FIREHOUSE SITE EVALUATION MODEL: EXECUTIVE SUMMARY

PREPARED FOR THE OFFICE OF POLICY DEVELOPMENT AND RESEARCH, DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

WARREN E. WALKER

R-1618/1-HUD
JUNE 1975

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PREFACE

This report describes in nontechnical terms a computer program called the Firehouse Site Evaluation Model. The report was written to help fire department administrators and other local government officials understand how the model can be used to determine good locations for a city's firehouses.

Preparation of this report was funded under contract H-2164 with the Office of Policy Development and Research of the U.S. Department of Housing and Urban Development. Among the objectives of this HUD contract are the development, field testing, and documentation of methods for improving the deployment of municipal emergency services.

For more detailed information about the model, readers should consult the companion volume to this report:

R-1618/2-HUD, *Firehouse Site Evaluation Model: Description and User's Manual*, Peter Dormont, Jack Hausner, and Warren Walker, June 1975.

Documentation of the Firehouse Site Evaluation Model constitutes part of a series of HUD-funded reports describing several different deployment models for police, fire, and ambulance services, and applications of the models in several cities. Further information about the models and their applications can be obtained from The Rand Corporation.

The HUD contract with The New York City-Rand Institute is one of the efforts supported under HUD's Community Development and Management Research Program. The Program is designed to develop, field test, and provide to state and local officials new approaches and methods for responsive community management. The Program intends to provide these officials with new methods of identifying alternative policies and actions, and of assessing the feasibility, cost, and consequences of these alternatives. The methods are tested in representative communities under actual operating conditions, and the results are made available to users in other communities.

SUMMARY

This report provides a nontechnical overview of the Firehouse Site Evaluation Model (or "siting model"). It is designed to help local government officials and fire department administrators understand what the model is, when it should be used, how it works, what output information it provides, and what data, computer, and manpower resources are needed to use it. The siting model is one of several models developed by The New York City-Rand Institute to assist fire departments in solving the general problem of firehouse location. A description is given of the circumstances in which the use of each model is most appropriate.

The siting model provides a way to estimate the fire protection levels that would result from implementation of any given arrangement of fire companies. Fire protection is measured by average travel times and travel distances to all fires, travel times and distances to specific locations, and fire company workloads. By comparing the fire protection levels resulting from one arrangement to those resulting from others, rational decisions can be made about the deployment of a city's fire companies.

ACKNOWLEDGMENTS

The Firehouse Site Evaluation Model was developed and refined at The New York City-Rand Institute by Peter Dormont, Jack Hausner, and Mei Ling over the course of several years. During this period it was used in performing fire company deployment analyses in: Yonkers, New York; Trenton and Jersey City, New Jersey; and Wilmington, Delaware. It includes features suggested by the civilian and uniformed personnel who worked with Institute staff members in these cities.

I would like to thank Barbara Woodfill and Jan Chaiken of The Rand Corporation, Ed Ignall, Ken Rider, Barry Richman, and Peter Dormont of The New York City-Rand Institute, and Hartley Fitts and Bob Baumgardner of the U.S. Department of Housing and Urban Development for their helpful comments on an earlier draft of this report.

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I. INTRODUCTION

The Firehouse Site Evaluation Model (also called the siting model) is a computer program that can help fire departments choose specific locations for their fire companies. It is used for long-range planning purposes, such as deciding which existing firehouses should be closed, expanded, or moved, and where new firehouses should be constructed. The model provides a way to estimate what fire protection levels would result from implementation of a specific arrangement of firehouses. By comparing the fire protection levels resulting from one arrangement to those resulting from others, a fire department can make rational decisions about the location of its fire companies.

A typical application of the siting model involves running the computer program several times, making step-by-step improvements in the arrangement of fire companies. First, locations and response assignments of the existing fire companies are described in a form that the computer program can read. The model then calculates the travel-time and workload characteristics for the existing arrangement. From this it might be seen that one fire company has too much work to do as compared to the others, or that travel times are unacceptably high in one part of the city. This information will suggest places to add, delete, or move firehouses, and will lead to the development of one or more new arrangements. The model can then be used to evaluate each arrangement's travel-time and workload characteristics. These runs might indicate the need for still further changes, in which case the process continues until a satisfactory arrangement is achieved.

The siting model does not, by itself, generate alternative firehouse configurations. It simply helps the fire department evaluate alternative configurations that their planning personnel create. What the model provides is detailed quantitative information about each configuration, thereby permitting a structured, reasoned analysis to select the best ones. This information must be combined with subjective judgments about other considerations, such as fire hazards and political constraints. It is then a matter of managerial and analytic judgment to choose, from among the several configurations, the one that best meets the fire protection needs of the city, while remaining within budgetary limits.

The Firehouse Site Evaluation Model was programmed, tested and refined during 1973 and 1974 by personnel of The New York City-Rand Institute. It

has been used in the analysis of fire company deployment policies in Trenton, New Jersey [1],* Yonkers, New York [2], Jersey City, New Jersey [3], and Wilmington, Delaware [4]. Each of these cities is in the process of making substantial changes in the number and arrangement of its fire-fighting resources based on the results of the analyses.

The computer program that constitutes the Firehouse Site Evaluation Model is now available to any fire department for the cost of duplication, by request to the address shown in the Appendix. It is supplied with a complete user's manual: Peter Dormont, Jack Hausner, and Warren Walker, *Firehouse Site Evaluation Model: Description and User's Manual*, R-1618/2-HUD.

This executive summary is a companion to the user's manual and tells when the siting model might be needed, how it works, how it can be used, and the amount of effort and expertise required to use it.

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*Numbers in brackets identify references listed at the end of this report.

II. WHEN TO USE THE SITING MODEL

Determining a configuration of fire companies for any city (or other local jurisdiction) involves obtaining the answers to two questions:

(1) How many fire companies does the city need in order to provide a certain level of fire protection?
(2) Where should the fire companies be located?

Answering these questions involves subjective judgments and trade-offs among competing objectives. The siting model is one of several complementary computer programs that can be used to help in answering the questions. Sometimes more than one will be used in a deployment study; sometimes only one will be used.

One of these programs, the Parametric Allocation Model [5], provides the user with a general picture of the number of fire companies needed in different parts of the city. It is very quick and inexpensive to use, and requires that very little data be collected. But it cannot be used to evaluate specific locations for the companies in any detail. Its primary purpose is for assistance in the initial steps of a fire station location study.

The Parametric Allocation Model can be used to compare average travel times and workloads among regions of the city, to see whether or not the current distribution of fire companies is satisfactory. If sizable imbalances are found, the model can also be used to determine how to reallocate the existing units among the regions to provide more balanced fire protection. If proposals for additional fire companies or for fewer fire companies are being considered, the model can also be used to determine the regions that should gain or lose the companies.

Once a fire department has chosen (at least tentatively) the number of companies to be assigned to each region of the city, it is not difficult to develop several alternative configurations of station sites that might lead to improved performance. These can be evaluated in detail using the Firehouse Site Evaluation Model described in this report, or the Fire Operations Simulation Model described elsewhere [6, 7]. Both require substantially more data than the Parametric Allocation Model.

The simulation model is a complex computer program that can only be used by persons who understand the special programming language used; it also requires a moderately large computer, is expensive to operate, and requires a very considerable amount of data as input. By comparison, the siting model can be used by persons who know nothing about programming; it is easier and less expensive to operate and requires a smaller computer and much less data than the simulation. So, the simulation should be used in preference to a siting model only if the greater capabilities and better accuracy of the simulation model are required for the analysis of the deployment policies being considered.

There are basically two situations in which the simulation is to be preferred to the siting model.

The first is when the deployment policies to be analyzed are not related to choosing the locations of firehouses. For example, the simulation can be used to evaluate alternative dispatching policies or policies to relocate available fire companies when a large fire is in progress. Second, the simulation is to be preferred if the alarm rate in the city is high relative to the number of companies, so that companies are often unavailable when alarms are received from their response areas. The siting model assumes that companies will nearly always be available in their firehouses to respond to alarms. This is a reasonable approximation for fire departments in most cities. If a department rarely has more than 10 percent of its units busy at one time, the siting model is to be preferred. While the simulation model gives a more accurate representation of the operations of a fire department, the differences will generally not be large enough to affect the choice of firehouse locations.

It is possible to use both the siting model and the simulation in a study of firehouse locations. The siting model, because it is relatively inexpensive to run, might be used to examine a wide range of alternative configurations in order to choose a small set of configurations for more detailed examination. The simulation would then be used to examine this reduced set of configurations. This approach was used in Denver [8]. In this case, results from the simulation model assured government decision-makers that the proposed new policy would actually work in the way that the siting model predicted.

III. HOW THE SITING MODEL WORKS

The Firehouse Site Evaluation Model requires that the user assign grid locations to every alarm box and firehouse in the city. The model uses these grid locations to estimate the distances traveled by companies to each alarm box. The distances are used to divide the city into response areas, where a company's first-due response area is the region of the city to which it is closer than any other company; its second-due response area is the region in which it is second closest; and so on. The calculation of distances and response areas considers only the situation in which all of the fire units in the area of an incident are available to respond from their firehouses when an alarm is received. The program assumes that the units geographically closest to the alarm will be dispatched.

After calculating the response distances, the program estimates travel times by using a simple mathematical formula to relate fire vehicle travel time and travel distance. The exact form of this relationship may be determined in each city by conducting a stopwatch experiment [9]. However, since a single relationship has been found to hold, with little variation, in several cities throughout the country, such an experiment is optional rather than essential.

These travel distance and travel time estimates are used in the model because they are fast to process by computer and require the user to gather very little data. They are approximations that will produce slightly incorrect representations of the travel distance and time for an individual trip, but have been shown to be sufficiently accurate for policy comparisons.

The siting model program has been written so that it can be used interactively, with the user sitting at a computer terminal connected to the telephone in his office. The user communicates with the program by means of a simple command language. He uses the language to specify the changes to be made in the arrangement of fire companies. The model calculates performance measures separately for each type of fire-fighting apparatus (e.g., pumpers and ladders), permitting the location of pumpers to be analyzed separately from the location of ladders. The user can also specify which of the performance measures (described in detail in Section V) he wants printed by the program.

IV. WHAT DATA ARE NEEDED

To use the siting model, the city to be studied must be divided into small subareas about the size of several city blocks. For cities having a relatively dense distribution of street alarm boxes, each subarea can correspond to the area covered by a single alarm box. The location of the center of each subarea (e.g., the box location) is specified on a grid map of the city. Travel times will be calculated to that point. The alarm rate in each subarea must be estimated by the user (in most instances from past data) for different types of alarms (structural fires, total alarms, etc.). For simplicity in our discussion, we will use the terms "subarea" and "alarm box" interchangeably throughout the rest of this report.

To facilitate the evaluation of alternative arrangements of fire companies, the siting model permits the user to divide the city into larger regions, which are called demand regions. Each demand region should be composed of subareas having similar characteristics from a fire-fighting point of view. Within each demand area, then, there would be relatively homogeneous fire hazards to life and property, potential fire-fighting problems, and alarm rates. With demand regions defined in this way, it is possible to compare fire protection in regions of the city that have similar demand characteristics to see if imbalances exist. Also, through the process of describing the characteristics of each region, areas can be identified which, by virtue of their greater fire hazards, require better levels of fire protection.

The siting model also permits the user to identify some specific subareas called "target hazards," as more important than others for achieving rapid response. The model will provide information on resulting travel times to each target hazard.

Data on the existing configuration of fire companies must also be supplied to the program. It requires a specification of the closest units to each alarm box. If this information is available (e.g. from "alarm assignment cards" or "running cards") it should be used. Otherwise the program will generate the information using the grid locations of the fire companies and alarm boxes.

V. THE SITING MODEL'S OUTPUT

Since it is not yet possible to quantify the effect of a rearrangement of fire companies on loss of life and property (the primary measures of the effectiveness of a fire department), the siting model uses travel time--the elapsed time between the dispatch of a fire company and its arrival at the scene--as its primary output measure. The assumption is that shorter travel times will lead to fewer lost lives and less property damage.

Different types of units perform different functions at a fire, depending mostly on the equipment they carry. For example, at a particular fire, a ladder company may be able to rescue a person who could not be saved by an engine company. So, in the siting model, travel times are calculated separately for each type of unit. In addition, two units of the same type working together may be able to take some action that neither could perform alone. Therefore, the time of arrival of each piece of equipment is of importance. The primary measures of effectiveness calculated by the siting model are, therefore, ordered lists of travel times for engines and ladders to every alarm box in the city. The list for engines tells the estimated time of arrival (relative to the time of dispatch) of the first engine, second engine, etc. at a given alarm box.

It is rare that one configuration of firehouses will result in travel times that are superior to those of another configuration for every alarm box. Consequently, the siting model provides information on the travel times to groups of alarm boxes. The boxes are grouped in several ways:

- Citywide (aggregate results are printed for the city as a whole);
- By demand region (results are printed separately for each of the previously defined demand regions constituting the city);
- By company response area (the boxes responded to by each company are aggregated and summary statistics are printed);
- By the boxes to which travel times are affected by the rearrangement of companies (in any use of the model, results are presented for two configurations of companies: a previously defined configuration that is called "current,"

and the new one under consideration, called "proposed." The "affected region" is the set of boxes to which travel times are different in the current and proposed configurations);

- All boxes that represent target hazards (travel times are printed for each of the target hazards and summarized for the whole group).

For each of the above groups of alarm boxes (except company response areas) the siting model provides the values of the following performance measures for both the "current" and "proposed" configurations:

- Average travel times to an alarm box (giving equal weight to each box);
- Average travel distance to an alarm box;
- Average travel time to an incident (taking into account the fact that some alarm boxes have more incidents than others);
- Average travel distance to an incident;
- Maximum travel time to any box in the group.

The output for each demand region, and the citywide output as well, includes a report that shows the number of alarm boxes whose travel time under the proposed configuration falls into each of a number of half-minute intervals. This can be used to see how frequently very long travel times occur using a particular configuration of companies.

For each company's response area (both current and proposed), the program prints the number of boxes in the area, the average and maximum travel times, and the alarm rates in the area. The alarm rates provide an estimate of the workload of the fire companies. These can be used to determine whether a proposed configuration of firehouses will result in an undue strain on a particular fire-fighting unit or large workload imbalances among the units. A list of the alarm boxes constituting each company's response area can also be printed, as well as a list of the alarm boxes in the affected region.

The program can also be used to generate the information needed to produce new "alarm assignment" or "running" cards corresponding to the new

configuration of fire companies, and information that can be used to produce maps showing the distribution of alarms or travel times throughout the city or the locations of the boxes affected by the change in configuration.

To make most effective use of the program's output, the department's planners would identify and summarize important results so that the relative rankings of the various arrangements of fire companies could be assessed. In some cases, a trial configuration may prove to be obviously unacceptable. For example, two demand regions that have approximately the same fire hazards and demands might be found to have very different travel times. A new trial configuration would then be designed, and the siting model would be used to determine whether an adequate improvement has been made. It is unlikely that the siting model results for several configurations will produce a particular arrangement that is obviously the best. For example, one configuration might improve travel times in the downtown area while degrading them in outlying areas, and another may improve first-due travel times throughout the city while making second-due times worse. Ultimately, an administrator who understands the entire operational and political context of the department must decide which of the arrangements studied appears best, all things considered, or whether still more arrangements should be analyzed.

Case studies showing the step-by-step process by which new arrangements of fire companies were determined in several cities using the siting model are contained in references 1-4. An agency wishing to use the siting model may find it useful to read one or more of these case studies to see the steps involved in a typical application.

VI. WHAT RESOURCES ARE NEEDED

The computer programs for the siting model are available in two ways:

(1) The programs can be obtained on punched cards or magnetic tape. In this case the programs, written in a language called FORTRAN, can be used in a batch or interactive mode on the user's own computer system. An agency wishing to use the model in this way must have access to a computer on which FORTRAN is available. If certain parameters that describe the city (such as number of alarm boxes, number of fire companies, etc.) fall within certain limits, then it is not necessary for any of the agency's staff to understand FORTRAN. Otherwise a person familiar with FORTRAN will have to modify some program statements, following instructions provided in the user's manual [10].

(2) The programs are available for use through a national computer time-sharing service. An agency wishing to use the model in this way need only have access to a computer terminal that can be coupled to the computer via telephone.

Information on obtaining the programs in either way is available from The Rand Corporation, as indicated in the Appendix.

The cost of computer time to run the siting model depends primarily on two factors: (a) the number of changes to be made in the existing configuration of fire companies, and (b) the number of alarm box locations in the city. The number of box locations also strongly affects the amount of core storage required.

On a PDP-10 computer, the siting model requires 27K words of core storage (approximately equivalent to 108K bytes of core storage on an IBM 360/370) for a city with 750 alarm boxes and 30 fire companies. Under these conditions, a single run using the model costs approximately $5.00 using the time-sharing service, although the cost of a run will vary from installation to installation depending upon the price structure.

The time and effort required to set up the siting model for use in a particular city will depend on whether or not: (a) grid locations have been determined for alarm boxes and firehouse locations, (b) computerized files

of incident reports have been maintained, and (c) the city has already been divided into regions of similar fire-fighting demands. If these conditions are met, then in two or three man-weeks a management analyst can set up the model. A few days of assistance from data processing personnel may be required. Otherwise, an additional two man-months will probably be required to collect and process the data. Persons with the skills to set up and run the siting model and analyze its output are likely to be found in most municipal governments. Little or no outside technical assistance should be required.

Fire departments wishing to use the Firehouse Site Evaluation Model may obtain all necessary materials as indicated in the Introduction. Questions can be addressed by phone or letter to one of the persons listed in the Appendix, but neither The New York City-Rand Institute nor The Rand Corporation provides full consultation or user services in connection with the products of its research.

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8. Thomas Hendrick and Donald Plane, *An Analysis of The Deployment of Fire-Fighting Resources in Denver, Colorado,* The New York City-Rand Institute, R-1566/3-HUD, May 1975.

9. Jack Hausner, *Determining The Travel Characteristics of Emergency Service Vehicles,* The New York City-Rand Institute, R-1687-HUD, April 1975.

10. Peter Dormont, Jack Hausner, and Warren Walker, *Firehouse Site Evaluation Model: Description and User's Manual,* The New York City-Rand Institute, R-1618/2-HUD, 1975.

APPENDIX

Addresses for Further Information

1. For documentation of the Firehouse Site Evaluation Model, copies of the program on cards or tape, information about the time-sharing computer service, or answers to questions about the program:

   Jan Chaiken
   The Rand Corporation
   1700 Main Street
   Santa Monica, California 90406

   (213) 393-0411

2. For copies of the reports listed in the references:

   Publications Department
   The Rand Corporation
   1700 Main Street
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3. Research Sponsor:

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