SIMULATION AND ALLOCATION: AN APPLICATION TO A MEDICAL FACILITY

Barry Jackson and Lawrence Bacher

School of Architecture
Rensselaer Polytechnic Institute
Troy, New York

ABSTRACT

One of the subproblems in the design of the built environment is the distance relationship of one activity to another. The data acquisition methods that are useful to "allocation models" have been subject to criticism. Computer simulation techniques offer a simple means of assisting the architectural designer in the task of gathering sufficient data to produce an improved built environment with reduced effort and cost.

This problem has been approached by developing programs which simulate process-oriented high-technology facilities, then utilize simulation results to suggest tentative floor plans to the designer. Two programs will be discussed in this paper, the Program for Architectural Simulation Studies (PASS) and ALLOCATE, a spatial allocation program.

INTRODUCTION

One of the problems in architecture is: where do the spaces go in relationship to one another; or stated in more precise terms: what is the optimal location for a set of spaces which must be interconnected? Very often no objective criteria can be established for the location of all of the spaces, and very often the designer's viewpoint of the design issues excludes a rigorous approach to the question. The question is sometimes overridden by issues of greater priority. But somewhere at the basis of design the question should be asked--particularly in facilities that can be thought of in terms of some measure of efficiency, such as medical facilities.

Architectural designers usually do not treat their problems within the traditional framework of optimization. While their concerns are usually complexly related and involve multiple objectives (3), the problem is usually fuzzy and ill-structured (7), and does not permit manipulation with simple modeling schemes.

Furthermore, designers have a tendency to continually re-define the set of constraints to a problem as they work through it. In design, the total set of constraints defines a feasible solution within that domain. The task is to find the feasible solution within that domain. A search for an "optimal" solution may take place during the initial passes through the problem, but when the initial constraints result in a trivial solution, either new constraints are added or old constraints are replaced. Conversely, when the problem seems intractable, the constraints are often relaxed.

Eastman suggests that ". . . optimization takes the form of iteratively modifying the problem definition until an appropriate balance between tractability and quality of results are achieved." (3) In some ways, problem solving and problem design merge.

Many design problems have finite solutions if they are properly defined. For example, the operating effectiveness of medical facilities depends heavily upon the effectiveness of the plan arrangement.

ALLOCATION

Since Koopmans' and Beckmann's study of quadratic assignment--which is the mathematical foundation upon which rests a generation of locational analysis, many authors have studied the issue of spatial relationships in either an abstract, industrial or architectural context.

The ideas in this paper are part of the stream of research into automated plan generation techniques. Elements of these ideas have been gathered from the literature and tested wholly or in part in various circumstances (4). This paper brings together two separate streams of thought regarding the uses of allocation and simulation.

The general form of the location problem can be expressed in two ways:

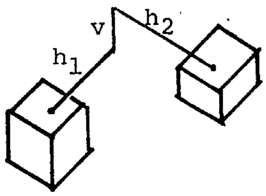


Figure 1

$$F = \sum_{0}^{n} (y_{ij})(d_{ij})$$

where F = the objective funcion to be minimized

d = some measure of the "distance" between entities

y = some measure of the proximity between entities

and $d = h_1 + v + h_2$ (refer to Figure 1)

Figure 2

Analogies to the solution vary from topological (2) to electrical, but most are wrong in three practical aspects:

(1) Generalization about the allocation problem without regard to building type;

(2) Disregard of the size of the problem;

(3) Lack of a logical method for determining the data which goes into the allocation model.

This paper addresses itself to the third aspect.

In the real world, there are sets of constraints or goals (possibly conflicting) which must be satisfied by the placement configuration: building orientation, external constraints (such as access to traffic patterns), relationships to existing facilities, potentiality for expansion or modification, and social factors.

From the practical standpoint, it is appropriate to view the design process as heuristic: allocation models or simulation provide insight to potential solutions, rather than serve as closed-end design processors. For the purposes of this paper the following brief review of the allocation problem will suffice; a complete review of the entire problem can be gleaned by reading Mitchell (7) or Hanan and Kutzberg (4).

The objective function in the ALLOCATE system is the minimization of the sum of the distances between all activity areas. In other words, a measure of the efficiency of the building in terms of movement between spaces.

ALLOCATE will either measure the efficiency of an existing spatial arrangement of spaces, or during the design process, generate alternative arrangements. It will also reposition an existing arrangement if it sees a more efficient location for one or more spaces.

The program reads in either the proscribed area or physical dimensions of each space and a matrix which represents the required proximity measure of the space with every other space. It also reads any restrictions, such as special locations, fixity or shape.

If the program is given no initial location, it develops one, then computes the matrix of distances between each of the given spaces. The program computes the objective function to minimize the sum of all of the proximity measures and the product of their distances.

The program determines the valid ways to modify the spatial arrangement to reduce the objective function, then moves parts of the pattern (two or three spaces), maintaining the initial constraints, and maintaining the validity of the initial forms. When no improvement in the relative location index is possible, it then outputs a diagram on either plotter, printer or CRT depending upon the user's request.

The final diagram from the computer is a pattern of the relative location of the spaces as generated and selected by an iterative process for obtaining near optimum locations.

ALLOCATE is an extension of the work of Armour and Buffa (1), who developed the earliest computerized relative allocation techniques. The present modification and extension considers the more complex issues of larger facilities, multifloor arrangements and development of initial plans. Output from the ALLOCATE system is a series of plan diagrams which give the design a starting point for the exploration and testing of alternative solutions and the merger of other systems (structural, energy, acoustic, etc.) into the design.

SIMULATION

A detailed numerical analysis of the distribution of activities in some building types can be developed through simulation

(6). The methods set forth in this paper make it possible to generate and test alternative arrangements of health facilities by first processing activity data through a model of the facility and secondly testing the "efficiency" of the three dimensional arrangement of the facility using an allocation model.

Therefore, the task was to develop a model of a health facility that would provide:

(1) The matrix of proximity relations used as input to most allocation routines and,

(2) A measure of the effectiveness of a proposed layout, in terms of total distance travelled.

One way to meet both goals is to simulate hospital traffic activity. The total trips between each pair of areas provides a measure of the strength of proximity relations between areas; the total trip distance for each provides the effectiveness measure. In addition to meeting these criteria, the model was designed to be:

(1) Easy to understand without prior knowledge of simulation techniques or computer programming,

(2) Not extravagant with machine time, and

(3) Flexible in a variety of situations--applicable to different departments and different structures.

The hospital was viewed as a vast treatment machine. Patients, staff and supplies are input to the system and run through standard procedures in specified areas or equipment, producing waste products, diagnostic information and healthier individuals. The simulation program allows a designer flexibility to model different departments and facilities by specifying a set of standard treatment procedures followed in the department. Each treatment procedure is described as an ordered sequence of tasks. These tasks may be unique to the department, or they may be shared with other departments or facilities. A task is completely described by its name, the type of space it requires, the time required to complete the task, and the staff required to complete the task. When a patient enters the system to follow a given treatment procedure, the program reserves space and staff for the patient as they become available when it is time for each task to occur. Figure 3 represents the path taken by only one patient through the hospital facility.

At the same time, other individuals will also be traveling through the facility on the same or similar paths, making simultaneous demands on facilities and staff. The program scheduling routine must resolve these conflicts, bringing patients up for treatment as the facilities or staff they required are released by other patients.

The PASS program is written in SIMSCRIPT II.5. It makes extensive use of SIMSCRIPT'S timing, reporting and statistical collection features to simplify programming effort and increase utility of the model. It requires from the user:

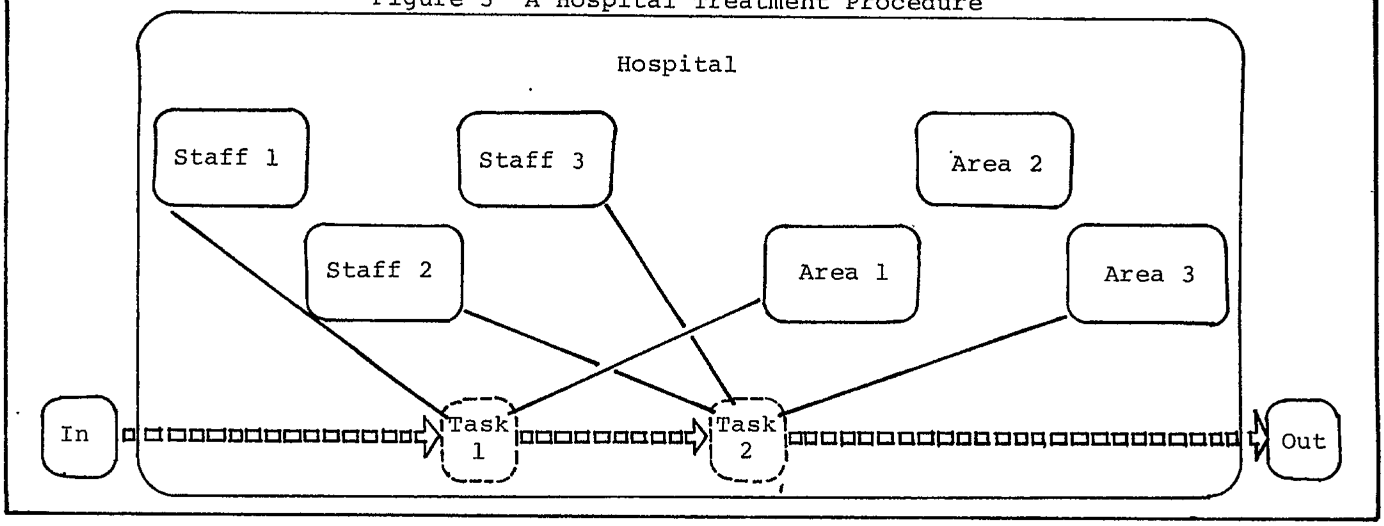
*a list of spaces in the proposed facility

*a list of staff in the facility

*a description of procedures or processes that will be used in the facility, and

*a description of the patients or clients to be serviced by the facility.

Figure 3 A Hospital Treatment Procedure



With this information the user "builds" a stochastic model of the proposed facility in the machine. PASS uses this model to simulate a day at the facility. The simulation is based on discrete-event, rather than discrete-interval, simulation. PASS is then able to provide as output, on request:

(1) A tally of all staff trips and distances traveled--a measure of the efficiency of a layout.

(2) A tally of all trips made between spaces in a facility, a description of traffic flows in the facility.

(3) A description of the waiting areas in a facility--the mean, maximum and total population these areas must serve, and

(4) A matrix of the relative strengths of interconnections between spaces in the facility based on simulation results. The first three types of output are useful for evaluating and modifying an existing design scheme. This last data is processed by ALLOCATE to produce initial floor plans for a facility.

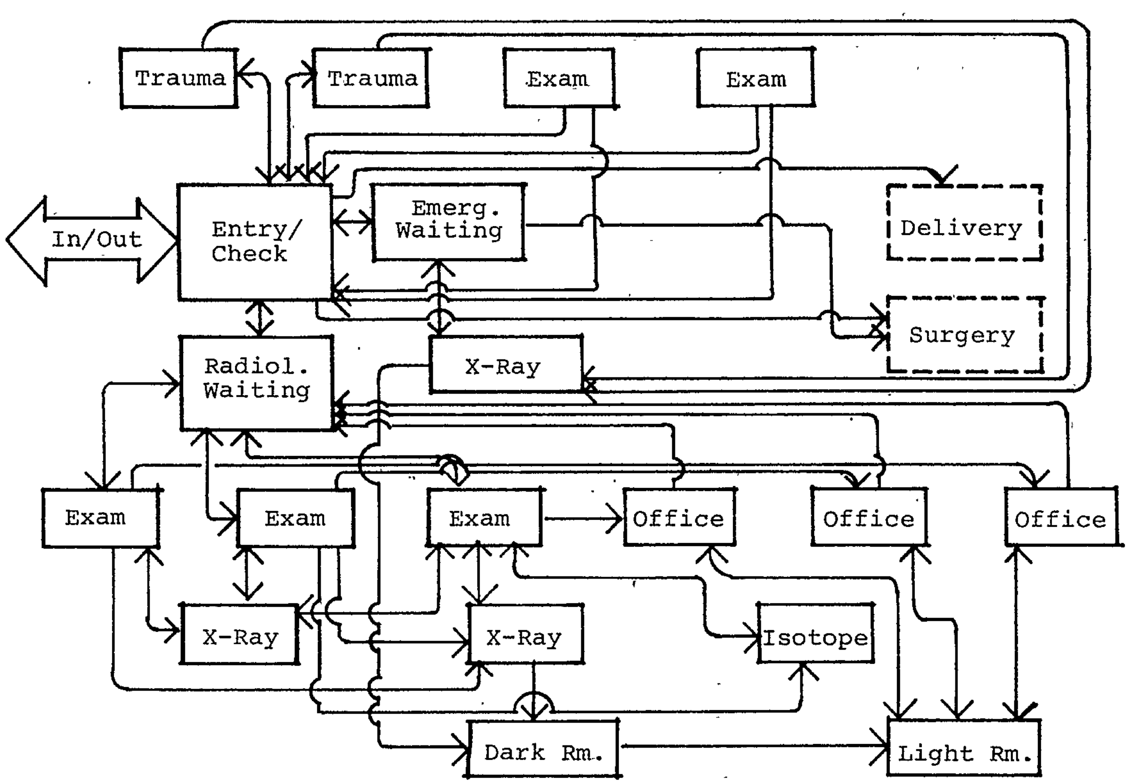
PROBLEMS

Research indicates that departmental groupings of hospital activities vary so widely in organization and procedure, that few modeling generalizations can be made. There are, however, sufficient similarities between departments of the same type operated in different hospitals to indicate that simulation of individual departments could be a promising line of research.

What will ultimately be required is a simulation package for the designer. This package would allow him to specify the parameters of each department in language as near his natural language as possible, the computer simulating each department individually, tying them together with an interdepartmental traffic model and producing alternative sketch floor plans directly from a spatial allocation routine.

Current work focuses on developing a simple, efficient model of several of the departments in a community-based general hospital. Paralleling the administrative structure of most general hospitals, the model will first examine intradepartmental operations on the micro level. Interdepartmental communications will then be studied on a macro scale.

Figure 4 A Hospital Emergency/Radiology Department



CONCLUSIONS

The interface between allocation and simulation models is an area that is still new and developing. The following criteria for development of allocation/simulation packages have been identified:

1. It must adapt to the problem. Health care facilities vary widely in equipment, scale and function. No one model will meet all needs. The model package must adapt to varying demands.

2. It must adapt to the data. Health care organizations operate record-maintenance systems that vary widely in scope, depth and content. Few generalizations can be made about the data any one facility will have available; therefore the model package must operate with whatever data files may be available and accessible.

3. It must be simple to use. The application of computing machinery to architectural design problems is a new and developing field. Many architectural designers are therefore wary of it. An approach that is inordinately complex or incomprehensible to an architectural designer with a standard design-oriented education will not be utilized.

4. It must be economically feasible. There must be economic justification for employing a computerized allocation/simulation approach to design problems; therefore the package must save the designer time (ergo:money) and/or it must produce a better result. A package that cannot be economically justified by a professional design firm will not be utilized.

5. It must produce a product that is intuitively comfortable. The product of the model must be viewed as the facility which is built and not the model itself. Not only must an allocation/simulation package produce a layout that works mathematically; designers and/or users of the product must be satisfied with the result. There is no real measure for this intuitive feeling, but the package will have to be adjusted to account for it.

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