1)).EQ.DUMY)) GO
1TO 88
442      GO TO 80
443 114 IF((SITE((I-1),(J-1)).NE.0).AND.(SITE((I-1),(J-1)).NE.DUMY)) GO
1TO 77
444      GO TO 80
445 1000 CONTINUE
446      IF(FCAD.LE.11) GO TO 120
447      SCLE = DEMI
448      SIDE = 5

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449      GO TO 125
450 120   SCLE = UN
451      SIDE = 10
452 125   PRINT130,( HRZN(K,1),(HRZN(K,2),L=2,SIDE) ,K=1,FCAD)
453 130   FORMAT(' ',20X,110A1)
454      DO 135 K = 1,FCAD
455      DO 135 L = 1,2
456      HRZN(K,L) = BLANK
457 135   CONTINUE
458      N = 1
459      DO 151 J = STCL , LNCL
460      IF(WALL(I,J).EQ.0) GO TO 150
461      PRTN(N) = EYE
462      IF((SITE(I,J).EQ.0).OR.(SITE(I,J).EQ.DUMMY)) GO TO 150
463      DO 140 L = 1,KEPT
464      IF(WRTN(L).EQ.SITE(I,J)) GO TO 150
465 140   CONTINUE
466      NMBR(N) = SITE(I,J)
467      WRTN(KEPT) = SITE(I,J)
468      KEPT = KEPT +1
469 150   N = N+1
470 151   CONTINUE
471      IF(SCLE.EQ.DEMI) GO TO 180
472      PRINT160,(PRTN(N),N=1,FCAD)
473 160   FORMAT(' ',12X,11A10)
474      PRINT170,(NMBR(N),N=1,FCAD)
475 170   FORMAT('+',14X,11I10)
476      DO 176 K = 1,4
477      PRINT175,(PRTN(N),N=1,FCAD)
478 175   FORMAT(' ',12X,11A10)
479 176   CONTINUE
480      GO TO 205
481 180   PRINT181,(PRTN(N),N=1,FCAD)
482 181   FORMAT(' ',17X,22A5)
483      PRINT190,(NMBR(N),N=1,FCAD)
484 190   FORMAT('+',19X,22I5)
485      PRINT200,(PRTN(N),N=1,FCAD)
486 200   FORMAT(' ',17X,22A5)
487 205   DO 206 K = 1,FCAD
488      PRTN(K) = BLANK
489      NMBR(K) = 0
490 206   CONTINUE
491 2000  CONTINUE
492      PRINT 210, SCLE,IFIX(SORT(FLOAT(SPMD)))
*EXTENSION* OTHER COMPILERS MAY NOT ALLOW EXPRESSIONS IN OUTPUT LISTS
493 210   FORMAT('O',20X,'SCALE',18X,'::',A6,' INCH =',I5,' FEET')
494      RETURN
495      END

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\$ENTRY

SUM OF VISITS FROM EACH ACTIVITY TO ANY OTHER ACTIVITY

| | VISITED ACTIVITIES | | | | | | | | | | | | | | | | | | | |
|------------|--------------------|----|----|----|----|---|----|----|----|----|----|----|-----|----|-----|----|----|----|----|----|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| VISITOR 1 | 0 | 0 | 18 | 7 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 82 | 0 | 0 | | | | | |
| VISITOR 2 | 0 | 0 | 2 | 8 | 2 | 2 | 6 | 10 | 10 | 4 | 2 | 0 | 24 | 40 | 72 | | | | | |
| VISITOR 3 | 9 | 8 | 0 | 17 | 1 | 3 | 4 | 0 | 3 | 3 | 12 | 0 | 12 | 0 | 144 | | | | | |
| VISITOR 4 | 0 | 55 | 24 | 0 | 5 | 0 | 8 | 4 | 0 | 6 | 3 | 0 | 26 | 4 | 109 | | | | | |
| VISITOR 5 | 0 | 42 | 14 | 6 | 0 | 0 | 1 | 0 | 0 | 1 | 3 | 0 | 22 | 1 | 124 | | | | | |
| VISITOR 6 | 0 | 2 | 2 | 0 | 4 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 42 | | | | | |
| VISITOR 7 | 0 | 19 | 1 | 7 | 1 | 0 | 0 | 2 | 16 | 2 | 0 | 0 | 86 | 6 | 155 | | | | | |
| VISITOR 8 | 0 | 26 | 0 | 0 | 0 | 0 | 3 | 0 | 4 | 10 | 0 | 0 | 24 | 7 | 60 | | | | | |
| VISITOR 9 | 0 | 22 | 2 | 2 | 2 | 0 | 36 | 42 | 0 | 8 | 2 | 0 | 24 | 30 | 18 | | | | | |
| VISITOR 10 | 0 | 42 | 3 | 2 | 21 | 0 | 38 | 22 | 10 | 0 | 0 | 0 | 54 | 0 | 114 | | | | | |
| VISITOR 11 | 8 | 0 | 17 | 0 | 8 | 0 | 0 | 0 | 10 | 2 | 0 | 2 | 6 | 0 | 214 | | | | | |
| VISITOR 12 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 3 | 0 | 21 | | | | | |
| VISITOR 13 | 0 | 0 | 2 | 0 | 2 | 0 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | | | | | |
| VISITOR 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | |
| VISITOR 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 990 | 0 | 0 | | | | | |

RELATIVE COST OF COMMUNICATION BETWEEN ACTIVITIES
 REPRESENTED BY THE SUM OF VISITS MADE FROM AND RECEIVED BY
 EACH ACTIVITY TO AND FROM ANY OTHER ACTIVITY

| | NUMBER OF ACTIVITY | | | | | | | | | | | | | | | | | | | |
|------------|--------------------|----|-----|-----|-----|----|-----|----|----|-----|-----|----|-----|----|-----|----|----|----|----|----|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| ACTIVITY 1 | 0 | 0 | 27 | 7 | 0 | 0 | 0 | 3 | 0 | 0 | 8 | 0 | 82 | 0 | 0 | | | | | |
| ACTIVITY 2 | 0 | 0 | 10 | 63 | 44 | 4 | 25 | 36 | 32 | 46 | 2 | 3 | 24 | 40 | 72 | | | | | |
| ACTIVITY 3 | 27 | 10 | 0 | 41 | 15 | 5 | 5 | 0 | 5 | 6 | 29 | 0 | 14 | 0 | 144 | | | | | |
| ACTIVITY 4 | 7 | 63 | 41 | 0 | 11 | 0 | 15 | 4 | 2 | 8 | 3 | 0 | 26 | 4 | 109 | | | | | |
| ACTIVITY 5 | 0 | 44 | 15 | 11 | 0 | 4 | 2 | 0 | 2 | 22 | 11 | 0 | 24 | 1 | 124 | | | | | |
| ACTIVITY 6 | 0 | 4 | 5 | 0 | 4 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 42 | | | | | |
| ACTIVITY 7 | 0 | 25 | 5 | 15 | 2 | 0 | 0 | 5 | 52 | 40 | 0 | 0 | 90 | 6 | 155 | | | | | |
| ACTIVITY 8 | 3 | 36 | 0 | 4 | 0 | 0 | 5 | 0 | 46 | 32 | 0 | 0 | 26 | 7 | 60 | | | | | |
| ACTIVITY 9 | 0 | 32 | 5 | 2 | 2 | 0 | 52 | 46 | 0 | 18 | 12 | 0 | 24 | 30 | 18 | | | | | |
| ACTIVITY10 | 0 | 46 | 6 | 8 | 22 | 4 | 40 | 32 | 18 | 0 | 2 | 0 | 54 | 0 | 114 | | | | | |
| ACTIVITY11 | 8 | 2 | 29 | 3 | 11 | 0 | 0 | 0 | 12 | 2 | 0 | 9 | 6 | 0 | 214 | | | | | |
| ACTIVITY12 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 3 | 0 | 21 | | | | | |
| ACTIVITY13 | 82 | 24 | 14 | 26 | 24 | 0 | 90 | 26 | 24 | 54 | 6 | 3 | 0 | 0 | 992 | | | | | |
| ACTIVITY14 | 0 | 40 | 0 | 4 | 1 | 0 | 6 | 7 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | |
| ACTIVITY15 | 0 | 72 | 144 | 109 | 124 | 42 | 155 | 60 | 18 | 114 | 214 | 21 | 992 | 0 | 0 | | | | | |

TOTAL SUM OF RELATIVE COST OF COMMUNICATION FOR EACH ACTIVITY PRESENTED BY
 THE SUM OF VISITS MADE FROM AND RECEIVED BY ANY ACTIVITY TO AND FROM ALL OTHER ACTIVITIES

| | | | | | | | | | | | | | | | |
|----------|-----|-----|-----|-----|-----|----|-----|-----|-----|-----|-----|----|------|----|------|
| ACTIVITY | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| COST SUM | 127 | 401 | 301 | 293 | 260 | 59 | 395 | 219 | 241 | 346 | 296 | 36 | 1365 | 88 | 2065 |

ACTIVITIES ARRANGED IN A DESCENDING ORDER
 ACCORDING TO THE SUM OF THEIR RELATIVE COST OF COMMUNICATION

| | | | | | | | | | | | | | | | |
|----------|------|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|----|----|----|
| ACTIVITY | 15 | 13 | 2 | 7 | 10 | 3 | 11 | 4 | 5 | 9 | 8 | 1 | 14 | 6 | 12 |
| COST SUM | 2065 | 1365 | 401 | 395 | 346 | 301 | 296 | 293 | 260 | 241 | 219 | 127 | 88 | 59 | 36 |

ARRANGEMENT OF ACTIVITIES ACCORDING TO PRIORITY OF CONTACT

15 13 7 11 10 3 4 2 5 9 8 1 14 6 12

ARRANGEMENT OF SPACE ELEMENTS ACCORDING TO PRIORITY OF CONTACT

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|----------|----|----|----|----|----|----|----|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| ELEMENT | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
| ACTIVITY | 15 | 15 | 15 | 13 | 13 | 13 | 13 | 7 | 7 | 11 | 11 | 11 | 10 | 3 | 3 | 3 | 4 | 4 | 4 | 2 | 2 | 2 | 2 | 2 | 2 | 5 | 5 | 5 | 9 | 8 | 1 | 1 | 14 | 14 | 6 | 12 |

MATRIX OF FORCE OF ATTRACTION BETWEEN ELEMENTS , ARRANGED ACCORDING TO THE TOTAL COST OF ACTIVITIES

| | | |
|----------|--|--|
| ELMNT 1 | 99999999 | 82 82 82 82 25 25 23 23 23 38 16 16 16 12 12 12 4 4 4 4 4 4 13 13 13 6 20 0 0 0 0 14 7 |
| ELMNT 2 | 99999999 | 82 82 82 82 25 25 23 23 23 38 16 16 16 12 12 12 4 4 4 4 4 4 13 13 13 6 20 0 0 0 0 14 7 |
| ELMNT 3 | 99999999 | 82 82 82 82 25 25 23 23 23 38 16 16 16 12 12 12 4 4 4 4 4 4 13 13 13 6 20 0 0 0 0 14 7 |
| ELMNT 4 | 82 82 829999999999999 | 11 11 0 0 0 13 1 1 1 2 2 2 1 1 1 1 1 1 2 2 2 6 6 10 10 0 0 0 0 |
| ELMNT 5 | 82 82 829999999999999 | 11 11 0 0 0 13 1 1 1 2 2 2 1 1 1 1 1 1 2 2 2 6 6 10 10 0 0 0 0 |
| ELMNT 6 | 82 82 829999999999999 | 11 11 0 0 0 13 1 1 1 2 2 2 1 1 1 1 1 1 2 2 2 6 6 10 10 0 0 0 0 |
| ELMNT 7 | 82 82 829999999999999 | 11 11 0 0 0 13 1 1 1 2 2 2 1 1 1 1 1 1 2 2 2 6 6 10 10 0 0 0 0 |
| ELMNT 8 | 25 25 25 11 11 11 11999999 | 0 0 0 20 0 0 0 2 2 2 2 2 2 2 2 2 0 0 0 26 2 0 0 1 1 0 0 |
| ELMNT 9 | 25 25 25 11 11 11 11999999 | 0 0 0 20 0 0 0 2 2 2 2 2 2 2 2 2 0 0 0 26 2 0 0 1 1 0 0 |
| ELMNT 10 | 23 23 23 0 0 0 0 0 0999999999 | 0 3 3 3 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 4 0 1 1 0 0 0 3 |
| ELMNT 11 | 23 23 23 0 0 0 0 0 0999999999 | 0 3 3 3 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 4 0 1 1 0 0 0 3 |
| ELMNT 12 | 23 23 23 0 0 0 0 0 0999999999 | 0 3 3 3 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 4 0 1 1 0 0 0 3 |
| ELMNT 13 | 38 38 38 13 13 13 13 20 20 0 0 0999 | 2 2 2 2 2 2 7 7 7 7 7 7 7 7 7 7 18 32 0 0 0 0 4 0 |
| ELMNT 14 | 16 16 16 1 1 1 1 0 0 3 3 3 2999999999 | 4 4 4 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 0 4 4 0 0 1 0 |
| ELMNT 15 | 16 16 16 1 1 1 1 0 0 3 3 3 2999999999 | 4 4 4 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 0 4 4 0 0 1 0 |
| ELMNT 16 | 16 16 16 1 1 1 1 0 0 3 3 3 2999999999 | 4 4 4 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 0 4 4 0 0 1 0 |
| ELMNT 17 | 12 12 12 2 2 2 2 2 2 0 0 0 4999999999 | 3 3 3 3 3 3 1 1 1 0 1 1 1 0 0 0 0 |
| ELMNT 18 | 12 12 12 2 2 2 2 2 2 0 0 0 4999999999 | 3 3 3 3 3 3 1 1 1 0 1 1 1 0 0 0 0 |
| ELMNT 19 | 12 12 12 2 2 2 2 2 2 0 0 0 4999999999 | 3 3 3 3 3 3 1 1 1 0 1 1 1 0 0 0 0 |
| ELMNT 20 | 4 4 4 1 1 1 1 2 2 0 0 0 7 0 0 0 3 3 3999999999999999999 | 2 2 2 5 6 0 0 3 3 0 0 |
| ELMNT 21 | 4 4 4 1 1 1 1 2 2 0 0 0 7 0 0 0 3 3 3999999999999999999 | 2 2 2 5 6 0 0 3 3 0 0 |
| ELMNT 22 | 4 4 4 1 1 1 1 2 2 0 0 0 7 0 0 0 3 3 3999999999999999999 | 2 2 2 5 6 0 0 3 3 0 0 |
| ELMNT 23 | 4 4 4 1 1 1 1 2 2 0 0 0 7 0 0 0 3 3 3999999999999999999 | 2 2 2 5 6 0 0 3 3 0 0 |
| ELMNT 24 | 4 4 4 1 1 1 1 2 2 0 0 0 7 0 0 0 3 3 3999999999999999999 | 2 2 2 5 6 0 0 3 3 0 0 |
| ELMNT 25 | 4 4 4 1 1 1 1 2 2 0 0 0 7 0 0 0 3 3 3999999999999999999 | 2 2 2 5 6 0 0 3 3 0 0 |
| ELMNT 26 | 13 13 13 2 2 2 2 0 0 1 1 1 7 1 1 1 1 1 2 2 2 2 2 2999999999 | 0 0 0 0 0 0 1 0 |
| ELMNT 27 | 13 13 13 2 2 2 2 0 0 1 1 1 7 1 1 1 1 1 2 2 2 2 2 2999999999 | 0 0 0 0 0 0 1 0 |
| ELMNT 28 | 13 13 13 2 2 2 2 0 0 1 1 1 7 1 1 1 1 1 2 2 2 2 2 2999999999 | 0 0 0 0 0 0 1 0 |
| ELMNT 29 | 6 6 6 6 6 6 6 26 26 4 4 4 18 1 1 1 0 0 0 5 5 5 5 5 5 0 0 0999 46 0 0 15 15 0 0 | |

ACTIVITIES TO BE PRE LOCATED IN PLAN TO COMPLY WITH SITE LIMITATIONS AND CLIENT REQUIREMENTS

| PRE LOCATED ACTIVITY | NUMBER OF ELEMENTS | RESERVED LOCATION |
|----------------------|--------------------|--|
| 1 | 2 | ARNG(11, 4) ARNG(12, 4) |
| 2 | 6 | ARNG(11, 6) ARNG(11, 7) ARNG(11, 8) ARNG(12, 6) ARNG(12, 7) ARNG(12, 8) |
| 3 | 3 | ARNG(8, 6) ARNG(8, 7) ARNG(8, 8) |
| 4 | 3 | ARNG(9, 6) ARNG(9, 7) ARNG(9, 8) |
| 5 | 3 | ARNG(10, 6) ARNG(10, 7) ARNG(10, 8) |
| 6 | 1 | ARNG(8, 4) |
| 7 | 2 | ARNG(8, 5) ARNG(9, 5) |
| 8 | 1 | ARNG(9, 4) |
| 9 | 1 | ARNG(10, 5) |
| 10 | 1 | ARNG(10, 4) |
| 11 | 3 | ARNG(7, 2) ARNG(7, 3) ARNG(8, 3) |
| 12 | 1 | ARNG(8, 2) |
| 13 | 4 | ARNG(9, 2) ARNG(9, 3) ARNG(10, 2) ARNG(10, 3) |

14

2

ARNG(11, 5)
ARNG(12, 5)

15

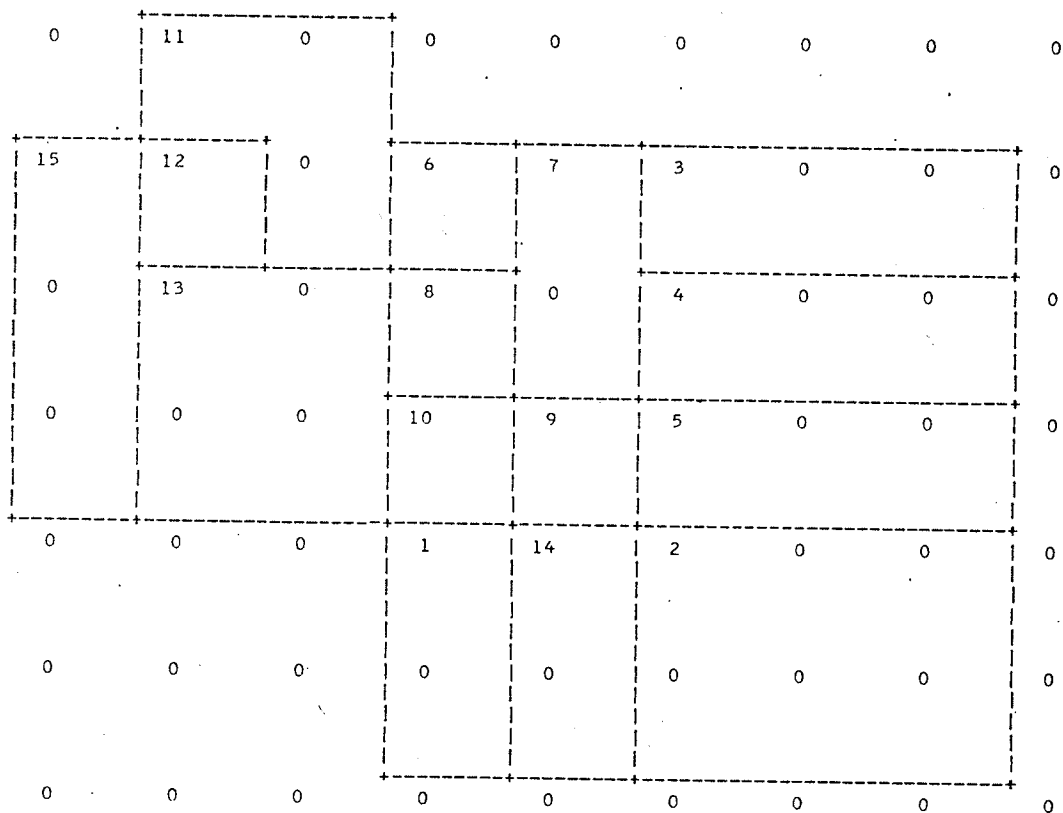
3

ARNG(8, 1)
ARNG(9, 1)
ARNG(10, 1)

RESTRICTIONS = 1
NUMBER OF PRELOCATED ACTIVITIES = 15
NUMBER OF DUMMY ELEMENTS = 82
PRELOCATED ACTIVITIES = 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

ARRANGEMENT OF MODULAR ELEMENTS THAT REPRESENTS THE MINIMUM COST OF COMMUNICATION BETWEEN ACTIVITIES

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|----|---|----|----|----|----|----|----|----|---|----|----|----|
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 10 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 1 | 36 | 12 | 35 | 8 | 14 | 15 | 16 | 0 | 0 | 0 | 0 |
| 9 | 2 | 4 | 5 | 30 | 9 | 17 | 18 | 19 | 0 | 0 | 0 | 0 |
| 10 | 3 | 6 | 7 | 13 | 29 | 26 | 27 | 28 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | 31 | 33 | 20 | 21 | 22 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | 32 | 34 | 23 | 24 | 25 | 0 | 0 | 0 | 0 |



SCALE : ONE INCH = 10 FEET

ANNUAL COST OF COMMUNICATION DUE TO PRE LOCATED ACTIVITIES = 3736 DOLLAR
 ANNUAL COST DUE TO COMPUTED ACTIVITIES = 0 DOLLAR
 ANNUAL TOTAL COST OF COMMUNICATION OF PLAN = 3736 DOLLAR
 ANNUAL COST PER SQUARE FOOT OF AREA CONSIDERED = 103 CENT

N.B. : THESE FIGURES DO NOT INCLUDE COST OF MOVEMENTS WITHIN EACH ACTIVITY

APPENDIX C

A complete set of tables of the movement pattern of each person are shown in the following tables. The sign (*) indicates the working station of the person involved.

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: 2
 PERSON: 2
 CATEGORY: 3

ACTIVITY: SAME
 PERSON: SAME
 CATEGORY: SAME

| Destination Point | Change of Direction Points |
|--|----------------------------|
| Date: Oct. 27, 70 Starting Time: 10.30 AM | |
| * | |
| 46 | 128-122-126 |
| 7 | 126-122 |
| 46 | 122-126 |
| 30 | 126-122-106 |
| * | 10 7 |
| 46 | 128-122-126 |
| 49 | 136 |
| * | 126-122-128 |
| 36 | 111-108-110 |
| * | 110-118-111 |
| 31 | |
| 35 | 10 7-109 |
| 33 | 109-108 |
| * | |
| 33 | |
| 28 | 106-105 |
| * | 105-106 |
| 43 | 10 6-128 |
| * | |
| 28 | 10 6-105 |
| 9 | 106-128 |
| * | 128-106 |
| End at: 12.00 Noon Time Recorded: 1.30 Hour | |

| Destination Point | Change of Direction Points |
|---|----------------------------|
| Date: SAM E Starting Time: 1.20 PM | |
| * | |
| 49 | 128-122-126 |
| * | 126-122-128 |
| 28 | 106-105 |
| * | 105-106-111 |
| 29 | 111-105 |
| 7 | 106-128-122 |
| * | 122-128 |
| 28 | 106-105 |
| 49 | 106-122-126 |
| * | 126-122-106 |
| 7 | 106-128-122 |
| 3 | 122-128 |
| 15 | 128-123 |
| 12 | 124-117 |
| * | 124-122-128 |
| 46 | 128-122-126 |
| * | |
| 46 | |
| * | |
| End at: 3.00 PM Time Recorded: 1.40 Hour | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: SAME

ACTIVITY: 2

PERSON: SAME

PERSON: 3

CATEGORY: SAME

CATEGORY: 3

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Nov. 2, 70 | |
| Starting Time: 2.00 PM | |
| * | |
| 3 | 106 |
| 35 | 107-109 |
| 28 | 109-107-105 |
| * | 105 |
| 28 | 105 |
| 49 | 105-128-136 |
| 28 | 136-128-105 |
| * | 105 |
| 46 | 102-122-136 |
| * | 136-122-102 |
| End at: 2.50 PM | |
| Time Recorded: 50 Minute | |

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Oct. 27, 70 | |
| Starting Time: 10.30 AM | |
| * | |
| 31 | |
| * | |
| 30 | 107 |
| 31 | |
| 35 | 107-108 |
| 17 | 107-128-122 |
| 35 | 122-128-107 |
| 30 | 109-107 |
| * | |
| 31 | |
| 38 | 109 |
| * | |
| 33 | 107-108 |
| * | |
| 14 | 128-122-124 |
| 31 | 124-122-128 |
| * | |
| End at: 12.00 Noon | |
| Time Recorded: 1.30 Hour | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: SAME

ACTIVITY: SAME

PERSON: SAME

PERSON: SAME

CATEGORY: SAME

CATEGORY: SAME

| Destination Point | Change of Direction Points |
|------------------------|----------------------------|
| Date: SAME | |
| Starting Time: 1.30 PM | |
| * | |
| 14 | 128-122-124 |
| 33 | 124-122-106 |
| 27 | 107-106-105 |
| 28 | |
| * | 105 |
| 28 | 105 |
| * | 105 |
| 49 | 128-122-126 |
| * | 126-122-128 |
| 16 | 128-122 |
| * | 122-128 |
| 11 | 128-122 |
| 5 | 121-116 |
| 22 | 116-118-126 |
| * | 126-122-128 |
| 16 | 128-122 |
| 14 | 124-125 |
| 18 | 125-124 |
| * | 124-128 |
| 7 | 128 |
| * | |
| 49 | 128-122-126 |
| * | 126-122-128 |
| 28 | 105 |
| 35 | 106-107 |
| 36 | 109-110 |
| * | 110-107 |
| 10 | 122-125-117 |
| 49 | 118-126 |
| End at: Cont. | |
| Time Recorded: Cont. | |

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: SAME | |
| Starting Time: SAME | |
| * | 126-122-128 |
| 12 | 128-121 |
| * | 121-128 |
| 2 | |
| 49 | 128-122-126 |
| 18 | 136-126 |
| * | 124-122-128 |
| 46 | 128-122-136 |
| 49 | 136 |
| * | 126-122-128 |
| 14 | 128-122-125 |
| * | |
| End at: 3.00 PM | |
| Time Recorded: 1.30 Hour | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: SAME

PERSON: SAME

CATEGORY: SAME

ACTIVITY: 3

PERSON: 4

CATEGORY: 1

| Destination Point | Change of Direction Points |
|--|----------------------------|
| Date: Nov. 2, 70 Starting Time: 1.20 PM | |
| * | |
| 33 | 107-108 |
| 34 | 108-109 |
| 46 | 107-122-136 |
| * | 136-122-106 |
| 46 | 128-122-126 |
| * | 136-122-106 |
| 49 | 106-122-136 |
| * | 136-122-106 |
| 32 | 107-108 |
| * | 108-107 |
| 31 | |
| * | |
| 28 | 105 |
| * | 105 |
| 46 | 128-122-126 |
| * | 126-122-128 |
| 28 | 105 |
| 46 | 106-122-136 |
| * | 136-122-106 |
| 49 | 106-122-136 |
| 46 | 136 |
| 49 | 136 |
| * | 128-122-126 |
| 28 | 105 |
| * | 105 |
| 16 | 106-128 |
| * | 128-106 |
| End at: 2.20PM Time Recorded: 1.00 Hour | |

| Destination Point | Change of Direction Points |
|--|----------------------------|
| Date: Oct. 26, 70 Starting Time: 10.45 AM | |
| * | |
| 5 | 112 |
| * | |
| 5 | 112 |
| * | |
| End at: 12.00 Noon Time Recorded: 1.15 Hour | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: SAME

PERSON: SAME

CATEGORY: SAME

ACTIVITY: SAME

PERSON: SAME

CATEGORY: SAM E

| Destination Point | Change of Direction Points |
|--|--|
| Date: SAME Starting Time: 1.15 PM | |
| * 6 * 16 * 5 * 5 * 13 49 * 5 * 49 46 * 49 | 115-120 120-115 116-122 122-116 112 112 115-116 116-122-126 126-122-116 112 116-122-116 136 126-122-116 116-122-126 |
| End at: 3.00 PM Time Recorded: 1.45 Hours | |

| Destination Point | Change of Direction Points |
|---|--|
| Date: Oct. 27, 70 Starting Time: 10.15 AM | |
| * 49 * 2 5 * 22 49 * 18 * | 116-122-126 126-122-116 116-122-128 128-122-116 116-122-136 136 126-122-116 116-122-124 |
| End at: 12.00 Noon Time Recorded: 1.45 Hours | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: SAME
 PERSON: SAME
 CATEGORY: SAME

ACTIVITY:3
 PERSON: 5
 CATEGORY:3

| Destination Point | Change of Direction Points |
|---------------------------|----------------------------|
| Date: SAME | |
| Starting Time: 1.20 PM | |
| * | |
| 49 | 116-122-136 |
| * | 136-122-116 |
| 10 | 115-118 |
| * | 118-115 |
| 1 | 122-126-101 |
| 6 | 126-120 |
| * | 120-115 |
| 5 | |
| * | |
| 49 | 116-122-136 |
| End at: 1.50 | |
| Time Recorded: .30 Minute | |

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Oct. 26, 70 | |
| Starting Time: 10.45 AM | |
| * | |
| 3 | 116-122-128 |
| * | 128-122-116 |
| 49 | 116-122-136 |
| * | 136-122-116 |
| 3 | 116-122-128 |
| 49 | 116-122-136 |
| * | 136-122-116 |
| 4 | |
| * | |
| 1 | 122-106-104 |
| * | 10 4-106-122 |
| End at: 12.00 Noon | |
| Time Recorded: 1.15 Hour | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: SAME

ACTIVITY: SAME

PERSON: SAME

PERSON: SAME

CATEGORY: SAME

CATEGORY: SAME

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: SAME | |
| Starting Time: 1.15 P M | |
| * | |
| 49 | 116-122-136 |
| * | 136-122-116 |
| 49 | 116-122-136 |
| * | 136-122-116 |
| 4 | |
| * | |
| 8 | 116-122-128 |
| 22 | 128-124-136 |
| * | 126-122-116 |
| 6 | 115-120 |
| * | 120-115 |
| 4 | |
| 46 | 116-122-136 |
| * | 136-122-116 |
| 49 | 116-122-136 |
| 1 | 136-101-102 |
| * | 101-126-122 |
| 4 | |
| * | |
| 4 | |
| * | |
| 22 | 116-122-136 |
| * | 136-122-116 |
| 6 | 115-120- |
| 3 | 120-122-128 |
| 49 | 128-122-136 |
| * | 136-122-116 |
| 4 | |
| 49 | 116-122-136 |
| End at: 3.00 PM | |
| Time Recorded: 1.45 Hour | |

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Oct.27, 70 | |
| Starting Time: 10.15 AM | |
| * | |
| 4 | |
| * | |
| 49 | 116-122-136 |
| * | 136-122-116 |
| 4 | |
| 49 | 116-122-136 |
| * | 136-122-116 |
| 46 | 116-122-136 |
| * | 136-122-116 |
| 49 | 116-122-136 |
| End at: 12.00 Noon | |
| Time Recorded: 1.45 Hour | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: SAME

PERSON: SAME

CATEGORY: SAME

ACTIVITY: 4

PERSON: 6

CATEGORY: 2

| Destination Point | Change of Direction Points |
|--|---|
| Date: SAME | |
| Starting Time: 1.15 PM | |
| * 6 49 * 4 * 11 49 22 46 * 4 * 22 * 49 * 4 * 4 33 * | 115-120 120-122-136 136-122-116 116-121 122-136 136 136 136-122-116 116-122-136 136-122-116 116-122-136 136-122-116 116-122-128 |
| End at: 3.00 PM | |
| Time Recorded: 1.45 Hour | |

| Destination Point | Change of Direction Points |
|--|---|
| Date: Oct. 27, 70 | |
| Starting Time: 10.20 AM | |
| * 7 49 * 49 * 7 22 * 49 * 49 * 49 * 49 * 49 | 113-120 120-122-136 136-122-120 120-122-136 136-122-120 113-120 120-122-136 136-122-120 120-122-136 136-122-120 120-122-136 136-122-120 120-122-136 136-122-120 120-122-136 |
| End at: 11.20 PM | |
| Time Recorded: 1.00 Hour | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: SAME

ACTIVITY: SAME

PERSON: SAME

PERSON: SAME

CATEGORY: SAME

CATEGORY: SAME

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: SAME | |
| Starting Time: 1.20 PM | |
| * | |
| 49 | 120-122-136 |
| * | 136-122-120 |
| 7 | 113-120 |
| * | 120-113 |
| 7 | 113-120 |
| 2 | 122-128 |
| 31 | |
| * | 128-122 |
| 7 | 113-120 |
| 4 | 120-115 |
| * | 115-120 |
| 33 | 120-122-106 |
| * | 106-122-120 |
| 5 | 120-115 |
| 7 | |
| * | |
| 49 | 120-122-136 |
| * | |
| 49 | |
| End at: 2.30 PM | |
| Time Recorded: 1.10 Hour | |

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Nov. 2, 70 | |
| Starting Time: 1.40 PM | |
| * | |
| 49 | 120-122-136 |
| 3 | 136-122-128 |
| * | 128-120 |
| 36 | 120-128-106 |
| * | 106-128-120 |
| 5 | 120-115 |
| * | 115-120 |
| 8 | 120-122-127 |
| * | 127-122-120 |
| 46 | 120-122-136 |
| * | 136-122-120 |
| 49 | 120-122-136 |
| * | 136-122-120 |
| 7 | 113-120 |
| 22 | 120-122-136 |
| 7 | 136-122-120 |
| 9 | 122 |
| * | 122 |
| 49 | 120-122-136 |
| * | 136-122-120 |
| 46 | 120-122-136 |
| * | 136-122-120 |
| 7 | 113-120 |
| * | 120-113- |
| 49 | 120-122-136 |
| * | 136-122-120 |
| 5 | 120-115 |
| 35 | 116-122-128 |
| * | 106-122-120 |
| End at: 3.30 PM | |
| Time Recorded: 1.50 Hour | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: 4

PERSON: 7

CATEGORY: 3

ACTIVITY: SAME

PERSON: SAME

CATEGORY: SAME

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Oct. 27, 70 | |
| Starting Time: 10.20 AM | |
| * | |
| 46 | 122-126 |
| * | 126-122 |
| 33 | 122-128 |
| * | 128-122 |
| 3 | 122-128 |
| * | |
| 46 | 122-126 |
| * | 126-122 |
| 6 | |
| * | |
| 6 | |
| * | |
| 5 | 120-115 |
| * | 115-120 |
| 35 | 122-128-107 |
| * | 107-128-122 |
| 35 | 122-128-107 |
| * | 107-128-122 |
| 33 | 122-128-111 |
| * | 111-128-122 |
| 5 | 120-115 |
| 37 | 122-128-111 |
| * | 111-128-122 |
| End at: 12.00 Noon | |
| Time Recorded: 1.40 Hour | |

| Destination Point | Change of Direction Points |
|------------------------|----------------------------|
| Date: SAME | |
| Starting Time: 1.20 PM | |
| * | |
| 6 | 120 |
| * | |
| 6 | 120 |
| * | |
| 6 | 120 |
| * | |
| 5 | 120-115 |
| 18 | 122-124 |
| * | 124-122 |
| 32 | 122-128 |
| 28 | 111-105 |
| 33 | 105-111 |
| * | 106-128-122 |
| 15 | 122-124 |
| 33 | 124-128-111 |
| 15 | 111-128-124 |
| 33 | 124-128-111 |
| * | 106-128-122 |
| 33 | 122-128-111 |
| 28 | 111-105 |
| * | 106-128-122 |
| 35 | 122-128-107 |
| 18 | 107-128-122 |
| 35 | 122-128-107 |
| 28 | 107-105- |
| 18 | 106-128-124 |
| * | 124-122 |
| 28 | 122-128-105 |
| 3 | 105 |
| End at: Cont. | |
| Time Recorded: Cont. | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: SAME

ACTIVITY: SAME

PERSON: SAME

PERSON: SAME

CATEGORY: SAME

CATEGORY: SAME

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: SAME | |
| Starting Time: SAME | |
| 28 | 105 |
| * | 106-128-122 |
| 35 | 122-128-107 |
| * | 107-128-122 |
| 46 | 122-126 |
| * | 126-122 |
| 49 | 122-126-136 |
| * | 136-126-122 |
| End at: 3.00 PM | |
| Time Recorded: 1.40 Hour | |

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Nov. 2, 70 | |
| Starting Time: 1.15 PM | |
| * | |
| 46 | 122-126 |
| 13 | 121 |
| 46 | 122-126 |
| 6 | 126-122-120 |
| 46 | 120-122-126 |
| * | 126-122 |
| 28 | 122-128-106 |
| 3 | 105 |
| * | 106-128-122 |
| 6 | 120 |
| * | 120 |
| 6 | 120 |
| * | 120 |
| 8 | 122-128-127 |
| * | 127-128-127 |
| 3 | 122-128-106 |
| 28 | 105 |
| 3 | 105 |
| * | 106-128-122 |
| 46 | 122-126 |
| 12 | 136-124-117 |
| 11 | 125 |
| * | 124-122 |
| 11 | 122-123 |
| * | 123-122 |
| 6 | 120 |
| 46 | 122-136 |
| 6 | 136-122 |
| * | 120 |
| 46 | 122-126 |
| End at: 1.55 PM | |
| Time Recorded: 40 Minute | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: 5

PERSON: 9

CATEGORY: 3

ACTIVITY: SAME

PERSON: SAME

CATEGORY: SAME

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Oct. 26, 70 | |
| Starting Time: 10.45 AM | |
| * | |
| 35 | 128-107 |
| * | 107-128 |
| 49 | 122-136 |
| 30 | 136-122-106 |
| * | 106-128 |
| 46 | 122-136 |
| * | 136-122 |
| 46 | 122-136 |
| * | 136-122 |
| * | 128-106 |
| 3 | 106-128 |
| * | 120 |
| 6 | 120-136 |
| 46 | 136-122-106 |
| 35 | 107-128 |
| * | 128-107 |
| 35 | 107-128 |
| * | |
| End at: 12.00 Noon | |
| Time Recorded: 1.15 Hour | |

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: SAME | |
| Starting Time: 1.15 PM | |
| * | |
| 6 | 120 |
| * | 120 |
| 5 | 120-115 |
| 34 | 120-122-128 |
| * | 107-128 |
| 37 | 128-106-111 |
| * | 106-128 |
| 28 | 128-106-105 |
| * | 106-128 |
| 36 | 106-128 |
| 38 | 128-107 |
| * | |
| 35 | 107-128 |
| * | 128-107 |
| 2 | 107-128 |
| * | 128 |
| 36 | 128 |
| * | 128-107-110 |
| 35 | 110-107-128 |
| * | 128-107-109 |
| 36 | 109-107-128 |
| * | 128-107-110 |
| 36 | 128-107-110 |
| * | 110-107-128 |
| End at: 3.00 PM | |
| Time Recorded: 1.45 Hour | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: SAME

ACTIVITY: 6

PERSON: SAME

PERSON: 10

CATEGORY: SAME

CATEGORY: 3

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Oct.27,70 | |
| Starting Time: 11.00 AM | |
| * | |
| 8 | 127 |
| * | 127 |
| 5 | 120-115 |
| * | 115-120 |
| 46 | 122-136 |
| * | 136-122 |
| 35 | 128-106 |
| * | 106-128 |
| 35 | 128-106 |
| * | 106-128 |
| 8 | 127 |
| * | 127 |
| 35 | 128-106 |
| 6 | 106-128 |
| * | 120 |
| End at: 12.00 Noon | |
| Time Recorded: 1.00 Hour | |

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Oct.27,70 | |
| Starting Time: 10.20 AM | |
| * | |
| 49 | 118-126-136 |
| * | 136-126-118 |
| 8 | 117-124-128 |
| * | 128-124-117 |
| 5 | 118-116 |
| * | 116-118 |
| 2 | 117-124-128 |
| * | 128-124-117 |
| 49 | 118-126-136 |
| * | 136-126-118 |
| 49 | 118-126-136 |
| * | 136-126-118 |
| End at: 12.00 Noon | |
| Time Recorded: 1.40 Hour | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: SAME

ACTIVITY: 7

PERSON: SAME

PERSON: 11

CATEGORY: SAME

CATEGORY: 2

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: SAME | |
| Starting Time: 1.20 PM | |
| * | |
| 49 | 118-126-136 |
| * | 136-126-118 |
| 49 | 118-126-136 |
| * | 136-126-118 |
| 18 | 118-126- |
| 8 | 122-127 |
| * | 122-124-117 |
| 8 | 117-124-128 |
| * | 128-124-117 |
| 49 | 118-126-136 |
| * | 136-126-118 |
| 49 | 118-126-136 |
| * | 136-136-118 |
| 18 | 126-118 |
| End at: 3.40 PM | |
| Time Recorded: 2.20 Hour | |

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Oct.2670 | |
| Starting Time: 10.45 AM | |
| * | |
| 12 | 121-116 |
| 46 | 122-126-136 |
| * | 136-123 |
| 46 | 123-136 |
| * | 136-123 |
| 49 | 123-136 |
| 12 | 136-124-117 |
| 49 | 117-124-136 |
| * | 136-123 |
| 46 | 123-136 |
| * | 136-123 |
| 13 | |
| * | |
| 49 | 123-136 |
| * | 136-123 |
| 2 | 136-122-128 |
| 49 | 128-122-136 |
| 12 | 136-124-117 |
| 46 | 117-124-136 |
| * | 136-123 |
| End at: 12.00 Noon | |
| Time Recorded: 1.15 Hour | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: SAME

ACTIVITY: SAME

PERSON: SAME

PERSON: SAME

CATEGORY: SAME

CATEGORY: SAME

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: SAME | |
| Starting Time: 1.20 PM | |
| * | |
| 46 | 123-136 |
| * | 136-123 |
| 46 | 123-136 |
| 12 | 136-124-117 |
| 46 | 117-124-136 |
| * | 136-123 |
| 46 | 123-136 |
| * | 136-123 |
| 3 | 136-122-128 |
| * | 128-122 |
| 46 | 123-136 |
| * | 136-123 |
| 46 | 123-136 |
| * | 136-123 |
| 13 | |
| 12 | 116 |
| 46 | 117-124-136 |
| * | 136-123 |
| 13 | |
| * | |
| 13 | |
| 12 | 116 |
| 46 | 117-124-136 |
| * | 136-123 |
| 46 | 123-136 |
| * | 136-123 |
| 46 | 123-136 |
| * | 136-123 |
| 12 | 121-116 |
| * | 116-121 |
| End at: 3.00 PM | |
| Time Recorded: 1.40 HOUR | |

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Oct. 27, 70 | |
| Starting Time: 10.50 AM | |
| * | |
| 4 | 116-115 |
| * | 115-116 |
| 49 | 123-136 |
| * | 136-123 |
| 46 | 123-136 |
| 49 | 136 |
| * | 136-123 |
| 12 | 121-116 |
| * | 116-121 |
| 40 | 116-117 |
| * | 117-116 |
| 46 | 123-136 |
| * | 136-123 |
| 49 | 123-136 |
| * | 136-123 |
| 12 | 121-116 |
| * | 116-121 |
| 49 | 123-136 |
| * | 136-123 |
| 12 | 121-116 |
| 46 | 124-136 |
| * | 136-123 |
| 46 | 123-136 |
| * | 136-123 |
| 46 | 123-136 |
| * | 136-123 |
| End at: 12.00 Noon | |
| Time Recorded: 1.10 Hour | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: SAME

ACTIVITY: 7

PERSON: SAME

PERSON: 12

CATEGORY: SAME

CATEGORY: 3

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: SAME | |
| Starting Time: 1.20 PM | |
| * | |
| 46 | 123-136 |
| * | 136-123 |
| 49 | 123-136 |
| * | 136-123 |
| 12 | 121-116 |
| * | 116-121 |
| 12 | 121-116 |
| * | 116-121 |
| 3 | 136-122-128 |
| * | 128-122 |
| 46 | 123-136 |
| * | 136-123 |
| 49 | 123-136 |
| * | 136-123 |
| 46 | 123-136 |
| * | 136-123 |
| 49 | 123-136 |
| * | 136-123 |
| 46 | 123-136 |
| * | 136-123 |
| 49 | 123-136 |
| * | 136-123 |
| 46 | 123-136 |
| * | 136-123 |
| 49 | 123-136 |
| * | 136-123 |
| 3 | 136-122-128 |
| 49 | 128-122-136 |
| * | 136-122-128 |
| End at: 3.00 P M | |
| Time Recorded: 1.40 Hour | |

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Oct.20,70 | |
| Starting Time: 2.00 P M | |
| * | |
| 46 | 117-124-136 |
| * | 136-124-117 |
| 46 | 117-124-136 |
| * | 136-124-117 |
| 46 | 117-124-136 |
| * | 136-124-117 |
| 46 | 117-124-136 |
| * | 136-124-117 |
| 46 | 117-124-136 |
| 13 | 136-124 |
| 46 | 121-122-136 |
| 49 | 136- |
| 46 | 136 |
| * | 136-124-117 |
| 45 | 116-122-128 |
| 46 | 128-122-136 |
| * | 117-124-136 |
| 19 | 119-124-126 |
| 46 | 126-136- |
| * | 117-124-136 |
| 46 | 136-124-136 |
| * | 117-124-136 |
| 49 | 117-124-136 |
| * | 136-124-117 |
| 11 | 116-121 |
| * | 121-116 |
| 46 | 117-124-136 |
| * | 136-124-117 |
| 11 | 116-121 |
| * | 121-116 |
| End at: 3.00 PM | |
| Time Recorded: 1.00 Hour | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: SAME

ACTIVITY: SAME

PERSON: SAME

PERSON: SAME

CATEGORY: SAME

CATEGORY: SAME

| Destination Point | Change of Direction Points |
|------------------------|----------------------------|
| Date: Nov. 2, 70 | |
| Starting Time: 1.00 PM | |
| * | |
| 11 | 116-121 |
| * | 121-116 |
| 46 | 117-124-136 |
| * | 136-124-117 |
| 3 | 116-122-128 |
| * | 128-122-116 |
| 46 | 117-124-136 |
| * | 136-124-117 |
| 11 | 116-121- |
| * | 121-116 |
| 13 | 116 |
| * | 116 |
| 46 | 117-124-136 |
| * | 136-124-117 |
| 46 | 117-124-136 |
| 43 | 136-122-128 |
| 46 | 128-122-136 |
| * | 136-124-117 |
| 46 | 117-124-136 |
| * | 136-124-117 |
| 11 | 116-121 |
| 49 | 123-136 |
| 43 | 136-122-128 |
| * | 128-122-116 |
| 46 | 117-124-136 |
| * | 136-124-117 |
| 46 | 117-124-136 |
| * | 136-124-117 |
| 46 | 117-124-136 |
| End at: Cont | |
| Time Recorded: Cont. | |

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: SAME | |
| Starting Time: SAME | |
| 11 | 136-123 |
| * | 122-116 |
| 46 | 117-124-136 |
| * | 136-124-117 |
| 46 | 117-124-136 |
| * | 136-124-117 |
| 43 | 116-122-128 |
| * | 128-122-116 |
| 46 | 117-124-136 |
| * | 136-124-117 |
| 13 | 116 |
| * | 116 |
| 45 | 116-122-128 |
| * | 128-122-116 |
| 46 | 117-124-136 |
| * | 136-124-117 |
| 46 | 117-124-136 |
| * | 136-124-117 |
| End at: 4.00 PM | |
| Time Recorded: 3.00 Hour | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: 7

PERSON: 13

CATEGORY: 3

ACTIVITY: SAME

PERSON: SAME

CATEGORY: SAME

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Oct. 26, 70 | |
| Starting Time: 10.00AM | |
| * | |
| 49 | 122-136 |
| * | 136-122 |
| 12 | 116 |
| * | 116 |
| 49 | 122-136 |
| * | 136-122 |
| 34 | 122-128-107 |
| * | 107-128-122 |
| 12 | 116 |
| * | 116 |
| 12 | 116 |
| * | 116 |
| 28 | 122-128-105 |
| * | 105-128-122 |
| 12 | 116 |
| * | 116 |
| 14 | 116-117 |
| * | 117-116 |
| 46 | 122-136 |
| * | 136-122 |
| 12 | 116- |
| * | 116 |
| 12 | 116 |
| * | 116 |
| 12 | 116 |
| * | 116 |
| 17 | 122-124 |
| * | 124-122 |
| End at: 12.00 Noon | |
| Time Recorded: 2.00 Hour | |

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Nov. 2, 70 | |
| Starting Time: 1.15 PM | |
| * | |
| 16 | 122-123 |
| * | 123-122 |
| 16 | 122-123 |
| 46 | 124-136 |
| * | 136-124 |
| 40 | 116-117 |
| * | 117-116 |
| 49 | 124-136 |
| * | 136-124 |
| 46 | 122-136 |
| * | 136-122 |
| 49 | 122-136 |
| * | 136-122 |
| 28 | 122-128-106 |
| * | 106-128-122 |
| 12 | 116 |
| * | 116 |
| 7 | 121 |
| * | 121 |
| 6 | 121-120 |
| * | 120-121 |
| 28 | 122-128-106 |
| * | 106-128-122 |
| End at: 3.15 PM | |
| Time Recorded: 2.00 Hour | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: 8

PERSON: 14

CATEGORY: 3

ACTIVITY: SAME

PERSON: SAME

CATEGORY: SAME

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Oct. 22, 70 | |
| Starting Time: 10.45 AM | |
| * | |
| 49 | 124-136 |
| * | 136-124 |
| 2 | 124-122-128 |
| * | 128-122-124 |
| 3 | 124-122-128 |
| * | 128-122-124 |
| 15 | |
| 2 | 124-122-128 |
| * | 128-122-124 |
| 18 | 125-124 |
| * | 124-125 |
| 15 | |
| * | |
| 49 | 124-136 |
| * | 136-124 |
| 46 | 124-136 |
| * | 136-124 |
| 46 | 124-136 |
| * | 136-124 |
| 46 | 124-136 |
| * | 136-124 |
| 3 | 124-122-128 |
| * | 128-122-124 |
| 49 | 124-136 |
| * | 136-124 |
| End at: 12.00 Noon | |
| Time Recorded: 1.15 Hour | |

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Oct. 27, 70 | |
| Starting Time: 1.20 PM | |
| * | |
| 3 | 124-122-128 |
| * | 128-122-124 |
| 46 | 124-136 |
| * | 136-124 |
| 18 | 125-124 |
| * | 124-125 |
| 18 | 125-124 |
| * | 124-125 |
| 41 | 117-118 |
| * | 118-117 |
| 28 | 124-128-105 |
| * | 105-128-124 |
| 49 | 124-136 |
| * | 136-124 |
| 28 | 124-128-10 5 |
| * | 105-128-124 |
| 18 | 125-124 |
| 49 | 126-136 |
| * | 136-124 |
| 49 | 124-136 |
| * | 136-124 |
| 33 | 124-122-128 |
| * | 128-122-124 |
| 41 | 117-118 |
| * | 118-117 |
| End at: 3.30 PM | |
| Time Recorded: 2.10 Hour | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: SAME

PERSON: SAME

CATEGORY: SAME

ACTIVITY: 8

PERSON: 15

CATEGORY: 3

| Destination Point | Change of Direction Points |
|---------------------------|----------------------------|
| Date: Nov. 2, 70 | |
| Starting Time: 1.20 PM | |
| * | |
| 40 | 117 |
| * | 117 |
| 18 | 125-124 |
| * | 124-125 |
| 46 | 124-136 |
| * | 136-124 |
| 3 | 124-122-128 |
| * | 128-122-124 |
| 3 | 124-122-128 |
| * | 128-122-124 |
| 34 | 124-122-128 |
| * | 128-122-124 |
| 18 | 125-124 |
| * | 124-125 |
| 43 | 124-122-128 |
| * | 128-122-124 |
| 46 | 124-136 |
| * | 136-124 |
| 40 | 117 |
| * | 117 |
| 41 | 117-118 |
| * | 118-117 |
| 27 | 124-128-105 |
| * | 105-128-124 |
| 49 | 124-136 |
| * | 136-124 |
| End at: 1.55 PM | |
| Time Recorded: 35. Minute | |

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Oct. 22, 70 | |
| Starting Time: 10 AM | |
| * | |
| 49 | 124-136 |
| 14 | 136-124-125 |
| * | |
| 46 | 124-136 |
| * | 136-124 |
| 46 | 124-136 |
| * | 136-124 |
| 34 | 124-122-128 |
| * | 128-122-124 |
| 28 | 124-122-10 6 |
| 16 | 106-122-123 |
| * | 124 |
| 46 | 124-136 |
| * | 136-124 |
| 14 | |
| 46 | 124-136 |
| * | 136-124 |
| 14 | |
| * | |
| 3 | 124-122-128 |
| 36 | 107-110 |
| 34 | 110-109 |
| * | 106-128-122 |
| 14 | |
| * | |
| 35 | 124-122-128 |
| * | 128-122-124 |
| 49 | 124-136 |
| * | 136-124 |
| End at: 12.00 Noon | |
| Time Recorded: 2.00 Hour | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: SAME

ACTIVITY: 9

PERSON: SAME

PERSON: 16

CATEGORY: SAME

CATEGORY: 3

| Destination Point | Change of Direction Points |
|---|----------------------------|
| Date: Nov. 2, 70 Starting Time: 1.20 PM | |
| * | |
| 49 | 124-136 |
| * | 136-124 |
| 34 | 124-122-128 |
| * | 128-122-124 |
| 49 | 124-136 |
| * | 136-124 |
| 14 | |
| * | |
| 49 | 124-136 |
| * | 136-124 |
| 33 | 124-122-128 |
| * | 128-122-124 |
| 42 | 124 |
| * | 124 |
| 42 | 124 |
| * | 124 |
| 46 | 124-136 |
| * | 136-124 |
| 46 | 124-136 |
| * | 136-124 |
| 46 | 124-136 |
| * | 136-124 |
| End at: 3.20 PM Time Recorded: 2.00 Hour | |

| Destination Point | Change of Direction Points |
|--|----------------------------|
| Date: Oct. 20, 70 Starting Time: 11.00 AM | |
| * | |
| 46 | 124-126 |
| * | |
| 28 | 128-106-105 |
| 46 | 106-128-126 |
| 40 | 126-125 |
| 41 | 118- |
| 20 | 125-124 |
| 41 | 118 |
| 20 | 126 |
| 28 | 122-128 |
| 45 | 106 |
| * | 128 |
| 40 | 124-117 |
| * | |
| 41 | 124-117-118 |
| * | |
| 41 | 124-117-118 |
| * | |
| 40 | 124-117 |
| * | |
| 28 | 128-107 |
| * | |
| 14 | 124-125 |
| * | |
| 43 | |
| 44 | |
| 17 | 123 |
| 43 | |
| 29 | 106 |
| End at: Cont. Time Recorded: Cont. | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: SAME

ACTIVITY: SAME

PERSON: SAME

PERSON: SAME

CATEGORY: SAME

CATEGORY: SAME

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: SAME | |
| Starting Time: SAME | |
| 44 | 106-128 |
| * | |
| 45 | 124-136 |
| 41 | 126 |
| 18 | 126 |
| 40 | 124-117 |
| 41 | 118-125 |
| * | |
| 40 | |
| 41 | |
| * | 126-124 |
| 43 | |
| * | |
| 43 | |
| * | |
| 22 | 124-136 |
| * | |
| 40 | 124-117 |
| 41 | |
| 28 | 126-122-106 |
| 45 | 106 |
| * | |
| 40 | 124-117 |
| 41 | |
| * | |
| 28 | 128-106 |
| * | |
| 40 | 124-117 |
| 43 | 117-124-122 |
| * | |
| End at: 12.00 Noon | |
| Time Recorded: 1.00 Hour | |

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Oct. 20, 70 | |
| Starting Time: 1.00 PM | |
| * | |
| 43 | |
| * | |
| 43 | |
| * | |
| 14 | 124-125 |
| * | |
| 14 | 124-125 |
| 18 | 124 |
| 45 | 122 |
| * | |
| 40 | 124-117 |
| * | |
| 28 | 128-106 |
| * | |
| 3 | 128-106 |
| * | 106-128 |
| 44 | |
| 46 | 124-126 |
| * | 126-124 |
| 14 | 124-125 |
| * | 125-124 |
| 46 | 124-126 |
| * | 126-124 |
| 33 | 122-128 |
| 43 | 107-128 |
| * | |
| 44 | |
| * | |
| 46 | 124-126 |
| End at: 3.00 PM | |
| Time Recorded: 2.00 Hour | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: SAME

ACTIVITY: 9

PERSON: SAME

PERSON: 17

CATEGORY: SAME

CATEGORY: 3

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Nov. 2, 70 | |
| Starting Time: 1.15 PM | |
| * | |
| 44 | 123 |
| 43 | 128 |
| * | |
| 44 | 123 |
| 46 | 122-126 |
| 7 | 126-122 |
| * | 122-123 |
| 28 | 128-106 |
| 45 | 106-128 |
| 13 | 128-122-121 |
| * | 121-122 |
| 45 | 123-122-128 |
| * | 128-122-123 |
| 13 | 123-122-121 |
| * | 121-122-123 |
| 13 | 123-122-121 |
| * | 121-122-123 |
| 43 | |
| * | |
| 35 | 122-128 |
| 15 | 106-128-124 |
| 45 | 124-122-128 |
| 43 | 128 |
| 13 | 122-121 |
| * | 121-122 |
| 35 | 122-128 |
| 43 | 106-128 |
| 3 | 128-106 |
| * | 106-128-122 |
| 35 | 122-128 |
| End at: 2.15 PM | |
| Time Recorded: 1.00 Hour | |

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Oct. 20, 70 | |
| Starting Time: 11.00 AM | |
| * | |
| 4 | 124-121 |
| * | |
| 49 | 124-126 |
| * | |
| 46 | 124-126 |
| 28 | 122-106 |
| * | |
| 39 | 122-107 |
| * | |
| 41 | 124-117 |
| 29 | 125-122-106 |
| 41 | |
| 40 | |
| 41 | |
| * | 117-124 |
| 41 | 126 |
| * | |
| 41 | 126 |
| 40 | |
| 41 | |
| 49 | 126 |
| 41 | |
| 40 | |
| 16 | 117-125 |
| 45 | 122-128 |
| 16 | |
| 34 | 128-107 |
| * | |
| End at: 12.00 Noon | |
| Time Recorded: 1.00 Hour | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: SAME

PERSON: SAME

CATEGORY: SAME

ACTIVITY: SAME

PERSON: SAME

CATEGORY: SAME

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: SAME | |
| Starting Time: 1.00 PM | |
| * 45 | 124-122 |
| * 49 | 124-136 |
| * 45 | 124-122 |
| * 46 | 126 |
| * 41 | 126 |
| * 40 | 124-117 |
| * 46 | 124-126 |
| * 16 | 126-124 |
| * 33 | 129 |
| * 45 | 124-122-128 |
| * 43 | 106-128 |
| * 38 | 128 |
| * 16 | 128-107 |
| * 45 | 128-122-124 |
| * 43 | 129-124 |
| * 45 | 122-128 |
| * 43 | 128-122-124 |
| * 43 | 124-123- |
| * 45 | 128 |
| * 43 | 128 |
| * 28 | 123-124 |
| * * | 124-128-106 |
| | 106-128-124 |
| End at: 3.00 PM | |
| Time Recorded: 2.00 Hour | |

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Nov. 2, 70 | |
| Starting Time: 1.20 PM | |
| * 28 | 124-128-106 |
| * 45 | 106-128 |
| * 28 | 128-106 |
| * 28 | 106-128-124 |
| * 45 | 124-128-106 |
| * 16 | 106-128 |
| * 16 | 128-122 |
| * 29 | 124-129 |
| * 33 | 124-128 |
| * 16 | 106-128-124 |
| * 44 | 124-128-106 |
| * 43 | 106-128-124 |
| * 16 | 129-124 |
| * 44 | 124-129 |
| * 43 | 129-124-123 |
| * 16 | 123-124-129 |
| * 44 | 124-122-128 |
| * 16 | 128-122-124 |
| * 44 | 129-124 |
| * 16 | 124-129 |
| * 44 | 129-124 |
| * 44 | 124-129 |
| * 44 | 129-124-123 |
| * 44 | 123-124-129 |
| * 44 | 129-124-123 |
| * 8 | 123-124-129 |
| * 44 | 129-124-123 |
| * 8 | 128-127 |
| * 44 | 127-128 |
| * * | 123-124-129 |
| End at: 2.20 PM | |
| Time Recorded: 1.00 Hour | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: 10

PERSON: 18

CATEGORY: 2

ACTIVITY: SAME

PERSON: SAME

CATEGORY: SAME

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Oct. 26, 70 | |
| Starting Time: 10.45 AM | |
| * | |
| 9 | 124-122 |
| 49 | 122-136 |
| 12 | 124-117 |
| * | 117-124 |
| 49 | 126-136 |
| * | 136-126 |
| 12 | 124-117 |
| 46 | 117-124-136 |
| * | 136-126 |
| 19 | |
| * | |
| 46 | 126-136 |
| 3 | 136-122-128 |
| * | 128-122-124 |
| 43 | 122-128 |
| * | 128-122 |
| 8 | 128-122-128 |
| 12 | 128-122-116 |
| * | 116-122-124 |
| 49 | 126-136 |
| * | 136-126 |
| 9 | 124-122 |
| 49 | 122-136 |
| * | 136-126 |
| 12 | 124-117 |
| * | 117-124 |
| 14 | 124-125 |
| * | 125-124 |
| 46 | 126-136 |
| * | 136-126 |
| End at: 12.00 Noon | |
| Time Recorded: 1.15 Hour | |

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: SAME | |
| Starting Time: 1.20 PM | |
| * | |
| 41 | 126 |
| * | 126 |
| 34 | 122-128-106 |
| * | 106-128-122 |
| 41 | 126 |
| 40 | 118 |
| * | 118-126 |
| 45 | 124-122-128 |
| 43 | 128 |
| 45 | 128 |
| * | 128-122-124 |
| 46 | 126-136 |
| 34 | 136-122-106 |
| 43 | 106-128 |
| * | 128-122 |
| 46 | 126-136 |
| * | 136-126 |
| 14 | 124-125 |
| * | 125-124 |
| 46 | 126-136 |
| * | 136-126 |
| 49 | 126-136 |
| * | 136-126 |
| 4 | 124-122-116 |
| * | 116-122-124 |
| End at: 3.20 P M | |
| Time Recorded: 2.00 Hour | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: SAME

ACTIVITY: 10

PERSON: SAME

PERSON: 19

CATEGORY: SAME

CATEGORY: 3

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Oct. 27, 70 | |
| Starting Time: 10.15 AM | |
| * | |
| 49 | 126-136 |
| * | 136-126 |
| 8 | 124-122-128 |
| * | 128-122-124 |
| 14 | 124-125 |
| * | 125-124 |
| 49 | 126-136 |
| * | 136-126 |
| 38 | 122-128-106 |
| 46 | 106-122-136 |
| * | 136-126 |
| 49 | 126-136 |
| 46 | 136 |
| * | 136-126 |
| 12 | 124-117 |
| * | 117-124 |
| 33 | 122-128-106 |
| 20 | 106-122-124 |
| * | 126 |
| End at: 11.00 AM | |
| Time Recorded: 45 Minute | |

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Oct. 20, 70 | |
| Starting Time: 11.00 AM | |
| * | |
| 9 | 126-122 |
| * | 122-126 |
| 49 | 126-136 |
| 12 | 136-124-117 |
| * | 124-126 |
| 33 | 126-122-106 |
| * | 106-122-126 |
| 46 | 126-136 |
| 34 | 126-122-106 |
| 46 | 106-122-126 |
| * | 136-126 |
| 35 | 126-122-106 |
| * | 106-122-126 |
| 18 | |
| * | |
| 49 | 126-136 |
| * | 136-126 |
| 2 | 126-122-128 |
| * | 128-122-126 |
| 49 | 126-136 |
| * | 136-126 |
| 12 | 126-124 |
| * | 124-126 |
| 46 | 126-136 |
| 12 | 126-124-117 |
| * | 124-126 |
| 12 | 126-124 |
| * | 124-126 |
| End at: 12.00 Noon | |
| Time Recorded: 1.00 Hour | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: SAME

ACTIVITY: SAME

PERSON: SAME

PERSON: SAME

CATEGORY: SAME

CATEGORY: SAME

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: SAME | |
| Starting Time: 1.10 PM | |
| * | |
| 13 | 126-124-125 |
| * | 125-124-126 |
| 13 | 126-124-125 |
| * | 125-124-126 |
| 13 | 125-124-126 |
| 31 | 124-122-106 |
| * | 106-122-126 |
| 20 | 126 |
| * | 126 |
| 49 | 126-136 |
| * | 136-126 |
| 9 | 126-122 |
| * | 122-126 |
| 20 | 162 |
| 8 | 124-122-128 |
| * | 128-122-124 |
| 8 | 126-122-128 |
| * | 128-122-126 |
| 8 | 126-122-128 |
| * | 128-122-126 |
| 12 | 126-124-117 |
| * | 117-124-126 |
| 31 | 126-122-106 |
| 35 | 107-109 |
| 36 | 109-110 |
| 49 | 107-122-136 |
| * | 136-126 |
| 46 | 126-136 |
| * | 136-126 |
| End at: 2.40 PM | |
| Time Recorded: 1.30 Hour | |

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Nov. 2, 70 | |
| Starting Time: 1.20 PM | |
| * | |
| 49 | 126-136 |
| 46 | 136 |
| * | 136-126 |
| 3 | 126-122-128 |
| * | 128-122-126 |
| 46 | 126-136 |
| * | 136-126 |
| 46 | 126-136 |
| * | 136-126 |
| 46 | 126-136 |
| * | 136-126 |
| 46 | 126-136 |
| * | 136-126 |
| 14 | 126-124-125 |
| 9 | 124-122 |
| 14 | 122-124 |
| 35 | 124-128-106 |
| 49 | 107-122-136 |
| * | 136-126 |
| 46 | 126-136 |
| * | 136-126 |
| 13 | 126-124-125 |
| * | 125-124-126 |
| 34 | 126-122-106 |
| * | 106-122-126 |
| 33 | 126-122-106 |
| 49 | 106-122-136 |
| * | 136-126 |
| 46 | 126-136 |
| * | 136-126 |
| End at: 2.50 PM | |
| Time Recorded: 1.30 Hour | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: 10

PERSON: 20

CATEGORY: 3

ACTIVITY: SAME

PERSON: SAME

CATEGORY: SAME

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Oct. 20, 70 | |
| Starting Time: 11.00 AM | |
| * | |
| 41 | 126 |
| * | 126 |
| 18 | 124 |
| * | 124 |
| 49 | 124-126 |
| 18 | 126 |
| 46 | 126-136 |
| 18 | 126- |
| 41 | 126 |
| * | 126-124 |
| 46 | 124-126 |
| * | 126-124 |
| 33 | 124-128 |
| 19 | 106-122-126 |
| * | 126-124 |
| 3 | 124-122-128 |
| * | 128-122-124 |
| 46 | 124-126 |
| * | 126-124 |
| 31 | 124-128-106 |
| * | 106-128-124 |
| End at: 12.00 Noon | |
| Time Recorded: 1.00 Hour | |

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Nov. 2, 70 | |
| Starting Time: 1.10 PM | |
| * | |
| 4 | 124-122-116 |
| * | 116-122-124 |
| 49 | 124-126 |
| * | 126-124 |
| 49 | 124-126 |
| * | 126-124 |
| 49 | 124-126 |
| * | 126-124 |
| 35 | 124-128-106 |
| * | 106-128-124 |
| 18 | 124 |
| * | 124 |
| End at: 4.10 PM | |
| Time Recorded: 3.00 Hour | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: 11

ACTIVITY: SAME

PERSON: 21

PERSON: SAME

CATEGORY: 1

CATEGORY: SAME

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Oct. 22, 70 | |
| Starting Time: 10.45 AM | |
| * | |
| 22 | 132 |
| * | |
| 22 | 132 |
| * | |
| 9 | 133-136-124 |
| 5 | 121-116 |
| 16 | 121-123 |
| 22 | 126 |
| * | |
| 49 | 133-136 |
| 22 | |
| * | |
| 4 | 136-123-116 |
| 49 | 116-123-136 |
| * | |
| 49 | 133-136 |
| 9 | 136-124 |
| 49 | 124-136 |
| * | 136 |
| 49 | |
| * | |
| 22 | 132 |
| * | |
| 22 | |
| * | |
| 22 | |
| * | |
| End at: 12.00 Noon | |
| Time Recorded: 1.15 Hour | |

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Nov. 2, 70 | |
| Starting Time: 1.15 PM | |
| * | |
| 22 | |
| * | |
| 22 | |
| 49 | 136 |
| * | |
| 22 | |
| * | |
| 22 | |
| 8 | 132-136-122 |
| * | 128-122-132 |
| 22 | |
| * | |
| 49 | |
| * | |
| 22 | |
| * | |
| 22 | |
| 1 | 136-101 |
| * | 101-136 |
| 22 | |
| * | |
| 22 | |
| * | |
| 49 | |
| * | |
| 22 | |
| * | |
| End at: 4.00 PM | |
| Time Recorded: 2.45 Hour | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY : 11

ACTIVITY : SAME

PERSON : 22

PERSON : SAME

CATEGORY : 3

CATEGORY : SAME

| Destination Point | Change of Direction Points |
|--|----------------------------|
| Date : Oct. 22, 70 Starting Time : 10.45 PM | |
| * | |
| 49 | 136 |
| * | |
| 43 | 136-124-123 |
| 49 | |
| * | 136 |
| 43 | 136-124-123 |
| * | |
| 49 | 136 |
| * | |
| 49 | |
| * | |
| 9 | 136-124 |
| 21 | 132 |
| * | |
| 21 | 132 |
| * | |
| 46 | 136 |
| 2 | 136-124-128 |
| * | 136-126 |
| End at : 12.00 Noon Time Recorded : 1.15 Hour | |

| Destination Point | Change of Direction points |
|---|----------------------------|
| Date : Nov. 2, 70 Starting Time : 1.15 PM | |
| * | |
| 18 | 136-126 |
| * | |
| 23 | 134 |
| * | |
| 46 | 136 |
| 4 | 126-122-116 |
| * | 116-122-126 |
| 49 | 136 |
| * | |
| 21 | 132 |
| * | 132 |
| 21 | 132 |
| 46 | 136 |
| 49 | 136 |
| * | 136-133 |
| 21 | 132 |
| 5 | 136-122-116 |
| * | 116-122-136 |
| 1 | 136-101 |
| 49 | 101-136 |
| * | 136-133 |
| End at : 4.00 PM Time Recorded : 2.45 Hour | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: 12

PERSON: 23

CATEGORY: 2

ACTIVITY: 13

PERSON: 24

CATEGORY: 3

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: Nov. 2, 70 | |
| Starting Time: 1.15 PM | |
| * 46 | 136 |
| * 49 | |
| * 49 | 136 |
| * 21 | |
| * 30 | 136-128 |
| * 22 | 128-136 |
| * 22 | 134 |
| * 22 | 134 |
| End at: 5.00 PM | |
| Time Recorded: 3.45 Hour | |

| Destination Point | Change of Direction Points |
|--------------------------|----------------------------|
| Date: OCT. 20, 70 | |
| Starting Time: 10.45 AM | |
| * 14 | 136-126 |
| * 46 | 126-136 |
| * 46 | |
| * 46 | |
| * 46 | |
| * 46 | |
| * 46 | |
| * 46 | |
| * 9 | 136-124-122 |
| * 46 | 122-124-136 |
| * 46 | |
| * 46 | |
| * 46 | |
| * 46 | |
| End at: 12.00 Noon | |
| Time Recorded: 1.15 Hour | |

TIME AND MOTION STUDY OF PERSONNEL

ACTIVITY: SAME

ACTIVITY:

PERSON: SAME

PERSON:

CATEGORY: SAME

CATEGORY:

| Destination Point | Change of Direction Points |
|---|----------------------------|
| Date: Oct. 20, 70 Starting Time: 1.15 PM | |
| * | |
| 46 | |
| * | |
| 12 | 136-124-117 |
| * | 117-124-136 |
| 46 | |
| * | |
| 46 | |
| 4 | 126-122-116 |
| * | 116-122-126 |
| 46 | |
| * | |
| 46 | |
| * | |
| 46 | |
| * | |
| 49 | 136 |
| 12 | 136-124-117 |
| * | 117-124-136 |
| End at: 3.00 PM Time Recorded: 2.45 | |

| Destination Point | Change of Direction Points |
|---------------------------|----------------------------|
| Date: Starting Time: | |
| (Empty table body) | |
| End at: Time Recorded: | |

APPENDIX D

Interactions between any pair of activities were obtained by summing up the number of exchanged visits between different destination points located within their boundaries. A complete set of tables showing the interactions between different activities are shown in the following pages.

INTERACTIONS BETWEEN ACTIVITIES

VISITING ACTIVITY: 2
VISITING PERSON: 2
CATEGORY: 3

| | RECEIVING ACTIVITIES | | | | | | | | | | | | | | | ALL |
|-----------------------------------|----------------------|---|---|---|---|---|---|---|---|----|----|----|----|----|----|-----|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | |
| NUMBER OF VISITS TO EACH ACTIVITY | | | | * | * | | * | * | * | | | | * | * | * | |
| Total visits in 4.00 hours | | | | 3 | 1 | | 1 | 1 | 1 | | | | 6 | 13 | 4 | 30 |
| Total visits/day | | | | 6 | 2 | | 2 | 2 | 2 | | | | 12 | 26 | 8 | 60 |
| Modified final interactions | | | | 6 | 2 | | 2 | 2 | 2 | | | | 12 | 26 | 8 | 60 |

INTERACTIONS BETWEEN ACTIVITIES

VISITING ACTIVITY: 2

VISITING PERSON: 3

CATEGORY: 3

| | RECEIVING ACTIVITIES | | | | | | | | | | | | | | | ALL | | |
|-----------------------------------|----------------------|---|---|---|---|---|---|---|---|----|----|----|----|----|----|-----|----|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | | | |
| NUMBER OF VISITS TO EACH ACTIVITY | | | * | * | | * | * | * | * | * | * | | * | * | * | * | * | * |
| Total visits in 4.00 hours | | | 1 | 1 | | 1 | 2 | 4 | 4 | 2 | 1 | | 6 | 7 | 8 | | 37 | |
| Total visits/day | | | 2 | 2 | | 2 | 4 | 8 | 8 | 4 | 2 | | 12 | 14 | 16 | | 74 | |
| Modified final interactions | | | 2 | 2 | | 2 | 4 | 8 | 8 | 4 | 2 | | 12 | 14 | 16 | | 74 | |

INTERACTIONS BETWEEN ACTIVITIES

VISITING ACTIVITY: 3

VISITING PERSON: 5

CATEGORY: 3

| | RECEIVING ACTIVITIES | | | | | | | | | | | | | | | ALL |
|-----------------------------------|----------------------|----|---|----|---|---|---|---|---|----|----|----|----|----|----|-----|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | |
| NUMBER OF VISITS TO EACH ACTIVITY | ** | ** | | ** | * | | * | | | | ** | | ** | | ** | |
| Total visits in 4.00 hours | 2 | 4 | | 3 | 1 | | 1 | | | | 4 | | 3 | | 13 | 31 |
| Total visits/day | 3 | 5 | | 4 | 1 | | 1 | | | | 5 | | 3 | | 16 | 38 |
| Modified final interactions | 3 | 5 | | 4 | 1 | | 1 | | | | 3 | | 3 | | 12 | 32 |

INTERACTIONS BETWEEN ACTIVITIES

VISITING ACTIVITY: 6

VISITING PERSON: 10

CATEGORY: 3

| | RECEIVING ACTIVITIES | | | | | | | | | | | | | | | |
|-----------------------------|-----------------------------------|---|---|---|---|---|---|---|---|----|----|----|----|----|----|-----|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | ALL |
| | NUMBER OF VISITS TO EACH ACTIVITY | | * | * | | * | | | | | * | | | | | * |
| Total visits in 4.00 hours | | 1 | 1 | | 3 | | | | | 2 | | | | | 7 | 14 |
| Total visits/day | | 2 | 2 | | 6 | | | | | 4 | | | | | 14 | 28 |
| Modified final interactions | | 2 | 2 | | 4 | | | | | 4 | | | | | 14 | 26 |

INTERACTIONS BETWEEN ACTIVITIES

VISITING ACTIVITY: 7

VISITING PERSON: 13

CATEGORY: 3

| | RECEIVING ACTIVITIES | | | | | | | | | | | | | | | ALL |
|-----------------------------------|----------------------|---|---|----|---|---|---|---|----|----|----|----|----|----|----|-----|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | |
| NUMBER OF VISITS TO EACH ACTIVITY | | * | | ** | | | | * | ** | | | | * | * | * | * |
| Total visits in 4.00 hours | | 1 | | 2 | | | | 1 | 3 | | | | 3 | 3 | 4 | 17 |
| Total visits/day | | 2 | | 4 | | | | 2 | 6 | | | | 6 | 6 | 8 | 34 |
| Modified final interactions | | 2 | | 4 | | | | 2 | 6 | | | | 6 | 6 | 8 | 34 |

INTERACTIONS BETWEEN ACTIVITIES

VISITING ACTIVITY: 11

VISITING PERSON: 22

CATEGORY: 3

| | RECEIVING ACTIVITIES | | | | | | | | | | | | | | | | |
|-----------------------------------|----------------------|---|---|---|---|---|---|---|---|----|----|----|----|----|----|-----|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | ALL | |
| NUMBER OF VISITS TO EACH ACTIVITY | * | | * | | * | | | | * | * | * | | * | * | * | * | * |
| Total visits in 4.00 hours | 1 | | 2 | | 1 | | | | 2 | 1 | | 1 | 3 | | 7 | 18 | |
| Total visits/day | 2 | | 4 | | 2 | | | | 4 | 2 | | 2 | 6 | | 14 | 36 | |
| Modified final interactions | 2 | | 4 | | 2 | | | | 4 | 2 | | 2 | 6 | | 12 | 34 | |

INTERACTIONS BETWEEN ACTIVITIES

VISITING ACTIVITY: 12

VISITING PERSON: 23

CATEGORY: 2

| | RECEIVING ACTIVITIES | | | | | | | | | | | | | | | ALL | |
|-----------------------------------|----------------------|---|---|---|---|---|---|---|---|----|----|----|----|----|----|-----|----|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | | |
| NUMBER OF VISITS TO EACH ACTIVITY | | * | | | | | | | | | | ** | | * | | ** | |
| Total visits in 4.00 hours | | 1 | | | | | | | | | | 2 | | 1 | | 2 | 6 |
| Total visits/day | | 2 | | | | | | | | | | 4 | | 2 | | 4 | 12 |
| Modified final interactions | | 2 | | | | | | | | | | 4 | | 2 | | 4 | 12 |

APPENDIX E

The cost figures on the University of Manitoba Administration Building, as obtained from the accounting department, are shown in the next pages, together with a letter addressed to the personnel of the Registrar's office to notify them of the particulars of the work study to take place in the office.

Inter-Departmental Correspondence

DATE October 8, 1970TO Mr. A. Grant, Registrar's OfficeFROM G. E. Phillips, Senior AccountantSUBJECT: COST FIGURES ON ADMINISTRATION BUILDING

The following are the cost figures you requested in your memo dated October 5, 1970, (except nos. 2 and 3 which we discussed on the telephone).

- | | |
|--|--------------|
| 1. Original Cost of Administration Building (1914) | \$ 271,400 |
| 4. Operating and Maintenance Costs | \$ 43,443 |
| 5. Total annual salary costs of employees in the Administration Building | \$ 1,458,615 |

I hope this information is sufficient for your requirements.

I would appreciate it very much if you could send us a copy of the results of the study.

GEP/ji

Inter-Departmental Correspondence

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DATE 5 October 1970TO ALL MEMBERS OF THE REGISTRAR'S STAFFFROM Mr. L. J. Hughes, RegistrarSUBJECT: OFFICE LAYOUT STUDY

Periodically during the next month Mr. Hussein Tawfik will be conducting a study in the Registrar's General Office and the Admissions Office. Mr. Tawfik is a Masters of Architecture student and is attempting to develop a method of designing an office building so that it will provide pleasant surroundings for the employees and at the same time be arranged to minimize the number of times personnel must get up from their desks and also minimize the lengths of these trips when they find they must move around.

Mr. Tawfik will be observing the movements of persons in these two offices and will be plotting these on a board. It is hoped that the results of this study will allow us to do a better job when we lay out the office under the proposed space expansion. The objective of this layout will be to make everyone's job as enjoyable as possible. Please be assured that Mr. Tawfik's observations will in no way be used in the evaluation of your job performance. It would be unrealistic to believe that any assessment of an office worker's performance could be based on a study of his movements in the office. Therefore, we ask your cooperation in this study.

Should you like more information regarding this study please feel free to ask Mr. Tawfik or Mr. Allan Grant, who will be helping him with this project.

Thank you in advance for your cooperation.

/bc