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# User's Manual for the Fire Safety Evaluation System Cost Minimizer Computer Program

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# USER'S MANUAL FOR THE FIRE SAFETY EVALUATION SYSTEM COST MINIMIZER COMPUTER PROGRAM

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PREFACE

This research was conducted under the sponsorship of the Center for Fire
Research and the Department of Health and Human Services by the Operations
Research Division, Center for Applied Mathematics, National Engineering
Laboratory, National Bureau of Standards.


This report is a product of the Fire and Life Safety Program. This program is
a joint Department of Health and Human Services (HHS) and National Bureau of
Standards (NBS) effort directed at the development of rational, technically
sound solutions to fire safety problems in health care facilities. In
addition to the types of work described in this report, the joint HHS/NBS
program has produced products in the areas of decision analysis, fire and
smoke detection, smoke movement and control, automatic extinguishment, and
behavior of institutional and other populations in fire situations.


This study serves as a User's Manual for applying and interpreting the results
of the Fire Safety Evaluation System Cost Minimizer (FSESCM) computer program.
The mathematical optimization techniques which are the core concept of the
FSESCM are used to identify the least-cost means of upgrading health care
facilities to compliance with the Life Safety Code. The program uses the
"optimal" solution as a reference point from which 10 to 20 compliance
strategies based on design considerations are generated. The computer program
is intended to be used as a management tool to facilitate the design selection
process by providing both information on relative costs and a chance to match
common compliance strategies across fire zones.

EXECUTIVE SUMMARY

This report describes a computer program which, using the Fire Safety
Evaluation System as its nucleus, employs mathematical optimization techniques
to identify the least-cost means of achieving a set of prescribed levels of
fire safety in health care facilities.  The Fire Safety Evaluation System
developed by the Center for Fire Research at the National Bureau of Standards,
through support from the Department of Health and Human Services, helps
decision makers by determining how combinations of several widely accepted
fire safety systems can be used to provide a level of safety equivalent to
that required by the Life Safety Code.

The economic consequences associated with the use of the Fire Safety
Evaluation System are likely to be great since concern over fire safety in
health care facilities has led to the enactment of legislation tying
certification for participation in the Medicare and Medicaid programs to an
ability to comply with the Life Safety Code.  Efforts to quantify the cost
savings attributable to the use of a performance-oriented system over that of
prescriptive compliance are simplified by noting that each of the building
safety features used in the Fire Safety Evaluation System has a unique value
which corresponds to prescriptive compliance.  An in-depth analysis of a
typical hospital is used to both illustrate how the Fire Safety Evalution
System Cost Minimizer (FSESCM) computer program would be applied in practice
and to support the claim that use of the FSESCM computer program can result in
savings of 50 percent or more over the cost associated with prescriptive
compliance to the Life Safety Code.  Since the Fire Safety Evaluation System
has been formally adopted into the 1981 edition of the Life Safety Code, any
solutions which the FSESCM computer program provides will satisfy both the
certification issue and the requirements of the code.  The potential cost
savings associated with this procedure are therefore of particular importance
to those health care facilities which have a strong dependence on revenues
from the Medicare and Medicaid programs.

The FSESCM computer program offers a great deal of flexibility to both users
and decision makers since it is usually able to identify from 10 to 20
near-optimal compliance strategies.  These compliance strategies are generated
by using the "optimal" solution as a reference point from which near-optimal
solutions can be systematically generated and examined.  The objective behind
these solutions is to facilitate the design selection process by providing
information on relative costs and the opportunity to match common retrofit
packages across all parts of the building.  The use of a predetermined set of
compliance strategies should therefore result in a considerable saving in time
in defining a comprehensive retrofit strategy for the entire building.

A cost study of a typical hospital is used to indicate the tremendous potential for reducing code compliance costs without compromising the safety and well-being of persons housed in health care facilities. Although the savings in retrofit costs which will accrue to the nation's stock of health care facilities is substantial, it is expected that savings will vary considerably as a function of the facility type, its condition, and its operational characteristics. Since the design places certain constraints on the retrofit process, the data required from the engineer in the field are organized in a manner which explicitly introduces relevant engineering issues into the cost minimization problem. The cost estimates produced by the procedure should permit the engineernig staff to quickly identify several compliance strategies which best reflect the specific attributes or peculiarities of the facility. Since the compliance strategies are built around those items deemed most important from an engineering viewpoint, their inclusion should simplify the problem of assessing the impacts of non-construction costs on the retrofit decision.

The FSESCM computer program is written in FORTRAN, a widely used language for scientific applications. The program has been thoroughly tested for ease of use and flexibility. For example, the program contains a series of user options which make it possible to alter the cost of any retrofit, preclude a retrofit, force a retrofit to be included, or demand a level of safety different from that required by the Life Safety Code. The program conforms to the major programming standard (ANSI X3.9-1978) and is executable on any standard system of adequate size. A companion report, <u>Programmer's Manual for the Fire Safety Evaluation System Cost Minimizer Computer Program</u>, is available which gives step-by step instructions for setting up and maintaining the program.

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# 1. INTRODUCTION

## 1.1 BACKGROUND

The identification of cost-effective levels of fire safety in health care facilities is a major concern to hospital administrators, fire safety engineers and public policy makers. Rising construction and operating costs coupled with more stringent building codes and continuing advances in medical and building technology have complicated the issue, forcing health care facility administrators to carefully assess the alternative means through which they can design, construct or update their facilities. Although multiple death fires in health care facilities are rare occurrences, the potential for major losses of life and property does exist and should be recognized in the selection of fire safety measures. This potential and the resulting need for a national commitment to fire safety in health care facilities has been emphasized in numerous congressional hearings.[1]

The National Fire Protection Association (NFPA) has long been recognized as a vehicle through which such a national commitment could be achieved. For over 60 years the NFPA has been a leader in the development of voluntary codes which establish acceptable fire safety levels. The Life Safety Code[2] is a widely used guide for identifying the minimum level of fire safety in buildings. Although the code may be thought of as prescriptive, since it prescribes fixed solutions for life safety in designated occupancies, performance concepts can be explicitly introduced through a provision which allows for equivalent solutions. In particular, Provision 1-5.1 states:

> Nothing in this code is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety to those prescribed by this Code, providing technical documentation is submitted to the authority having jurisdiction to demonstrate equivalency and the system method, or device is approved for the intended purpose.[3]

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[1]U.S. Congress, House, Select Committee on Aging, Subcommittee on Long-Term Care, Tragedy of Multiple Death Nursing Home Fires: The Need for a National Commitment to Safety, 1976.

[2]National Fire Protection Association, Code for Safety to Life from Fire in Buildings and Structures, NFPA 101-1981, Quincy, Mass., 1981.

[3]NFPA 101-1981, op cit.

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In light of this provision, the National Bureau of Standards' Center for Fire Research, through support from the Department of Health and Human Services, has developed a system, the Fire Safety Evaluation System (FSES), for determining how combinations of several widely accepted fire safety systems could be used to provide a level of safety equivalent to that required in the Life Safety Code.[1] The FSES equivalency methodology which emerged from this effort is particularly attractive since it lends itself to computer optimization techniques. Such optimization techniques should result in improved fire safety in health care facilities because they will resolve many of the differences of opinion surrounding the cost impacts of fire safety in health care facilities in general and the Life Safety Code in particular.

## 1.2  PURPOSE

The purpose of this report is to present a user-oriented description of the economic and engineering considerations that went into the development of a linear programming algorithm which permits the least-cost means of achieving compliance to the Life Safety Code to be identified.

The Fire Safety Evaluation System Cost Minimizer (FSESCM) computer program discussed in this report is particularly useful because it is based on the equivalency methodology developed by the Center for Fire Research. Since the NFPA has adopted this equivalency methodology into the Life Safety Code[2], any solutions from the computer program will be in compliance with the Life Safety Code. Furthermore, since each of the parameters used in the equivalency methodology has a unique value which corresponds to prescriptive compliance, it is possible to quantify the cost savings attributable to a performance-based approach, or equivalency methodology, over that of prescriptive compliance. Although the procedure is valid for both new and existing facilities, it is anticipated that its primary use will be in identifying alternative courses of action open to decision makers faced with retrofitting existing facilities.

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[1]H. E. Nelson and A. J. Shibe, A System for Fire Safety Evaluation of Health Care Facilities, National Bureau of Standards, NBSIR 78-1555, Washington, D.C., 1980.

[2]Appendix C of NFPA 101 describes the Fire Safety Evaluation System for health care occupancies. For those readers wishing an extended discussion of this as well as other topics in NFPA 101, the Life Safety Code Handbook is highly recommended. James K. Lathrop, editor, Life Safety Code Handbook, National Fire Protection Association, Quincy, Mass., 1981.

The computer program uses as its primary input information collected as an integral part of a thorough fire safety evalution. This information permits the current state of the health care facility to be unambiguously identified. The least-cost or optimal combination of retrofits is identified using the following information:

(1)  the current state of the health care facility;

(2)  the minimum passing "score" needed to achieve compliance; and

(3)  the anticipated costs of each retrofit measure.

The computer program then generates and analyzes a class of alternative retrofits. The optimal combination of retrofits and any alternatives which the program produces, usually between 10 and 20, are then summarized in tabular form and ranked according to cost. By using this approach, health care facility decision makers should have greater flexibility in choosing among retrofit combinations. In particular, by providing alternatives, the decision maker has the opportunity to assess very effectively the impact that non-construction costs would have on the choice of the optimal retrofit combination.


## 1.3  SCOPE AND APPROACH

The documentation for the FSESCM computer program is divided into two parts, each of which is designed to be self-contained and hence may be read independently. The first part, which includes this document, is designed to serve as a User's Manual. The second part is intended for use as a Programmer's Manual. This approach was taken because most users are not concerned with the internal workings of the program. On the other hand, it is frequently useful for the programmer, who has the responsibility of both setting up the program on the host system as well as making changes to the source code which reflect user demands or peculiarities of the operating system, to have access to the User's Manual so that changes can be made in the most efficient manner.

The final section of chapter 1 outlines the Fire Safety Evaluation System and establishes a framework for the development of the FSESCM computer program discussed in the remainder of the report.


The FSESCM computer program is outlined briefly in Chapter 2. A description of the philosphy and methodology behind FSESCM is given first, followed by a discussion of the data requirements, the various options available to the user, as well as some of the limitations of the program. A description of the program outputs is given in the final section of Chapter 2.

Chapter 3 consists of a detailed example in which all inputs to the FESECM computer program are carefully discussed. The chapter uses the evaluation of a typical health care facility as a means of exposition. The chapter begins with a description of the facility. A complete set of FSESCM worksheets are then presented, followed by a discussion of the data collection worksheet designed especially for the FSESCM computer program. The chapter concludes with a line-by-line description of the input deck.

The output associated with the example constructed in chapter 3 is rigorously analyzed in chapter 4. This chapter aims at both illustrating the types of output reports produced by FSESCM as well as a line-by-line description of what the output means. Three categories of output reports will be analyzed.

The fifth chapter provides a set of guidelines for making efficient use of the FSESCM computer program. Topics discussed which are thought to be of interest to a large group of users include: (1) when and how to use a particular combination of options; (2) how to batch runs so that more than one facility can be analyzed at any one time; and (3) how to find and correct input errors.

The companion report[1], which serves as a Programmer's Manual, contains the documentation for the FSESCM computer program. A mathematical discussion of the linear programming package serves to introduce the basic philosophy behind the algorithm. Each routine is then described, focusing on such topics as: (1) purpose; (2) calling sequence, (3) common blocks used, and (4) reports produced. A series of descriptive tables are used to define all variables and reports. The report includes a discussion of test results (e.g., run times experienced, validation activities, and program portability) and provisions for updating or modifying the source code. The program is written in FORTRAN and complies with the guidelines set down in the ANSI X3.9-1978 software standard.[2]

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[1]R.E. Chapman and W.G. Hall, Programmer's Manual for the Fire Safety Evaluation System Cost Minimizer Computer Program, National Bureau of Standards, NBSIR 83-2749, Washington, D. C., 1983.

[2]American National Standards Institute, American National Standard Programming Language FORTRAN, ANSI X3.9-1978, New York, 1978.

## 1.4   THE FIRE SAFETY EVALUATION SYSTEM

The Fire Safety Evaluation System (FSES) is a quantitative evaluation system for grading fire safety in health care facilities.  The primary use of the FSES is to determine how combinations of widely accepted fire safety equipment and building construction features may provide a level of safety equivalent to that required by the Life Safety Code.  Three major concepts are basic to the FSES.  They are:[1]

   (1)  Occupancy Risk:  the number of people affected by a given fire, the level of fire they are likely to encounter, and their ability to protect themselves.

   (2)  Building Safety Features:  the ability of the building and its fire protection systems to provide measures of safety commensurate with the risk.

   (3)  Safety Redundancy:  in-depth protection, through the simultaneous use of alternative safety methodologies such as Containment, Extinguishment, and People Movement.  The design of the complete fire safety system is intended to ensure that the failure of a single protection device or method will not result in a major failure of the entire system.

The concept of safety redundancy is of central importance to the FSES since Provision 2-1 of the Life Safety Code requires:

   The design of exits and other safeguards shall be such that reliance for safety to life in case of fire or other emergency will not depend solely on any single safeguard; additional safeguards shall be provided for life safety in case any single safeguard is ineffective due to human or mechanical failure.[2]

The task of ensuring that the FSES satisfied Provision 2-1 of the Life Safety Code was the responsibility of a panel of fire safety experts.  The goal of the panel was to reach consensus on all relevant fire safety issues.  To facilitate this process, a management tool known as the Delphi Method was used.  The Delphi Method, as used in developing the FSES, consisted of four steps.  These steps are illustrated in Figure 1.1.  Notice that the steps illustrated in the figure form a closed loop.  This is because a certain amount of recycling of ideas was needed in order to achieve consensus.

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[1]Definitions are taken from the report by Nelson and Shibe, op cit.

[2]NFPA 101-1981, op cit.

Figure 1.1  Delphi Method

**SELECT
SAFETY
FACTORS**

**IDENTIFY
SAFETY
PARAMETERS**

**REASSESS**

**ASSIGN
WEIGHTS TO
PARAMETERS**
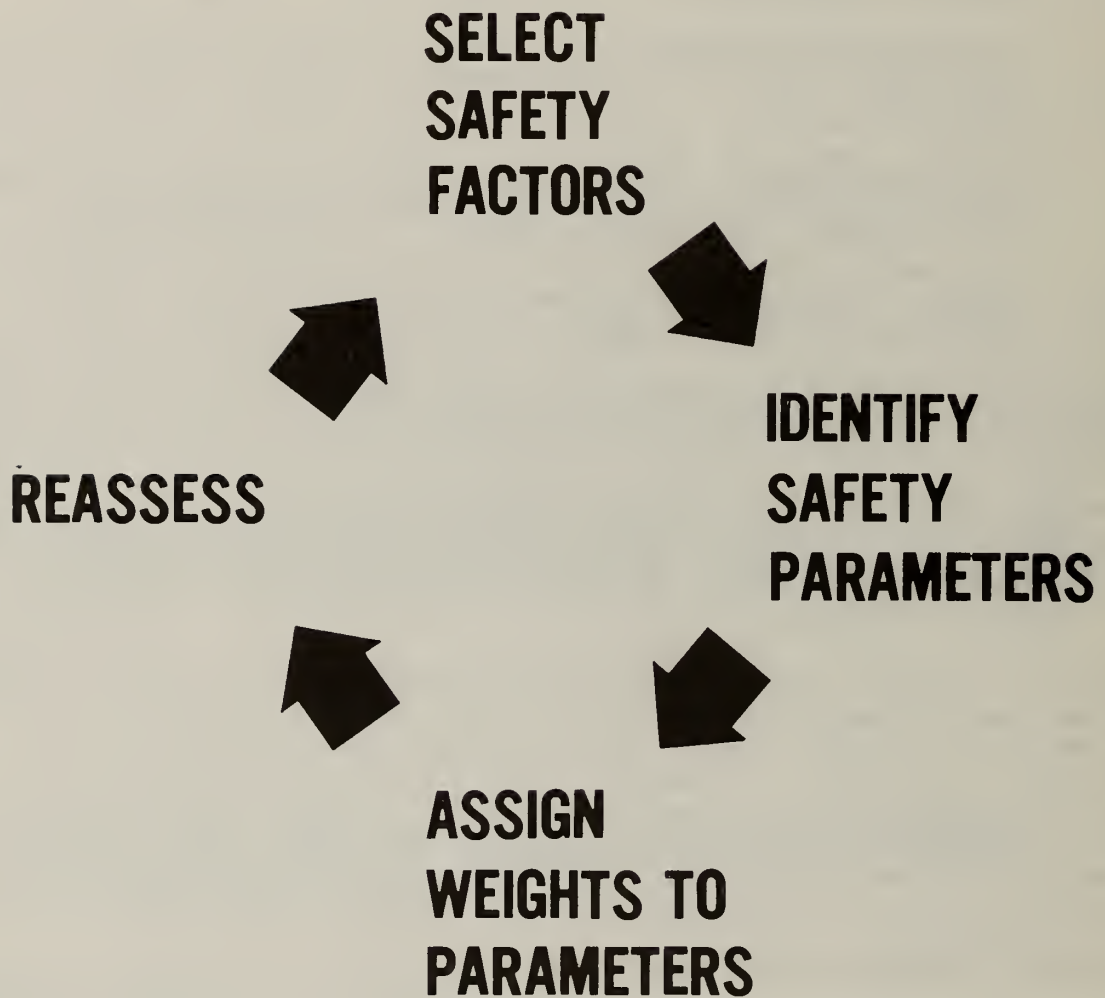
The first step in the process was to select a set of key safety factors. These factors were related to the concepts of "occupancy risk" and "building safety features" mentioned earlier. (For example, occupancy risk includes as a factor, patient mobility; building safety features includes as a factor, interior finish in the corridor and exits.) The second step focused upon the identification of a set of states associated with each factor. (For example, patient mobility includes as states mobile, limited mobility, not mobile, not movable. Interior finishes in the corridor and exists includes Class A, Class B, and Class C flame spread ratings as states.) The third and most critical step was to assign a weight to each state which best reflects either the relative risk posed by the state or its net contribution to life safety. More specifically, negative values reflected greater risks whereas positive values contributed toward a higher level of safety within the fire zone.[1] The system treats a value of zero as "safety" neutral. (The values for the three states associated with the safety factor interior finish in the corridor and exits are: Class C, -5 points; Class B, 0 points; and Class A, 3 points.) In the fourth step, each state value assigned by the panel is reassessed for adequacy and consistency. In the event that the system which emerged from the panel was shown to be inadequate or inconsistent, the entire four-stage process was repeated. The end result of the panel's work was a series of worksheets which permitted the relative merits of each state within the FSES to be carefully assessed. These worksheets are presented as exhibits 1.1 through 1.4.

It is important to point out that the tables illustrated in exhibits 1.1 through 1.4 may differ slightly from those presented in the report by Nelson and Shibe. The source of the differences relates to changes made by the NFPA committees charged with incorporating the Fire Safety Evaluation System into the Life Safety Code. Since Appendix C of NFPA is the official version of the Fire Safety Evaluation System for measuring equivalence to the 1981 edition of the Life Safety Code, it was decided to include these tables rather than those published in the report by Nelson and Shibe.

Since each of the 13 building safety features (see table 1.1 for hospitals and table 1.2 for nursing homes) has a unique state which corresponds to prescriptive compliance, it was possible to compute the score, or level of safety, provided by the Life Safety Code for Extinguishment, Containment and People Movement Safety. These values were then used as a base which any alternative to prescriptive compliance to the Life Safety Code had to match or exceed.

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[1] A fire zone is defined as a space separated from all other spaces by floors, horizontal exits, or smoke barriers.

The first worksheets, shown as exhibit 1.1, consist of a brief description of the fire zone and the means for calculating occupancy risk. Occupancy risk is calculated by selecting the appropriate value for each of the five factors shown in the part of exhibit 1.1 corresponding to Table 1 of the FSES. These values are then entered into the coded spaces in FSES Table 2 (see exhibit 1.1) and multiplied together to get an unadjusted occupancy risk factor. The resultant is then entered either in FSES Table 3A (see exhibit 1.1) if the building is new or in FSES Table 3B if the building is existing.[1] The occupancy risk factor for the fire zone is then calculated by taking the product of the weighting factor and the unadjusted occupancy risk factor. The occupancy risk factor is then used to establish the minimum level of General Safety which must be provided by the 13 building safety features in order to be deemed in compliance to the Life Safety Code.

The second worksheet, Table 4 of the FSES, shown as exhibit 1.2, provides the foundation for the FSESCM computer program. It gives the scores associated with all possible states within each of the 13 building safety features. To evaluate each fire zone, it is first necessary to identify the appropriate value associated with each of the 13 building safety features. The existing state of the fire zone is then defined by recording (circling, marking, or checking) all of these values on FSES Table 4 (exhibit 1.2). In the evaluation, it is important to point out that the level of each building safety feature is determined by the worst-case condition within the fire zone. Referring once again to exhibit 1.2 it can be seen, for each building safety feature, that those states which have a higher score represent potential retrofits. For example, if in the current state the flame spread rating on interior finishes in the corridor and exits was Class C, then both Class B and Class A flame spread ratings would be potential retrofits. More importantly, by combining the improvement in score with the anticipated retrofit costs, it is possible to establish a means for upgrading the level of fire safety within the fire zone in the most cost-effective manner.

The third worksheet, FSES Table 5, is shown in exhibit 1.3. Exhibit 1.3 provides a means for calculating the score associated with the four safety redundancy requirements. (The four safety redundancy requirements are: (1) Containment Safety; (2) Extinguishment Safety; (3) People Movement Safety; and (4) General Safety.) In order to calculate the score for each of the safety redundancy requirements, it is necessary to enter the state value identified in Table 4 of the FSES as corresponding to the existing state of the building safety feature into the appropriate spaces in the coded rows of exhibit 1.3. (No values are entered in the shaded spaces of exhibit 1.3.) Each of the four columns is then summed to get an overall score. These scores are labeled $S_1$, $S_2$, $S_3$ and $S_G$ in exhibit 1.3.

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[1]NFPA 101 defines an existing building as one already in existence when the code went into effect.

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Table 1.1 Values of Safety Parameters Corresponding to Prescriptive
Compliance to the Life Safety Code for Hospitals

| Building Safety Feature | Building Type | | | |
| --- | --- | --- | --- | --- |
| | New 1-Story (1) | New More Than 1-Story (2) | Existing 1-Story (3) | Existing More Than 1-Story (4) |
| | Prot. Non-Comb. | Fire Resistive | Prot. Non-Comb. | Fire Resistive |
| 1. Construction | 2 | 4 | 2 | 4 |
| 2. Interior Finish [Corr. & Exit] | Class A | Class A | Class B | Class B |
| | 3 | 3 | 0 | 0 |
| 3. Interior Finish [Rooms] | Class B | Class B | Class B | Class B |
| | 1 | 1 | 1 | 1 |
| 4. Corridor Partitions/Walls | >1 hr | >1 hr | 1/3-1 hr | 1/3-1 hr |
| | 2 | 2 | 1 | 1 |
| 5. Doors to Corridor | >20 min | >20 min | >20 min | >20 min |
| | 1 | 1 | 1 | 1 |
| 6. Zone Dimensions[a] | 100'-150' | 100'-150' | 100'-150' | 100'-150' |
| | 0 | 0 | 0 | 0 |
| 7. Vertical Openings | Not Applicable | 2 hr | Not Applicable | 1-2 hr |
| | 0 | 3 | 0 | 2 |
| 8. Hazardous Areas | No Deficiencies | No Deficiencies | No Deficiencies | No Deficiencies |
| | 0 | 0 | 0 | 0 |
| 9. Smoke Control | Smoke Part. | Smoke Part. | Smoke Part. | Smoke Part. |
| | 0 | 0 | 0 | 0 |
| 10. Emergency Movement Routes | Multiple Routes | Multiple Routes | Multiple Routes | Multiple Routes |
| | 0 | 0 | 0 | 0 |
| 11. Manual Fire Alarm | With FD Conn. | With FD Conn. | With FD Conn. | With FD Conn. |
| | 2 | 2 | 2 | 2 |
| 12. Smoke Detection & Alarm | None | None | None | None |
| | 0 | 0 | 0 | 0 |
| 13. Automatic Sprinklers | None | None | None | None |
| | 0 | 0 | 0 | 0 |
| TOTAL VALUE | 11 | 16 | 7 | 11 |

[a]No dead ends greater than 30 feet and corridor length is as recorded.

Table 1.2  Values of Safety Parameters Corresponding to Prescriptive
Compliance to the Life Safety Code for Nursing Homes

| Building Safety Feature | Building Type | | | |
|---|---|---|---|---|
| | New 1-Story (1) | New More Than 1-Story (2) | Existing 1-Story (3) | Existing More Than 1-Story (4) |
| | Prot. Non-Comb. | Fire Resistive | Prot. Non-Comb. | Fire Resistive |
| 1.  Construction | 2 | 4 | 2 | 4 |
| 2.  Interior Finish [Corr. & Exit] | Class A | Class A | Class B | Class B |
| | 3 | 3 | 0 | 0 |
| 3.  Interior Finish [Rooms] | Class B | Class B | Class B | Class B |
| | 1 | 1 | 1 | 1 |
| 4.  Corridor Partitions/Walls | >1 hr | >1 hr | 1/3-1 hr | 1/3-1 hr |
| | 2 | 2 | 1 | 1 |
| 5.  Doors to Corridor | >20 min | >20 min | >20 min | >20 min |
| | 1 | 1 | 1 | 1 |
| 6.  Zone Dimensions[a] | 100'-150' | 100'-150' | 100'-150' | 100'-150' |
| | 0 | 0 | 0 | 0 |
| 7.  Vertical Openings | Not Applicable | 2 hr | Not Applicable | 1-2 hr |
| | 0 | 3 | 0 | 2 |
| 8.  Hazardous Areas | No Deficiencies | No Deficiencies | No Deficiencies | No Deficiencies |
| | 0 | 0 | 0 | 0 |
| 9.  Smoke Control | Smoke Part. | Smoke Part. | Smoke Part. | Smoke Part. |
| | 0 | 0 | 0 | 0 |
| 10. Emergency Movement Routes | Multiple Routes | Multiple Routes | Multiple Routes | Multiple Routes |
| | 0 | 0 | 0 | 0 |
| 11. Manual Fire Alarm | With FD Conn. | With FD Conn. | With FD Conn. | With FD Conn. |
| | 2 | 2 | 2 | 2 |
| 12. Smoke Detection & Alarm | Corridor Only | Corridor Only | None | None |
| | 2 | 2 | 0 | 0 |
| 13. Automatic Sprinklers | None | None | None | None |
| | 0 | 0 | 0 | 0 |
| TOTAL VALUE | 13 | 18 | 7 | 11 |

[a]No dead ends greater than 30 feet and corridor length is as recorded.

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Exhibit 1.1   Occupancy Risk Factor Calculation Worksheets

## Table 1.    OCCUPANCY RISK PARAMETER FACTORS

**RISK PARAMETERS**                    **RISK FACTOR VALUES**

**1. PATIENT MOBILITY (M)**

| MOBILITY STATUS | MOBILE | LIMITED MOBILITY | NOT MOBILE | NOT MOVABLE |
|---|---|---|---|---|
| RISK FACTOR | 1.0 | 1.6 | 3.2 | 4.5 |

**2. PATIENT DENSITY (D)**

| PATIENT | 1-5 | 6-10 | 11-30 | >30 |
|---|---|---|---|---|
| RISK FACTOR | 1.0 | 1.2 | 1.5 | 2.0 |

**3. ZONE LOCATION (L)**

| FLOOR | 1ST | 2ND OR 3RD | 4TH TO 6TH | 7TH AND ABOVE | BASE-MENTS |
|---|---|---|---|---|---|
| RISK FACTOR | 1.1 | 1.2 | 1.4 | 1.6 | 1.6 |

**4. RATIO OF PATIENTS TO ATTENDANTS (T)**

| PATIENTS | 1-2 | 3-5 | 6-10 | >11 | ONE OR* MORE |
|---|---|---|---|---|---|
| ATTENDANT | 1 | 1 | 1 | 1 | NONE |
| RISK FACTOR | 1.0 | 1.1 | 1.2 | 1.5 | 4.0 |

**5. PATIENT AVERAGE AGE (A)**

| AGE | UNDER 65 YEARS AND OVER 1 YEAR | 65 YEARS & OVER 1 YEAR & YOUNGER |
|---|---|---|
| RISK FACTOR | 1.0 | 1.2 |

**\* RISK FACTOR OF 4.0 IS CHARGED TO ANY ZONE THAT HOUSES PATIENTS WITHOUT ANY STAFF IN IMMEDIATE ATTENDANCE**

### Table 2.  OCCUPANCY RISK FACTOR CALCULATION

OCCUPANCY RISK    $\boxed{\phantom{M}}^{M}$ × $\boxed{\phantom{D}}^{D}$ × $\boxed{\phantom{L}}^{L}$ × $\boxed{\phantom{T}}^{T}$ × $\boxed{\phantom{A}}^{A}$ = $\boxed{\phantom{F}}^{F}$

### Table 3A. (NEW BUILDINGS)

$1.0^{X} \boxed{\phantom{F}}^{F} = \boxed{\phantom{R}}^{R}$

### Table 3B. (EXISTING BUILDINGS)

$0.6^{X} \boxed{\phantom{F}}^{F} = \boxed{\phantom{R}}^{R}$

| Table 4. | SAFETY PARAMETERS VALUES | | | | | | |
|---|---|---|---|---|---|---|---|
| **PARAMETERS** | **PARAMETERS VALUES** | | | | | | |
| **1. CONSTRUCTION** | **COMBUSTIBLE** | | | | **NON-COMBUSTIBLE** | | |
| | WOOD FRAME | | ORDINARY | | | | |
| FLOOR OF ZONE | UNPROTECTED | PROTECTED | UNPROTECTED | PROTECTED | UNPROTECTED | PROTECTED | FIRE RESIST. |
| FIRST | −2 | 0 | −2 | 0 | 0 | 2 | 2 |
| SECOND | −7 | −2 | −4 | −2 | −2 | 2 | 4 |
| THIRD | −9 | −7 | −9 | −7 | −9 | 2 | 4 |
| 4TH & ABOVE | −13 | −7 | −13 | −7 | −9 | −7 | 4 |

| **2. INTERIOR FINISH (Corr. & Exit)** | CLASS C | CLASS B | CLASS A | | | |
|---|---|---|---|---|---|---|
| | −5 | 0 | 3 | | | |

| **3. INTERIOR FINISH (Rooms)** | CLASS C | CLASS B | CLASS B | | | |
|---|---|---|---|---|---|---|
| | −3 | 3 | 3 | | | |

| **4. CORRIDOR PARTITIONS/WALLS** | NONE OR INCOMPLETE | <1/3 HR | >1/3 <1.0 HR | ≥1.0 HR. | | |
|---|---|---|---|---|---|---|
| | −10 (0)* | 0 | 1 (0)* | 2 (0)* | | |

| **5. DOORS TO CORRIDOR** | NO DOOR | <20 MIN.FR | >20 MIN. FR | >20 MIN. FR & AUTO CLOS. | | |
|---|---|---|---|---|---|---|
| | −10 | 0 | 1 (0)+ | 2 (0)+ | | |

| **6. ZONE DIMENSIONS** | DEAD END MORE THAN 100' | DEAD END 50'-100' | DEAD END 30'-50' | NO DEAD ENDS >30' & ZONE LENGTH IS: | | |
|---|---|---|---|---|---|---|
| | | | | ≥150' | 100'−150' | <100' |
| | −6 (0)** | −4 (0)** | −2(0)** | −2 | 0 | 1 |

| **7. VERTICAL OPENINGS** | OPEN 4 OR MORE FLOORS | OPEN 2 OR 3 FLOORS | ENCLOSED WITH INDICATED FIRE RESIST. | | |
|---|---|---|---|---|---|
| | | | <1 HR. | ≥1HR.<2 HR. | ≥2 HR. |
| | −14 | −10 | 0 | 2 (0)++ | 3 (0)++ |

| **8. HAZARDOUS AREAS** | DOUBLE DEFICIENCY | | SINGLE DEFICIENCY | | NO DEFICIENCIES |
|---|---|---|---|---|---|
| | IN ZONE | OUTSIDE ZONE | IN ZONE | IN ADJACENT ZONE | |
| | −11 | −5 | −6 | −2 | 0 |

| **9. SMOKE CONTROL** | NO CONTROL | SMOKE PARTITION | MECH. ASSISTED SYSTEMS BY ZONE | |
|---|---|---|---|---|
| | −5(0)*** | 0 | 3 | |

| **10. EMERGENCY MOVEMENT ROUTES** | <2 ROUTES | MULTIPLE ROUTES | | | |
|---|---|---|---|---|---|
| | | DEFICIENT CAPACITY | W/O HORIZONTAL EXIT(s) | HORIZONTAL EXIT(s) | DIRECT EXIT(s) |
| | −8 | −2 | 0 | 3 | 5 |

| **11. MANUAL FIRE ALARM** | NO MANUAL FIRE ALARM | MANUAL FIRE ALARM | | |
|---|---|---|---|---|
| | | W/O F.O. CONN. | W/F.O. CONN. | |
| | −4 | 1 | 2 | |

| **12. SMOKE DETECTION & ALARM** | NONE | CORRIDOR ONLY | ROOMS ONLY | CORRIDOR & HABIT. SPACE | TOTAL SPACE |
|---|---|---|---|---|---|
| | 0 | 2 | 3 | 4 | 5 |

| **13. AUTOMATIC SPRINKLERS** | NONE | CORRIDOR & HABIT. SPACE | TOTAL SPACE | |
|---|---|---|---|---|
| | 0 | 8 | 10 | |

NOTE:   * Use (0) when item 5 is −10.                          + Use (0) when item 4 is −10.

   ** Use (0) when item 10 is −8.                     ++ Use (0) when item 1 is based on first floor zone

   *** Use (0) in zone with less than 31 patients            or on an unprotected type of construction.
       in existing buildings.

## Table 5. INDIVIDUAL SAFETY EVALUATIONS

| SAFETY PARAMETERS | CONTAINMENT SAFETY $(S_1)$ | EXTINGUISHMENT SAFETY $(S_2)$ | PEOPLE MOVEMENT SAFETY $(S_3)$ | GENERAL SAFETY $(S_G)$ |
|---|---|---|---|---|
| 1. CONSTRUCTION | | | | |
| 2. INTERIOR FINISH (Corr. & Exit) | | | | |
| 3. INTERIOR FINISH (Rooms) | | | | |
| 4. CORRIDOR PARTITIONS/WALLS | | | | |
| 5. DOORS TO CORRIDOR | | | | |
| 6. ZONE DIMENSIONS | | | | |
| 7. VERTICAL OPENINGS | | | | |
| 8. HAZARDOUS AREAS | | | | |
| 9. SMOKE CONTROL | | | | |
| 10. EMERGENCY MOVEMENT ROUTES | | | | |
| 11. MANUAL FIRE ALARM | | | | |
| 12. SMOKE DETECTION & ALARM | | | | |
| 13. AUTOMATIC SPRINKLERS | | | ÷ 2 = | |
| TOTAL VALUE | $S_1 =$ | $S_2 =$ | $S_3 =$ | $S_G =$ |

Exhibit 1.4  Worksheet for Evaluating Fire Zone Safety Equivalency

| Table 6. | MANDATORY SAFETY REQUIREMENTS | | | | | |
|---|---|---|---|---|---|---|
| | CONTAINMENT $S_a$ | | EXTINGUISHMENT $S_b$ | | PEOPLE MOVEMENT $S_c$ | |
| ZONE LOCATION | New | Exist. | New | Exist. | New | Exist. |
| FLOOR 1 | 9 | 5 | 6(4)* | 4 | 6(4)* | 1 |
| ABOVE OR BELOW FLOOR 1 | 14 | 9 | 8(6)* | 6 | 9(7)* | 3 |

\* Use values in parentheses ( ) for hospitals

| Table 7. | ZONE SAFETY EQUIVALENCY EVALUATION | | | | YES | NO |
|---|---|---|---|---|---|---|
| CONTAINMENT SAFETY $(S_1)$ | less | MANDATORY CONTAINMENT $(S_a)$ | $\geq 0$ | $\boxed{\phantom{S_1}}^{S_1} - \boxed{\phantom{S_a}}^{S_a} = \boxed{\phantom{C}}^{C}$ | | |
| EXTINGUISHMENT SAFETY $(S_2)$ | less | MANDATORY EXTINGUISHMENT $(S_b)$ | $\geq 0$ | $\boxed{\phantom{S_2}}^{S_2} - \boxed{\phantom{S_b}}^{S_b} = \boxed{\phantom{E}}^{E}$ | | |
| PEOPLE MOVEMENT SAFETY $(S_3)$ | less | MANDATORY PEOPLE MOVEMENT $(S_c)$ | $\geq 0$ | $\boxed{\phantom{S_3}}^{S_3} - \boxed{\phantom{S_c}}^{S_c} = \boxed{\phantom{P}}^{P}$ | | |
| GENERAL SAFETY $(S_G)$ | less | OCCUPANCY RISK $(R)$ | $\geq 0$ | $\boxed{\phantom{S_G}}^{S_G} - \boxed{\phantom{R}}^{R} = \boxed{\phantom{G}}^{G}$ | | |

The last worksheets provide the means for determining whether or not the fire zone generates a level of fire safety equivalent to that of the Life Safety Code. Basically, this is done by taking the four scores calculated in FSES Table 5 and entering them in the boxes labeled $S_1$, $S_2$, $S_3$ and $S_G$. The user then selects the values from FSES Table 6 (see exhibit 1.4) for Containment Safety, Extinguishment Safety, and People Movement Safety for the appropriate building type and fire zone location. These values are entered in the boxes labeled $S_a$, $S_b$, $S_c$ in FSES Table 7 shown in exhibit 1.4. The occupancy risk factor calculated on the first worksheet is then entered in the box labeled R. Based on these two sets of numbers, it is possible to test if the fire zone provides a level of safety equivalent to the Life Safety Code. This test is performed by determining if the difference between the first set of numbers, $S_1$, $S_2$, $S_3$, and $S_G$, and the second set of numbers, $S_a$, $S_b$, $S_c$, and R, in Table 7 of the FSES is greater than or equal to zero.

In the event that the fire zone fails to pass the equivalency test, it will be necessary to select a retrofit strategy which will ensure that the building safety features produce scores which match or exceed each of the four safety redundancy requirements. A systematic means for doing this which explicitly introduces relative costs into the retrofit decision is the subject of the remainder of this report.

# 2. THE FIRE SAFETY EVALUATION SYSTEM COST MINIMIZER (FSESCM) COMPUTER PROGRAM

## 2.1  THE BASIC METHODOLOGY BEHIND FSESCM

The FSESCM computer program is designed to balance score improvements against the cost of retrofitting so that the least-cost means of achieving compliance to the Life Safety Code can be identified. The core concept behind FSESCM is a mathematical technique known as linear programming. In its usual context linear programming deals with the problem of allocating limited resources among competing activities in an optimal way. At the foundation of any linear programming problem is a mathematical model which describes the problem of concern. In this case, the mathematical model is the Fire Safety Evaluation System. The term "linear" refers to the requirement that all mathematical functions in the model are linear. The term "program" is used in the general sense in that it refers to a plan rather than a computer program per se. The basic reason why all mathematical functions involved in the problem are linear may be explained through reference to Tables 4 and 5 of the FSES. In Table 4, there is a unique level for each building safety feature possible at any one time. This is due to the requirement that the most-hazardous level associated with each building safety feature determines its score. In Table 5, the score for each of the four safety redundancy requirements (Containment Safety, Extinguishment Safety, People Movement Safety, and General Safety) is the sum of the values of the appropriate parameter identified in Table 4 as either the existing state or a potential retrofit.

In addition to the least-cost solution, FSESCM contains a procedure for systematically generating alternative solutions, many of which are close in cost to the optimum. Two groups of alternative solutions are generated to facilitate the design selection process. The first group is based on the input condition of each fire zone. The objective here is to provide an opportunity to force each initial condition to stay in a solution and for each potential retrofit to be in a solution. The second group of solutions is based on a prespecified set of design variable qualifiers. The objective here is to ensure design compatibility across fire zones. Both groups of solutions are generated for each fire zone input. The second group of solutions is used to produce a series of compliance strategies for the entire building within which the key design variable qualifiers are held constant. These solutions are then printed out in ascending order of cost. The added information provided by the alternative solutions should assist health care facility administrators and construction specialists to assess better the costs of code compliance and hence resolve many of the differences of opinion surrounding the cost impacts of fire safety in general and the Life Safety Code in particular. In addition, the information conveyed by the alternative solutions provides an opportunity to introduce the impact that non-construction costs would have on the selection of the "best" retrofit strategy.

The basic methodology behind the FSESCM computer program is summarized in figure 2.1. This figure is a gross-level flowchart of the computer program; it consists of two pages of diagrams. In the discussion which follows, it will be assumed that data on several buildings are being run in a batch mode.

The computations begin with the circular symbol labeled as FSESCM. Prior to the analysis of any data, however, all key variables are first initialized. Background information which includes the facility name and location, the contact person, the type of facility, and a set of cost multipliers is then read in. If the facility type or cost multipliers are out of range, an error message is written and the defective variable is reset to its default value. These errors are not treated as fatal (i.e., they do not cause the run for this building to abort) since it was rationalized that users would benefit more from diagnostics received later on (most of which are associated with fatal errors) if the program were allowed to continue screening their data. Thus although it is possible that the incorrect problem could be solved, due to a default setting, it is more likely that other errors will be encountered later on whose diagnostics will give the user a better idea of where the problem is incorrectly formulated than if the run for the building were aborted after the first block of cards was read. The background information as input or after modification is then printed out for reference and as an aid for comparing the results of different sets of runs for the same building.

The fire zone inputs are then read. This information includes: the location of the fire zone; the number of patients; the risk parameter numbers; the building safety feature numbers; and the critical element counts. If an error is encountered at this time, the logic flow is transferred to statement label C on the second page of the flowchart. Immediately after entering the section of logic which begins with statement label C, the program writes an error message which should enable the user to locate the problem. The model then reads over the remaining data for this building, printing out the information on the cards (up to 20) following the one where the error occurred. If this was not the last building in the batch, then the program is transferred back to the logic flow which follows statement label A, where the program attempts to read the background information on the next building. If this was the last building in the batch, then the program stops. If no error was encountered when the fire zone inputs were read, then an input summary is printed out as well as the estimated costs for each retrofit state in Table 4 of the FSES which was deemed feasible.

The control card(s) for the fire zone are then read within the section of logic which follows statement label D on the first page of the flowchart. If an error is encountered on a control card, the logic flow is transferred to statement label C and the operations discussed above are performed. If no error was encountered, then the program will check if a solution is desired. If so, the logic flow is transferred to statement label E on the second page of the flowchart.

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Figure 2.1  Flowchart of the FSESCM Computer Program

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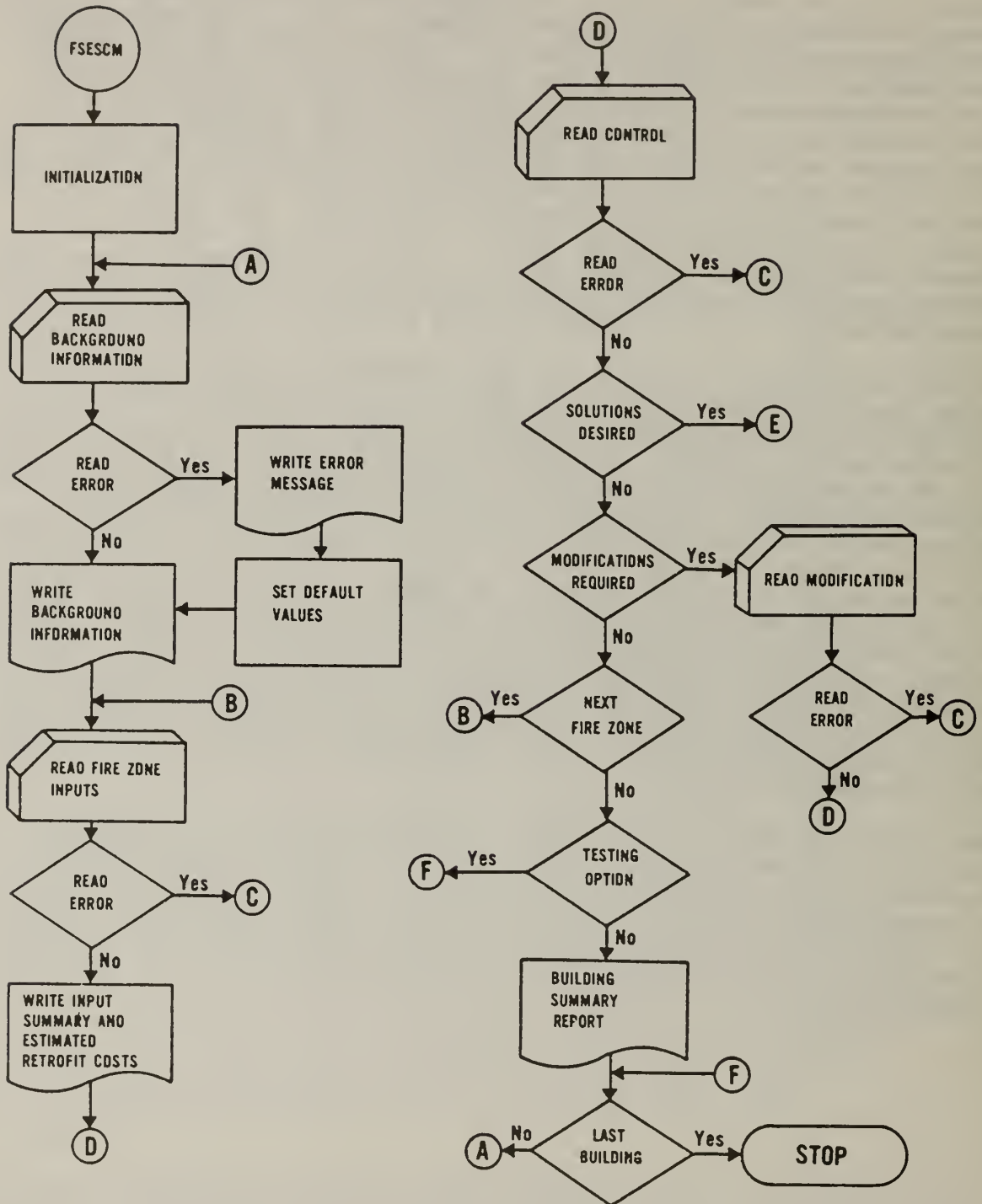
Figure 2.1  Flowchart of the FSESCM Computer Program (continued)
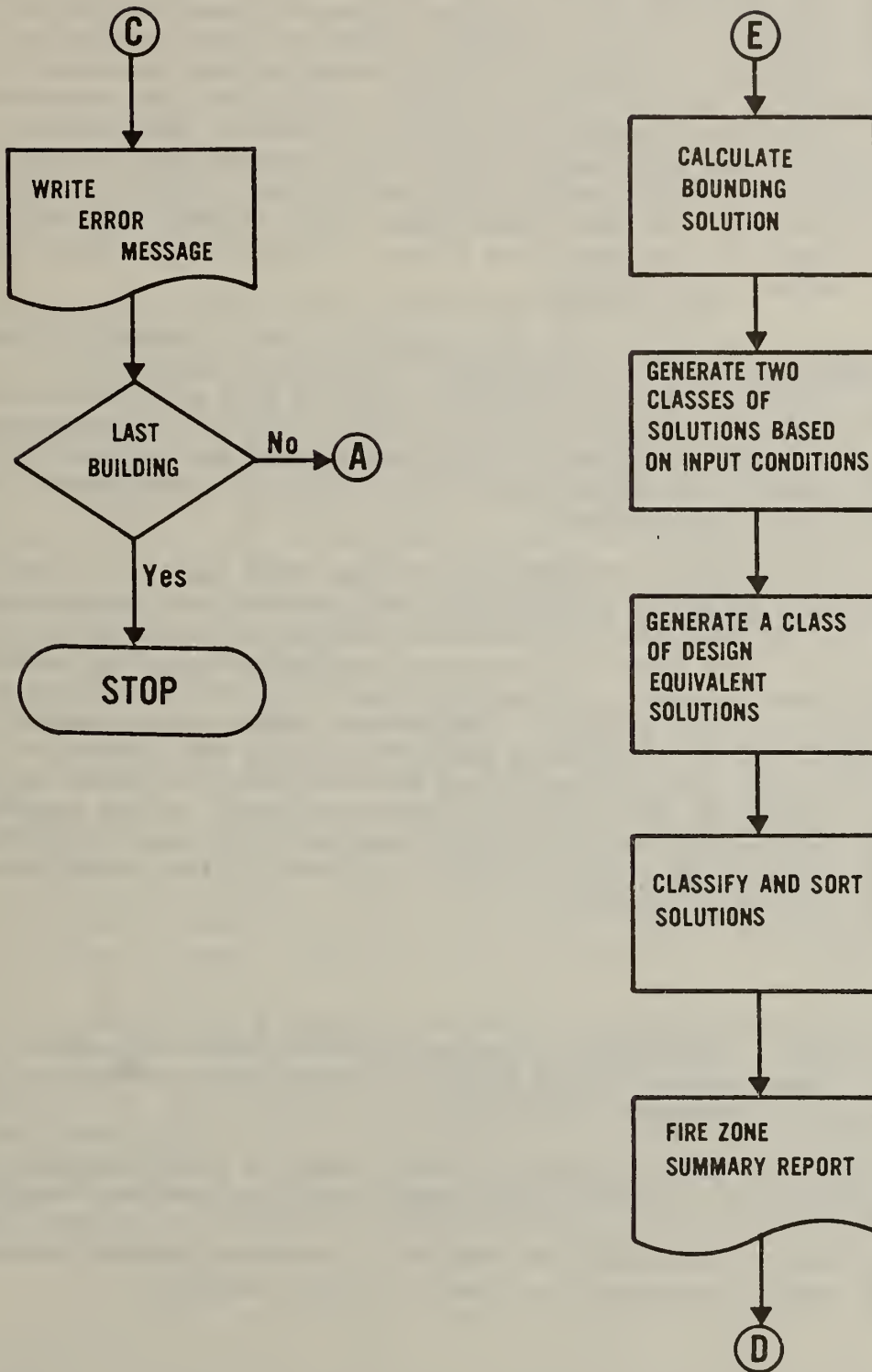
The logic associated with the four processing symbols (shown below statement label E) is as follows. First, the linear programming relaxation[1] is solved and stored as a bounding solution and an advanced starting point[2] for all future solutions for this fire zone. The two classes of solutions discussed earlier are then generated based on the input values for each of the 13 building safety features. A class of design equivalent solutions for use in matching common retrofit strategies across fire zones is then generated. The program then classifies and sorts all solutions. Once all four processes have been completed, a Fire Zone Summary Report is printed out. This report includes data on the fire zone location and a set of information on each solution generated (the post-retrofit state name for each building safety feature, any surplus over the safety requirement (i.e., $S_a$, $S_b$, $S_c$, and R), and the cost to comply). The logic flow is then returned to statement label D where the next control card is read.

Following the logic flow down to the second decision block beneath statement label D and assuming no solution is desired, the program checks if a modification is required. If so, the modification is read and checked for correctness. If an error is encountered, the logic flow is transferred to statement label C where the operations described earlier are carried out. If no error was encountered, then the logic flow is returned to statement label D where the next control card is read.

Returning to statement label D, following the logic flow down to the third decision block and assuming no modifications are required, the program checks if all fire zones for this building have been analyzed. If more fire zones are to be analyzed, the logic flow is transferred to statement label B, where data on the next fire zone are read. The program then checks if the testing option has been exercised for this building. The testing option permits users to check their input data for consistency without incurring the costs of generating the various classes of solutions for the first fire zones and then encountering a fatal error on one of the last fire zones.[3] If the testing option for the building has been exercised, then the logic flow skips down to statement label F where the program checks if this is the last building in the batch. If so, the program stops.

---

[1] The formulation associated with the FSES is actually a 0-1 integer programming problem. FSESCM uses a heuristic post-processor to ensure integrality. Those readers wishing a detailed discussion of the algorithm are referred to the Programmer's Manual.

[2] The advanced starting point permits all other solutions to be generated with only a fraction of the iterations which would otherwise have been required.

[3] The solutions from a previous batch run for a particular building are not stored, so it would be necessary to rerun the entire building.

If the testing option has not been exercised, then this is the last fire zone
for the building under consideration, then the Total Building Summary Report
is output. This report is divided into two parts. The first part shows for
each design classification: the design variable qualifiers; the total cost
for the building; and the cost of prescriptive compliance for the building.
The second part shows for each fire zone: the fire zone location; the post-
retrofit name for each building safety feature; any surplus over the safety
requirement; and the cost to comply for that fire zone. The program then
checks if this is the last building in the batch. If it is not, then the
logic flow is transferred to statement label A where the program attempts to
read the background information on the next building. If this is the last
building in the batch, then all buildings have been analyzed and the program
stops.

## 2.2 DATA REQUIREMENTS, USER OPTIONS AND RESTRICTIONS

All data used as inputs to the FSESCM computer program are designed so that
they can be easily and reliably collected at the same time as the facility is
evaluated. The inputs are tied closely to the various tables of the FSES.
Particular emphasis is placed on tying the computer program to Table 4 of the
FSES since it occupies a central position in the optimization problem. Once
each fire zone has been evaluated (i.e., a complete set of FSES worksheets
have been filled out), it will be necessary to identify a set of potential
retrofits. At this stage, engineering judgment should be used to preclude any
retrofits which are technically infeasible. It is important to include as many
retrofits as possible, however, so that the solution to the optimization
problem is not predetermined.

There are two basic types of information required to run the FSESCM computer
program. The first type is designated as "background information" (see table
2.1). This information covers such items as the name and location of the
facility, who to contact if a question arises and the type of building being
analyzed. The second type is designated as "specific information" and refers
to data which must be input for each fire zone. These data are used to set up
the optimization problem; they are also summarized in table 2.1. In addition,
the user has available a set of options which affect the optimization problem
in a variety of ways. Each option and its effect on the solution is
described in table 2.2.

Once a set of potential retrofits has been identified, it becomes necessary to
count the number of elements which must be retrofitted in order to move to a
higher state. The elements are designed to capture all possible state
transitions within Table 4 of the FSES. Since some states within Table 4 are
not associated with a single element; it was necessary to develop a worksheet
which lists those building components which must be retrofitted in order to
move from one state within a building safety feature to another. This
worksheet as well as the retrofit measures which the data from the worksheet

permit the program to consider are discussed in detail in chapter 3. Data on the critical elements (e.g., the number of elements associated with all of the "no door" charges within the fire zone that would have to be retrofitted) are read into an "element count matrix". The total cost of each potential retrofit is then calculated by multiplying the element count matrix by its appropriate element cost matrix. It is important to point out that the user has the option to modify both the cost of a particular retrofit and the score required to pass.

The program does have several limitations which may be important in certain instances. First, the costing procedure used in the model is limited to the costs of installing (including any demolition and removal costs) all possible combinations of the fire safety measures defined in FSES Table 4. Consequently, any costs which are not construction related (e.g., lost revenues, future operation and maintenance costs and insurance differentials) are not included. If these costs are deemed sufficiently important, a life-cycle cost analysis of the alternatives which result from this procedure should be performed. The accuracy of the costs presented by the model should be sufficient to discriminate among alternative solutions; however, they should not be used as a firm figure for actually carrying out the work.

Second, FSESCM does not contain a procedure for estimating the costs of mechanically assisted smoke control systems. Thus, if a transition to a mechanically assisted system is desired, users must input their own cost estimates via the CHANGE option (see table 2.2). A similar limitation exists for the direct exit state for emergency movement routes. Users can, however, input their own cost estimate using the CHANGE option. There are two states listed in FSES Table 4 which FSESCM treats as impossible; these are cases where a hazardous area has either a double or single deficiency outside the fire zone. These states are precluded because the entire cost of upgrading the deficiency is allocated to the fire zone where the deficiency occurs. If a building enters with such a set of deficiencies which can not be removed, then the user must preclude all states but the one input for each hazardous area. Since this will affect the set of solutions based on a prespecified set of design variable qualifiers, its use is not recommended.[1]

Third, the current procedure for insuring the compatibility of a set of designs for the entire facility, imposes a limitation of 10 fire zones for any one building. This limitation can be relaxed however, by merely increasing one set of storage capacity statements. Finally, the way in which alternative solutions are generated may not provide enough flexibility for some specific uses. In such a case, modifications to the source code will be required. Guidelines for modifying the way in which the alternative solutions are generated are given in the Programmer's Manual.

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[1] In the event that hazardous areas in some fire zones can be upgraded and others can not, it will be necessary for the user to identify all adjacent fire zones where no upgrades can occur. The worst deficiency in the adjacent fire zone will then determine the score for the fire zone under consideration.

Table 2.1 Input Data Requirements for the FSESCM Computer Program

| Major Heading | Item | Purpose |
|---|---|---|
| Background Information | Facility Name and Location | Mailing label for the finished run. |
| | Contact Person and Telephone Number | Who to talk to for more information. |
| | Building Type | Specifies columns of Table 6 of the FSES*. |
| | Cost Multipliers | Adjusts relative costs for cost growth over time and for regional price differentials in labor and material. |
| Specific Information | Fire Zone Location | Specifies the row of Table 6 of the FSES*. Affects the scores of construction and vertical openings parameter. |
| | Number of Patients | Affects the score of the smoke control parameter. |
| | Risk Parameters | Determines the value of the General Safety requirement. See Table 1 of the FSES. |
| | Building Safety Feature Numbers | Determines the current scores for all four safety attributes. Constrains the retrofit options to those parameters with a higher state number. |
| | Element Counts | Shows minimum number of deficient elements which must be treated to move to a higher state. |
| | | Entered for each building safety feature. See section 3.2. |
| | Options | Tells program what to do or look for next. See table 2.2. |

*Table 6 of the FSES defines the mandatory safety requirements for Containment, Extinguishment and People Movement Safety.

Table 2.2   User Options Available with the FSESCM Computer Program

| Option | Purpose |
|--------|---------|
| SOLVE | Causes an optimum solution for the fire zone input to be generated. A set of retrofit strategies which satisfy all of the requirements of the Life Safety Code as well as several building design criteria is also generated. |
| CHANGE | Adjusts the state transition cost to the value specified by the user. |
| REQUIR | Increases a safety requirement by a percentage specified by the user. |
| NEXT | Tells the program to look for data on the next fire zone or the next building. |
| LAST | Signals that all data for the building under study has been analyzed and that the solutions for the total building should be output. |
| TEST | Checks all input data for consistency. |
| FINAL | Tells the program to stop; all data for the run have been input. |

## 2.3 THE PROGRAM OUTPUT

The information printed out by the FSESCM computer program fits into three major output classifications, which are summarized in table 2.3. Each output classification is described briefly in the text which follows. A detailed description based on a case application is presented in chapter 4.

The first class consists of background information and includes a title page and Tables 1, 6 and 4 of the FSES. The title page also serves as a mailing label and identifies the appropriate staff member to contact in the event that a problem is encountered in analyzing the facility. The three tables from the FSES are included in order to show how the occupancy risk factors are used to calculate the General Safety requirement, what values for Containment, Extinguishment and People Movement Safety are required for equivalence, and the full range of state values which contribute toward fire zone safety.

The second class consists of reference data and solutions. This class is output for each fire zone. These outputs consist of a summary of all data input for the fire zone, the estimated costs of moving from the input state to each potential retrofit, and all distinct solutions generated for the fire zone. The Input Summary Report provides the user with a concise statement of the data used in setting up the problem for solution. It provides the user an opportunity to check the correctness of any values input as well as a means of differentiating among several runs for the same fire zone. This report shows the location of the fire zone, the number of patients and the appropriate set of occupancy risk factors for the fire zone under study. Data on each of the 13 building safety features are then printed out. The costs of moving from the input state to all potential retrofits are then presented. The Summary of Estimated Retrofit Costs Report includes the location of the fire zone and three types of contruction cost modifiers. The data show the input and prescriptive state and the estimated cost of going to each potential retrofit. The cost of prescriptive compliance for the fire zone is also shown as a basic reference point. The Fire Zone Summary Report is then output. This report shows each distinct solution generated as a line of output. In order to easily identify a particular solution and for ease in differentiating among solutions, the state name is printed beneath each of the 13 building safety feature column headings. The state names closely resemble and hence can be easily matched to the labels in Table 4 of the FSES. The order in which the solutions are output is based on the 40 design classifications listed in table 2.4.[1] All solutions are ranked from least costly to most costly within a design classification; so if more than one solution was generated, the least costly is printed first followed by the second, until all solutions for that design classification are output.

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[1]In interpreting the information presented in table 2.4, readers should recognize that the term "INPUT" under the smoke detection and alarm and automatic sprinklers headings refers to the initial condition of that building safety feature rather than a specific state. If more than one fire zone is to be evaluated, it is possible for differences to exist in the level of protection provided by smoke detectors and/or sprinklers. More reasonable solutions can therefore be expected by working with the input conditions then the two "none" states.

Table 2.3  Outputs of the FSESCM Computer Program

| Output Classification | Report Name | Information Reported |
|---|---|---|
| Background Information | Title Page<br>FSES Tables | Facility Name and Address, Contact Person, Telephone Number.<br>Table 1 (Occupancy Risk), Table 6 (Safety Requirements),<br>Table 4 (Building Safety Features). |
| Reference Data and Solutions | Input Summary<br><br>Summary of Estimated Retrofit Costs<br><br><br>Fire Zone Summary | Fire Zone Location, Patient Count, Table 1 (State Number),<br>Table 4 (Input, Prescriptive, Element Counts).<br>Fire Zone Location, Time/Regional Cost Modifiers,<br>Table 4 (Input, Prescriptive, Transition Costs),<br>Prescriptive Compliance Cost.<br>Fire Zone Location, For Each Solution by Design<br>Classification (Post-Retrofit State Name for Each<br>Building Safety Feature, Surplus Over Each Safety<br>Requirement, Cost to Comply for that Fire Zone). |
| Design Solutions | Total Building Summary | For Each Design Classification (Design Variable Qualifiers,<br>Total Cost for the Building, Prescriptive Compliance Cost<br>for the Building), For Each Fire Zone (Fire Zone Location,<br>Post-Retrofit State Name for Each Building Safety Feature,<br>Surplus Over Each Safety Requirement, Cost to Comply for<br>That Fire Zone). |

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The program then outputs the solution(s) for the next design classification for which at least one solution was generated until the list is exhausted. The prescriptive compliance solution is then output. Three other groups of solutions are also output. They are: (1) solutions which have no deficiencies in hazardous areas but do not belong to one of the design classifications; (2) solutions which have a single deficiency in a hazardous area; and (3) solutions which have a double deficiency in a hazardous area.

The third class of outputs consists of the best solutions by design classification for the entire building. The design classification solutions are generated and stored for each fire zone. Once all data on the fire zones have been input and analyzed, all solutions are screened. The ones which match the prespecified set of design variable qualifiers are identified. If every fire zone input has at least one solution which was identified as a member of the design classification under consideration, then a Total Building Summary Report is generated. This report gives the design variable qualifiers, the total cost of retrofitting the building for this design classification and the total cost of prescriptive compliance for the building under study. The prescriptive solution serves as a bench mark for comparison. The design classification solutions are printed out in ascending order of estimated retrofit cost for the entire building to facilitate comparison among competing design alternatives. In order to facilitate the identification of each solution, the state names for each of the 13 building safety features are printed out as are the surpluses and retrofit cost for each fire zone. Each fire zone takes up one line in the printout. If one or more fire zones did not contain this design class, no printout for the entire building is generated. Should the user wish such a retrofit, it would be necessary to synthesize it from the individual fire zone printouts.

Table 2.4  Design Variable Qualifiers Used in Establishing the 40
Design Classifications

| Hazardous Areas | Construction | Zone Dimensions | Emergency Movement Routes | Smoke Detection and Alarm | Automatic Sprinklers |
|---|---|---|---|---|---|
| NO DEF | RESIST | NO DED | HOR*EX | INPUT | INPUT |
| NO DEF | PROTECT | NO DED | HOR*EX | INPUT | INPUT |
| NO DEF | RESIST | DED*30 | HOR*EX | INPUT | INPUT |
| NO DEF | PROTECT | DED*30 | HOR*EX | INPUT | INPUT |
| NO DEF | RESIST | NO DED | NO H*E | INPUT | INPUT |
| NO DEF | PROTECT | NO DED | NO H*E | INPUT | INPUT |
| NO DEF | RESIST | DED*30 | NO H*E | INPUT | INPUT |
| NO DEF | PROTECT | DED*30 | NO H*E | INPUT | INPUT |
| NO DEF | RESIST | NO DED | HOR*EX | CORHAB | INPUT |
| NO DEF | PROTECT | NO DED | HOR*EX | CORHAB | INPUT |
| NO DEF | RESIST | DED*30 | HOR*EX | CORHAB | INPUT |
| NO DEF | PROTECT | DED*30 | HOR*EX | CORHAB | INPUT |
| NO DEF | RESIST | NO DED | NO H*E | CORHAB | INPUT |
| NO DEF | PROTECT | NO DED | NO H*E | CORHAB | INPUT |
| NO DEF | RESIST | DED*30 | NO H*E | CORHAB | INPUT |
| NO DEF | PROTECT | DED*30 | NO H*E | CORHAB | INPUT |
| NO DEF | RESIST | NO DED | HOR*EX | INPUT | CORHAB |
| NO DEF | PROTECT | NO DED | HOR*EX | INPUT | CORHAB |
| NO DEF | RESIST | DED*30 | HOR*EX | INPUT | CORHAB |
| NO DEF | PROTECT | DED*30 | HOR*EX | INPUT | CORHAB |
| NO DEF | RESIST | NO DED | NO H*E | INPUT | CORHAB |
| NO DEF | PROTECT | NO DED | NO H*E | INPUT | CORHAB |
| NO DEF | RESIST | DED*30 | NO H*E | INPUT | CORHAB |
| NO DEF | PROTECT | DED*30 | NO H*E | INPUT | CORHAB |
| NO DEF | RESIST | NO DED | HOR*EX | TTLZON | INPUT |
| NO DEF | PROTECT | NO DED | HOR*EX | TTLZON | INPUT |
| NO DEF | RESIST | DED*30 | HOR*EX | TTLZON | INPUT |
| NO DEF | PROTECT | DED*30 | HOR*EX | TTLZON | INPUT |
| NO DEF | RESIST | NO DED | NO H*E | TTLZON | INPUT |
| NO DEF | PROTECT | NO DED | NO H*E | TTLZON | INPUT |
| NO DEF | RESIST | DED*30 | NO H*E | TTLZON | INPUT |
| NO DEF | PROTECT | DED*30 | NO H*E | TTLZON | INPUT |
| NO DEF | RESIST | NO DED | HOR*EX | INPUT | TTLBLD |
| NO DEF | PROTECT | NO DED | HOR*EX | INPUT | TTLBLD |
| NO DEF | RESIST | DED*30 | HOR*EX | INPUT | TTLBLD |
| NO DEF | PROTECT | DED*30 | HOR*EX | INPUT | TTLBLD |
| NO DEF | RESIST | NO DED | NO H*E | INPUT | TTLBLD |
| NO DEF | PROTECT | NO DED | NO H*E | INPUT | TTLBLD |
| NO DEF | RESIST | DED*30 | NO H*E | INPUT | TTLBLD |
| NO DEF | PROTECT | DED*30 | NO H*E | INPUT | TTLBLD |

3. GUIDELINES FOR APPLYING THE FSESCM COMPUTER PROGRAM

3.1 AN ANALYSIS OF A TYPICAL HEALTH CARE FACILITY

The purpose of this section is to demonstrate how one would apply the FSESCM program to a typical hospital. The hospital analyzed in the case study is thought to be typical of many facilities since it consists of the original (1917) building and a post World War II addition (1959). The layout of the patient room floors is shown in figure 3.1; the patient room floors are treated as a single fire zone. The overall length of the fire zone is approximately 180 feet. The exterior bearing walls of the original structure do, however, provide an excellent opportunity for installing a horizontal exit to reduce the overall dimensions of the fire zone. Each patient room floor of the facility contains 22 patient rooms and covers a total floor area of 11,000 square feet.

The hospital as constructed has structural steel framing, reinforced concrete floors, fixed windows, and masonary exterior walls. Since all steel columns are bricked, concreted, and/or plastered to provide fire resistance, negligible differences are believed to exist between steel and reinforced concrete framing for the purposes of this study. The facility is modeled as having four fire zones. These zones include: (1) the basement which houses most of the facility's mechanical equipment; (2) the first floor which houses the emergency room and outpatient services; (3) the second floor which consists mainly of laboratories and offices; and (4) the third through ninth floors which are the patient room floors.

An assessment of the facility based on the FSES as described in Appendix C of the Life Safety Code indicated that all fire zones required retrofittng in order to be deemed equivalent. The initial condition for each of the 5 patient risk parameters is summarized in table 3.1. The initial condition for each of the 13 building safety features is summarized in table 3.2. From this information a series of retorfit strategies were hypothesized. The type and nature of each retrofit are presented in the next section, along with the worksheets used to record the critical element counts. A detailed discussion of the critical elements counts for the typical hospital are discussed in section 4.1. The solutions, their interpretation and implications, for this building are described in sections 4.2 and 4.3.

3.2 HOW TO COLLECT THE NECESSARY DATA

As mentioned in section 2.2, the data inputs closely parallel the Tables 1 and 4 of the FSES. This was done both for ease of collection and so that critical elements would neither be omitted nor double counted. In addition, the strategy for data collection closely adheres to the guidelines given in Appendix C of the Life Safety Code.

The remainder of this section is divided into two parts. The first discusses the guidelines given in Appendix C of the Life Safety Code regarding the

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Figure 3.1  Layout of the Patient Room Floors for the Case Study Building
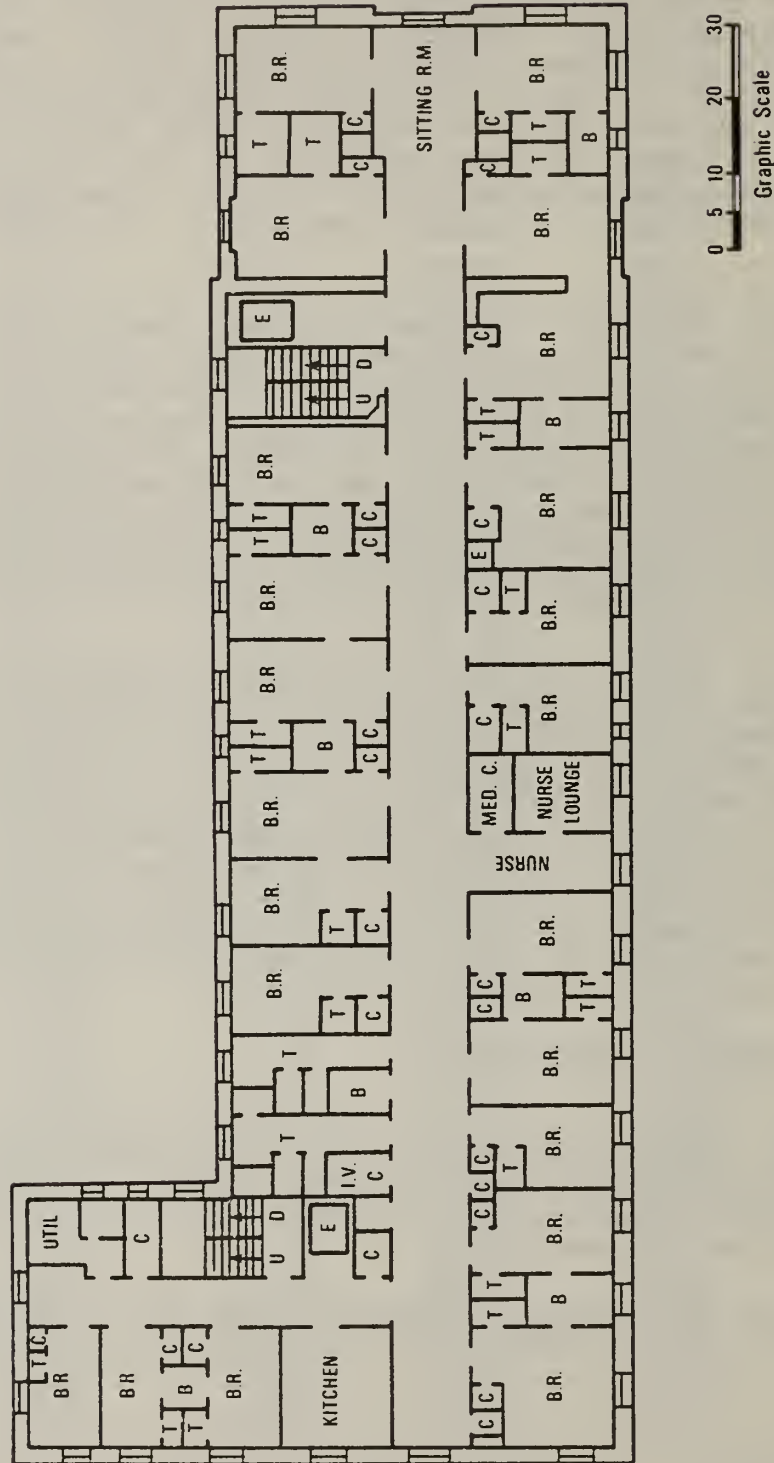
Table 3.1  Summary of Initial Conditions for the Five Patient Risk Parameters[a]

| Parameter | Fire Zone | | | |
| --- | --- | --- | --- | --- |
| | Basement | First Floor | Second Floor | Patient Room Floors |
| Patient Mobility | Mobile | Mobile | Not Movable | Not Movable |
| Patient Density | 1-5 | 1-5 | 11-30 | >30 |
| Zone Location | Basement | First | Second | Seventh and above |
| Ratio to Attendants | 1-2 | 1-2 | 1-2 | 1-2 |
| Patient Average Age | 1<Age<65 | 1<Age<65 | 1<Age<65 | 1<Age<65 |

[a]Based on a worst-case condition within the fire zone.

Table 3.2  Summary of Initial Conditions for the Thirteen Building Safety Features[a]

| Building Safety Feature | Fire Zone | | | |
| --- | --- | --- | --- | --- |
| | Basement | First Floor | Second Floor | Patient Room Floors |
| Construction | Fire Resistive | Fire Resistive | Fire Resistive | Fire Resistive |
| Interior Finish [C&E] | Class A | Class A | Class A | Class A |
| Interior Finish [Rooms] | Class A | Class A | Class C | Class C |
| Corr. Partitions/Walls | >1 Hour | >1 Hour | >1 Hour | >1 Hour |
| Doors to Corridor | No Door | No Door | No Door | No Door |
| Zone Dimensions | >150'NDE[b] | >150'NDE[b] | >150'NDE[b] | DE |
| Vertical Opening | <1 Hour | <1 Hour | <1 Hour | <1 Hour |
| Hazardous Areas | No Deficiencies | Single Deficiency | Single Deficiency | Single Deficiency |
| Smoke Control | Smoke Partition | Smoke Partition | Smoke Partition | Smoke Partition |
| Emergency Movement | <2 Routes | <2 Routes | <2 Routes | Deficient capacity |
| Manual Fire Alarm | With F.D. Connection | With F.D. Connection | With F.D. Connection | With F.D. Connection |
| Smoke Detection & Alarm | None | None | None | None |
| Automatic Sprinklers | Corridor & Habit Space | None | None | None |

[a]Based on a worst-case condition within the fire zone.
[b]NDE = No Dead End
[c]DE 30-50 = Dead End between 30 and 50 feet

selection of fire zones for analysis. The second presents a set of sample worksheets. These worksheets are discussed in detail in this and the next section, where they are related to the input file.

## Selection of Fire Zone to be Evaluated[1]

Obviously, the most comprehensive means of approaching this problem would be to rigorously analyze each and every fire zone in the building. In most cases however, this approach would not be necessary. From a more pragmatic viewpoint, most health care facilites have repetitive arrangements so that a complete picture can be developed by evaluating typical zones until all combinations are evaluated. If several basic criteria are followed, this task becomes relatively straightforward. First, when aggregating zones, the "worst-case condition" within the aggregation must be adhered to strictly. If one or more fire zones are in a much more hazardous condition than others within the aggregation, then consideration should be given to analyzing them separately. If minor differences exist, then they can be easily handled through the critical element counts on the worksheets. Second, consideration should be given to how the post-retrofit building safety features will be maintained. Since the FSESCM model focuses on the initial costs of retrofitting the facility, an inadequate maintenance policy could seriously limit the usefulness of the options provided by the model. The Life Safety Code is quite explicit on this point; Appendix C states that:

> Any protection system, requirements, or arrangement which is not maintained in a dependable operating condition or is used in such a manner that the intended fire safety function or hazard constraint is impaired should be considered as defective and receive no credit in the evaluation.

Finally, the data required to exercise the model must be based on information provided by qualified engineering staff. Ideally, such individuals could have undergone some formal training on the FSES so that familiarity with the terminology and grading system can be assumed.

In terms of which fire zones should be evaluated, the guidelines given in Appendix C of the Life Safety Code are quite explicit. The zones selected should include:

(1) each type of patient zone having a different type of mobility, density, or attendant ratio as classified in FSES Table 1;

(2) each zone that represents a significantly different type of construction, finish or protection system; and

(3) each zone that contains special medical treatment or support activities (operating suites, intensive care units, laboratories).

_____

[1]This section draws heavily on the relevant sections of Appendix C of the Life Safety Code.

A fourth criterion concerns zones not involving housing, treatment, or customary access for patients. Under these circumstances the two following points should be considered. First, any zone, whether used for patient egress or not, may be evaluated on the same basis as a patient use zone. In such case the value of F (unadjusted occupancy risk) in FSES Table 2 shall be assigned the value of L (fire zone location) in FSES Table 1. In such cases, building safety feature 10 (emergency movement routes) shall be graded "deficient capacity" if the exit capacity is less than that prescribed for the actual occupancy of the space as "< 2 routes" if less than 75 percent of the prescribed exit capacity is present. Second, if the zone is separated from all patient use zones by 2-hour fire resistive construction (including any members that bear the load of a patient zone and with Class B fire doors on any communicating openings), it may be excluded from evaluation. In such case, that space shall conform with the portion of the Life Safety Code appropriate to its use. In addition, appropriate charges under building safety feature 8 (hazardous areas) in FSES Table 4 shall be charged against other zones in the facility.

## FSESCM Worksheets

As mentioned earlier, the data required to exercise the FSESCM computer program follows closely the guidelines given in Appendix C of the Life Safety Code regarding the use of the Fire Safety Evaluation System. This relationship is formalized in a set of 16 worksheets. These worksheets may be divided into four distinct categories. The four categories are: (1) background information on the building (Worksheet I); (2) background information on the fire zone (Worksheet II); (3) specific information on each building safety feature (Worksheets III through XV); and (4) control options to be exercised (Worksheet XVI). Table 3.3 provides a brief summary of each FSESCM Worksheet which should serve as a convenient reference point in the discussion which follows.

In responding to the questions posed on each worksheet, users should keep in mind that the sequence with which the information is recorded is crucial. For example, question 1 of Worksheet I requests six pieces of information. This is because the model expects to read information on the: (1) facility name; (2) building name; (3) contact person; (4) address; (5) city, state, zip code; and (6) telephone number of the contact. Consequently, when entering the information into the data file, it is necessary to code in six lines (card images) of data. If six lines of data are not coded in, then the input deck will be out of sequence and the run will abort for the building under analysis. Since element counts are expected for each retrofit, those states which are above the input but are not feasible should have a value of minus one (-1) coded into each space where data on a critical element is requested. If a potential retrofit is feasible, but for some reason one or more of its critical elements do not exist within the fire zone under study, then a value of zero (0) should be entered in the space where data on that critical element is requested.

Table 3.3 FSESCM Worksheets

| Worksheet Number | Worksheet Title | Purpose |
|---|---|---|
| I | Background Information | Mailing label; building type; building qualifier; construction cost modifiers. |
| II | Fire Zone Data | Zone location; current states for FSES Tables 1 and 4. |
| III | Construction | Potential retrofits and critical element counts for the first building safety feature. |
| IV | Interior Finish [Corridors and Exits] | Potential retrofits and critical element counts for the second building safety feature. |
| V | Interior Finish [Rooms] | Potential retrofits and critical element counts for the third building safety feature. |
| VI | Corridor Partitions/ Walls | Potential retrofits and critical elements counts for the fourth building safety feature. |
| VII | Doors to Corridor | Potential retrofits and critical element counts for the fifth building safety feature. |
| VIII | Zone Dimensions | Potential retorfits and critical element counts for the sixth building safety feature. |
| IX | Vertical Openings | Potential retrofits and critical element counts for the seventh building safety feature. |
| X | Hazardous Areas | Potential retrofits and critical element counts for the eighth building safety feature. |
| XI | Smoke Control | Potential retrofits and critical element counts for the ninth building safety feature. |
| XII | Emergency Movement Routes | Potential retrofits and critical element counts for the tenth building safety feature. |
| XIII | Manual Fire Alarm | Potential retrofits and critical element counts for the eleventh building safety feature. |
| XIV | Smoke Detection and Alarm | Potential retrofits and critical element counts for the twelfth building safety feature. |
| XV | Automatic Sprinklers | Potential retrofits and critical element counts for the thirteenth building safety feature. |
| XVI | User Options to be Exercised | Major control options, minor control options, sequencing. |

Worksheet I requests four types of information. The first, a set of six responses, was discussed previously and serves as a mailing label for the run. The second and third designate whether the building under analysis is a hospital or nursing home and its age classification. These responses serve to define the values from FSES Table 6 which are used as mandatory safety requirements and govern the calculation of the occupancy risk factor. The last bit of information is concerned with a set of three factors which are used to adjust for cost growth over time and differences in the labor and materials markets due to local effects. Recall that all costs stored within FSESCM are based on data from the Washington, D.C. area during the summer of 1981. There are numerous sources of information for the values of each of the three factors.

Worksheet II requests background information on the fire zone to be analyzed. Information on the location of the fire zone and the number of patients is entered under question 1. These data are used to recompute certain state values within FSES Table 4 and as a means of controlling the output when a building has more than one fire zone. Next, information on the current FSES Table 1 states is entered under question 2. These data are used to compute the occupancy risk factor for the fire zone. The appropriate value is determined by counting rightward within the appropriate row of FSES Table 1 until the current state is reached. For example, within the row of FSES Table 1 which corresponds to patient mobility, not movable is the fourth state. Finally, information on the current FSES Table 4 states is entered under question 3. These data define lower limits on DO loops through which information on all critical element counts are read in. They signal to the model that data on all states which lie to the right of the current FSES Table 4 state are to be read in. The appropriate value is determined by counting rightward within the appropriate row of FSES Table 4 until the current state is reached. For example, within the first building safety feature, construction, fire resistive non-combustible is the seventh state. (Recall that only one of the four construction rows is appropriate at any one time.)

Worksheet III is the first of the 13 building safety feature worksheets. It deals with construction type. Directions should be followed carefully when completing this worksheet. The model treats information on construction type in a special purpose routine. If the building was initially classified as combustible-wood frame, then no transitions to either the combustible - ordinary or non-combustible states is possible. If, however, the building entered in an unprotected-wood frame state, then a transition to the protected-wood frame state is possible. If the building was originally classified as in a combustible - ordinary state, then no transitions to the non-combustible states is possible. Once again, if the building entered in the unprotected-ordinary state, then a transition to the protected-ordinary state is possible. For those buildings which were initially in a non-combustible state, transition to either the protected or fire resistive states is possible. When preparing the data for input, consideration should be given to sequencing if the building was classified as being in one of the four combustible states.

Worksheets IV and V record information on interior finishes. All information requested on these worksheets is self explanatory with perhaps one exception. This exception relates to the installation of drywall. This retrofit should be considered only if the zone contains Class C or worse paneling.

Worksheet VI records information on corridor partitions/walls. As indicated earlier, most information required is self explanatory. If the zone was initially classified as in the none or incomplete state, in order to avoid double counting, the answers to questions 1.g, 1.h, and 2.h, should be recorded as zero. Similarly, if the zone was initially classified as in the less than 1/3 hour state, the answers to question 2.h should be recorded as zero.

Worksheet VII, doors to corridor, requires special care when being completed. This is due to the ways in which closing devices are evaluated. First, if it can be established that the doors are constantly kept in the normally closed position except when persons are actually passing through the opening, a self closing device shall be considered as equal to an automatic closing device and credited accordingly. Second, if a self closing door is blocked open, it shall be classified as "no door" and the -10 charge invoked.

Worksheet VIII is divided into two parts. The first part requests information on the overall zone length and whether or not a smoke partition can be installed to reduce the zone length. If a smoke partition can be installed, then the model will calculate how many are needed in order to reduce the length of the fire zone to the 100-150 feet and less than 100 feet states. The second part includes space for all critical element counts.

Worksheet IX records information on vertical openings. All entries on this worksheet are self explantory.

Worksheet X is divided into three parts. This approach was taken because hazardous areas within a fire zone may contain one or more: (1) double deficiency areas; (2) single deficiency non-sprinklered areas; or (3) single deficiency sprinklered areas. Within each of the three parts, the user must aggregate information on all such areas within the fire zone. For purposes of sequencing when constructing the input deck, users should keep in mind that FSESCM treats transitions to the double and single deficiency states outside the fire zone as impossible. This subject will be discussed in detail in the section which follows.

Worksheet XI records information on smoke control. Since the mechanically assisted by zone state requires special costing not included in the model, the only element counts possible are those associated with the installation of a smoke partition.

Worksheet XII records information on emergency movement routes. As pointed out earlier, the direct exits state requires special costing not included within the FSESCM model. The element counts associated with transitions to all other states are self explanatory.

Worksheet XIII records information on manual fire alarms. The element counts associated with transitions to all states within this building safety feature are self explanatory.

Worksheets XIV and XV record information on smoke detection and alarm and automatic sprinklers, respectively. Both worksheets are designed around special costing subroutines. A series of cost estimating relationships within each subroutine is used to compute the state transition costs. For automatic sprinklers, the user must specify both the type of sprinkler system and whether or not the water supply is adequate.

Worksheet XVI defines the sequence with which the user options are to be exercised. The responses are divided into two types: major options and minor options. Whereas a major option may be used only once for each fire zone, a minor option may be used repeatedly. The influence on problem structure associated with repeated use of minor options is, however, cumulative.

Exhibit 3.1   Sample Worksheet I:   Background Information

(1) Mailing label:
    (i)    Facility name:  _____;
    (ii)   Building name:  _____;
    (iii) Contact:  _____;
    (iv)  Address:  _____;
    (v)   City, state, zipcode:  _____; and
    (vi)  Telephone number:  _____.

(2) Building type designation:  _____;
    (i)   Hospital:  Designation = 1; and
    (ii)  Nursing Home:  Designation = 2.

(3) Building qualifier:  _____;
    (i)   New single story:  Designation = 1;
    (ii)  New multi story:  Designation = 2;
    (iii) Existing single story:  Designation = 3; and
    (iv) Existing multi story:  Designation = 4.

(4) Construction cost modifiers:
    (i)   Cost growth factor:  _____;
    (ii)  Labor cost differential:  _____;
    (iii) Material cost differential:  _____;

Exhibit 3.2  Sample Worksheet II:  Fire Zone Data

(1) General information:
    (i)    Floor number: _____;
    (ii)   Zone number: _____; and
    (iii)  Number of patients: _____.

(2) FSES Table 1:
    (i)    Patient mobility: _____;.
    (ii)   Patient density: _____;
    (iii)  Zone location: _____;
    (iv)   Ratio of patients to attendants: _____; and
    (v)    Patient average age: _____.

(3) FSES Table 4:
    (i)     Construction: _____;
    (ii)    Interior finish (corridor and exits): _____;
    (iii)   Interior finish (rooms): _____;
    (iv)    Corridor partitions/walls: _____;
    (v)     Doors to corridor: _____;
    (vi)    Zone dimensions: _____;
    (vii)   Vertical openings: _____;
    (viii)  Hazardous areas: _____;
    (ix)    Smoke control: _____;
    (x)     Emergency movement routes: _____;
    (xi)    Manual fire alarms: _____;
    (xii)   Smoke detection and alarm: _____; and
    (xiii)  Automatic sprinklers: _____.

Exhibit 3.3  Sample Worksheet III:  Construction (BSF=1)

Current state: _____.
Note:  Do not complete this form if already in the fire resistive state.

Potential retrofits:
    (a) Resheath bearing walls and partitions: square feet;
    (b) Protect columns: linear feet;
    (c) Protect beams: linear feet; and
    (d) Protect decking: square feet.

(1) Element counts to move to protected state:
    (a) Square feet of bearing walls and partitions: _____.
    (b) Linear feet of columns: _____;
    (c) Linear feet of beams: _____; and
    (d) Square feet of decking: _____.

(2) Element counts to move to fire resistive state*:
    (a) Square feet of bearing walls and partitions: _____;
    (b) Linear feet of columns: _____;
    (c) Linear feet of beams: _____; and
    (d) Square feet of decking: _____.

*Complete this portion of the worksheet only if the building was classified
 as non-combustible.

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Exhibit 3.4  Sample Worksheet IV:  Interior Finish [Corridors and Exits]
          (BSF=2)

Current state: _____.
Note:  Do not complete this form if already in the Class A state.

Potential retrofits
     (a) Install drywall: square feet;*
     (b) Coat walls with retardant: square feet;
     (c) Coat ceilings with retardant: square feet; and
     (d) Install carpet: square feet.

(1) Element counts to move to Class B:
     (a)* Square feet of paneling: _____;
     (b) Square feet of walls: _____;
     (c) Square feet of ceilings: _____; and
     (d) Square feet of carpet: _____.

(2) Element counts to move to Class A:
     (a)* Square feet of paneling: _____;
     (b) Square feet of walls: _____;
     (c) Square feet of ceilings: _____; and
     (d) Square feet of carpet: _____.

* To be installed only if the zone contains Class C (or worse) paneling.

Exhibit 3.5  Sample Worksheet V:  Interior Finish [Rooms] (BSF=3)

Current state: _____.
Note:  Do not complete this form if already in the Class A state.

Potential retrofits:
     (a) Install drywall: square feet;*
     (b) Coat walls with retardant: square feet; and
     (c) Coat ceilings with retardant: square feet.

(1) Element counts to move to Class B:
     (a)* Square feet of paneling: _____;
     (b) Square feet of walls: _____; and
     (c) Square feet of ceilings: _____.

(2) Element counts to move to Class A:
     (a)* Square feet of paneling: _____:
     (b) Square feet of walls: _____; and
     (c) Square feet of ceilings: _____.

*To be installed only if the zone contains Class C (or worse) paneling.

Exhibit 3.6   Sample Worksheet VI:   Corridor Partitions/Walls (BSF=4)

Current state: _____.
Note:   Do not complete this form if alredy in the > 1 hour state.

Potential retrofits:
    (a) Install partition slab-to-slab: linear feet;
    (b) Extend existing partition to slab: linear feet;
    (c) Replace windows (glass only): number;
    (d) Replace windows (glass only): area (in$^2$);
    (e) Replace windows (glass and frames): number;
    (f) Replace windows (glass and frames): area (in$^2$);
    (g) Sheath existing (< 1/3 hour) partition: linear feet; and
    (h) Sheath existing (1/3-1 hour) partition: linear feet.

(1) Element counts to move to < 1/3 hour state:

    (a) Linear feet of partition: _____;
    (b) Linear feet of extension: _____;
    (c) Number of windows (glass only): _____;
    (d) Square inches of windows (glass only): _____;
    (e) Number of windows (glass and frames): _____;
    (f) Square inches of windows (glass and frames): _____;
    (g) Linear feet of sheathing (< 1/3 hour): _____; and
    (h) Linear feet of sheathing (1/3-1 hour): _____.

(2) Element counts to move to 1/3-1 hour state:

    (a) Linear feet of partition: _____;
    (b) Linear feet of extension: _____;
    (c) Number of windows (glass only): _____;
    (d) Square inches of windows (glass only): _____;
    (e) Number of windows (glass and frames): _____;
    (f) Square inches  of windows (glass and frames): _____;
    (g) Linear feet of sheathing (< 1/3 hour): _____; and
    (h) Linear feet of sheathing (1/3-1 hour): _____.

(3) Element counts to move to > 1 hour state:

    (a) Linear feet of partition: _____;
    (b) Linear feet of extension: _____;
    (c) Number of windows (glass only): _____;
    (d) Square inches of windows (glass only): _____;
    (e) Number of windows (glass and frames): _____;
    (f) Square inches of windows (glass and frames): _____;
    (g) Linear feet of sheathing (< 1/3 hour): _____; and
    (h) Linear feet of sheathing (1/3-1 hour): _____.

Exhibit 3.7  Sample Worksheet VII:  Doors to Corridor (BSF=5)

Current state: _____.
Note:  Do not complete this form if already in the > 20 minute and automatic
       closers state.

Potential retrofits:
    (a) Replace doors and frames (single): number;
    (b) Replace doors and frames (double): number;
    (c) Replace doors (single): number;
    (d) Replace doors (double): number;
    (e) Replace latch: number;
    (f) Replace view panel: number;
    (g) Install closers (normal): number; and
    (h) Install closers (automatic): number.

(1) Element counts to move to < 20 minute fire rating state:
    (a) Number of doors and frames (single): _____;
    (b) Number of doors and frames (double): _____;
    (c) Number of doors (single): _____;
    (d) Number of doors (double): _____;
    (e) Number of latches: _____;
    (f) Number of view panels: _____;
    (g) Number of closers (normal): _____; and
    (h) Number of closers (automatic): _____.

(2) Element counts to move to ≥ 20 minute fire rating state:
    (a) Number of doors and frames (single): _____;
    (b) Number of doors and frames (double): _____;
    (c) Number of doors (single): _____;
    (d) Number of doors (double): _____;
    (e) Number of latches: _____;
    (f) Number of view panels: _____;
    (g) Number of closers (normal): _____; and
    (h) Number of closers (automatic): _____.

(3) Element counts to move to ≥ 20 minute fire rating with automatic
    closers state:
    (a) Number of doors and frames (single): _____;
    (b) Number of doors and frames (double): _____;
    (c) Number of doors (single): _____;
    (d) Number of doors (double): _____;
    (e) Number of latches: _____;
    (f) Number of view panels: _____;
    (g) Number of closers (normal): _____; and
    (h) Number of closers (automatic): _____.

Exhibit 3.8  Sample Worksheet VIII:  Zone Dimensions (BSF=6)

Current state: _____.
Note:  Do not complete this form if already in the no dead ends state with a
       zone length less than 100 feet.

Potential retrofits:
    (a) Create a cross connection to a parallel corridor: linear feet;
    (b) Install interior stairway: number;
    (c) Install exterior stairway: number;
    (d) Install smoke partition: number;
    (e) Install partition slab-to-slab: linear feet;
    (f) Extend existing partition to slab: linear feet; and
    (g) Install smoke dampers: number.

(1) Design qualifiers
    (i)  What is the total length in feet of all zones currently being
         analyzed? _____.
    (ii) Can a new smoke partition be installed to reduce the length of the
         fire zone? _____ (0 implies no, 1 implies yes)

(2) Element counts to move to 50-100 feet Dead End state:
    (a) Linear feet of cross connection: _____;
    (b) Number of interior stairways: _____;
    (c) Number of exterior stairways: _____;
    (d) Number of smoke partitions: _____;
    (e) Linear feet of partition: _____;
    (f) Linear feet of extension: _____; and
    (g) Number of smoke dampers: _____.

(3) Element counts to move to 30-50 foot dead end state:
    (a) Linear feet of cross connection: _____;
    (b) Number of interior stairways: _____;
    (c) Number of exterior stairways: _____;
    (d) Number of smoke partitions: _____;
    (e) Linear feet of partition: _____;
    (f) Linear feet of extension: _____; and
    (g) Number of smoke dampers: _____.

(4) Element counts to move to no dead end and a zone length greater than
    150 feet state:
    (a) Linear feet of cross connection: _____;
    (b) Number of interior stairways: _____;
    (c) Number of exterior stairways: _____;
    (d) Number of smoke partitions: _____;
    (e) Linear feet of partition: _____;
    (f) Linear feet of extension: _____; and
    (g) Number of smoke dampers: _____.

Exhibit 3.8  Sample Worksheet VIII:  Zone Dimensions (Continued)

(5) Element counts to move to no dead ends and a zone length between 100-150
    feet state:
    (a) Linear feet of cross connection: _____;
    (b) Number of interior stairways: _____;
    (c) Number of exterior stairways: _____;
    (d) Number of smoke partitions: _____;
    (e) Linear feet of partition: _____;
    (f) Linear feet of extension: _____;  and
    (g) Number of smoke dampers: _____.

(6) Element counts to move to no dead ends and a zone length of less than
    100 feet state:
    (a) Linear feet of cross connection: _____;
    (b) Number of interior stairways: _____;
    (c) Number of exterior stairways: _____;
    (d) Number of smoke partitions: _____;
    (e) Linear feet of partition: _____;
    (f) Linear feet of extension: _____;  and
    (g) Number of smoke dampers: _____.

Exhibit 3.9  Sample Worksheet IX:  Vertical Openings (BSF=7)

Current state: _____.
Do not complete this form if already in the > 2 hour state.

Potential retrofits:
     (a) Frame and sheath enclosure: square feet;
     (b) Sheath existing enclosure: square feet;
     (c) Install doors and frames: number; and
     (d) Install doors: number.

(1) Element counts to move to the open 2 or 3 floors state:
     (a) Square feet of enclosure: _____;
     (b) Square feet of sheathing: _____;
     (c) Number of doors and frames: _____; and
     (d) Number of doors: _____.

(2) Element counts to move to enclosed with less than 1 hour fire rating
    state:
     (a) Square feet of enclosure: _____;
     (b) Square feet of sheathing: _____;
     (c) Number of doors and frames: _____; and
     (d) Number of doors: _____.

(3) Element counts to move to enclosed with a 1 to 2 hour fire rating state:
     (a) Square feet of enclosure: _____;
     (b) Square feet of sheathing: _____;
     (c) Number of doors and frames: _____; and
     (d) Number of doors: _____.

(4) Element counts to move to enclosed with at least a 2 hour fire rating
    state:
     (a) Square feet of enclosure: _____;
     (b) Square feet of sheathing: _____;
     (c) Number of doors and frames: _____; and
     (d) Number of doors: _____.

Exhibit 3.10  Sample Worksheet X:  Hazardous Areas (BSF=8)

Current state: _____.
Note:  Do not complete this form if already in no deficiencies state.

Potential retrofits:
    (a) Upgrade enclosure: square feet;
    (b) Install door:  Number; and
    (c) Install sprinklers: area in square feet.

Complete this section for <u>all</u> high hazard areas.

(1) Element counts to move to the single deficiency state:
    (a) Square feet of enclosure: _____;
    (b) Number of doors: _____; and
    (c) Square feet of high hazard areas: _____.

(2) Element counts to move to the no deficiency state:
    (a) Square feet of enclosure: _____;
    (b) Number of doors: _____; and
    (c) Square feet of high hazard areas: _____.

Complete this section for <u>all</u> non-sprinklered single deficiency areas.

(3) Element counts to move to no deficiency state:
    (a) Square feet of enclosure: _____;
    (b) Number of doors: _____; and
    (c) Square feet of all hazardous areas of this type: _____.

Complete this section for <u>all</u> sprinklered single deficiency areas.

(4) Element counts to move to no deficiency state:
    (a) Square feet of enclosure: _____;
    (b) Number of doors: _____; and
    (c) Square feet of all hazardous areas of this type: _____.

Note:  FSESCM treats transitions to the double deficiency and single
       deficiency outside the fire zone states as impossible.  Three values of
       minus one (-1) should therefore be used as the relevant element
       counts.

Exhibit 3.11   Sample Worksheet XI:   Smoke Control (BSF=9)

Current state: _____.
Note:   Do not complete this form if already in the smoke partition state.*

Potential retrofits:
    (a) Install smoke partition: number;
    (b) Install partition slab-to-slab: linear feet;
    (c) Extend existing partition to slab: linear feet; and
    (d) Install smoke dampers: number.

(1) Element counts to move to smoke partition state:
    (a) Number of smoke partitions: _____;
    (b) Linear feet of partition: _____;
    (c) Linear feet of extension: _____; and
    (d) Number of smoke dampers: _____.

*The mechanically assisted by zone state requires special costing not included
 within the FSESCM model.  Four values of minus one (-1) should therefore be
 used as the relevant element counts.

Exhibit 3.12 Sample Worksheet XII:  Emergency Movement Routes (BSF=10)

Current state: _____.
Note:  Do not complete this form if already in the horizontal exit state.*

Potential retrofits:
    (a)  Install interior stairway: number;
    (b)  Install exterior stairway: number;
    (c)  Install emergency light: number;
    (d)  Install horizontal exit: number;
    (e)  Install partition slab-to-slab: linear feet;
    (f)  Extend existing partition to slab: linear feet; and
    (g)  Install smoke dampers: number;

(1) Element counts to move to deficient capacity state:
    (a)  Number of interior stairways: _____;
    (b)  Number of exterior stairways: _____;
    (c)  Number of emergency lights: _____;
    (d)  Number of horizontal exits: _____;
    (e)  Linear feet of partition: _____;
    (f)  Linear feet of extension: _____;
    (g)  Number of smoke dampers: _____.

(2) Element counts to move to no horizontal exit state:
    (a)  Number of interior stairways: _____;
    (b)  Number of exterior stairways: _____;
    (c)  Number of emergency lights: _____;
    (d)  Number of horizontal exits: _____;
    (e)  Linear feet of partition: _____;
    (f)  Linear feet of extension: _____;
    (g)  Number of smoke dampers: _____.

(3) Element counts to move to horizontal exit state:
    (a)  Number of interior stairways: _____;
    (b)  Number of exterior stairways: _____;
    (c)  Number of emergency lights: _____;
    (d)  Number of horizontal exits: _____;
    (e)  Linear feet of partition: _____;
    (f)  Linear feet of extension: _____;
    (g)  Number of smoke dampers: _____.

*The direct exits state requires special costing not included within the
 FSESCM model.  Seven values of minus one (-1) should therefore be used as
 the relevant element counts.

Exhibit 3.13   Sample Worksheet XIII:   Manual Fire Alarm (BSF=11)

Current state: _____.
Note:   Do not complete this form if already in the fire department connection
        state.

Potential retrofits:
    (a) Install control panel: Number;
    (b) Install pull station: Number; and
    (c) Connect zone(s) with fire department: Number.

(1) Element counts to move to no fire department connection state:
    (a) Number of control panels: _____;
    (b) Number of pull stations: _____; and
    (c) Number of connections: _____.

(2) Element counts to move to fire department connection state:
    (a) Number of control panels: _____;
    (b) Number of pull stations: _____; and
    (c) Number of connections: _____.

Exhibit 3.14   Sample Worksheet XIV:   Smoke Detection and Alarm (BSF=12)

Current state: _____.
Note:  Do not complete this form if already in the total space state.

Potential retrofit:
    (a) Install smoke detectors: number.

(1) Element counts to move to corridor only state:
    (i)    Linear feet of corridors: _____;
    (ii)   Number of patient rooms: _____;
    (iii) Square feet of common areas: _____;
    (iv)   Number of non-patient rooms: _____; and
    (v)    Number of bathrooms and closets: _____.

(2) Element counts to move to rooms only state:
    (i)    Linear feet of corridors: _____;
    (ii)   Number of patient rooms: _____;
    (iii) Square feet of common areas: _____;
    (iv)   Number of non-patient rooms: _____; and
    (v)    Number of bathrooms and closets: _____.

(3) Element counts to move to corridor and habitable space state:
    (i)    Linear feet of corridors: _____;
    (ii)   Number of patient rooms: _____;
    (iii) Square feet of common areas: _____;
    (iv)   Number of non-patient rooms: _____; and
    (v)    Number of bathrooms and closets: _____.

(4) Element counts to move to total space state:
    (i)    Linear feet of corridors: _____;
    (ii)   Number of patient rooms: _____;
    (iii) Square feet of common areas: _____;
    (iv)   Number of non-patient rooms: _____; and
    (v)    Number of bathrooms and closets: _____.

Exhibit 3.15   Sample Worksheet XV:   Automatic Sprinklers (BSF=13)

Current state: _____.
Note:  Do not complete this form if already in the total space state.

(1) Potential retrofit designation: _____;
    (a) Wet exposed: Designation = 1;
    (b) Wet concealed: Designation = 2;
    (c) Dry exposed: Designation = 3; and
    (d) Dry concealed: Designation = 4.

(2) Water supply qualifier: _____;
    (i)   Adequate: Designation = 1;
    (ii)  Not Adequate: Designation = 2; and
    (iii) Unknown: Designation = 3.

(3) Element counts to move to corridor and habitable space state:
    (i)   Linear feet of corridors: _____;
    (ii)  Number of rooms (< 200 square feet): _____;
    (iii) Number of rooms (200-400 square feet): _____;
    (iv)  Number of rooms (400-600 square feet): _____;
    (v)   Floor area of common spaces and wards (> 600 square feet): _____;
    (vi)  Square feet of floor area analyzed (total): _____; and
    (vii) Number of bathrooms and closets: _____.

(4) Element counts to move to total space state:
    (i)   Linear feet of corridors: _____;
    (ii)  Number of rooms (< 200 square feet): _____;
    (iii) Number of rooms (200-400 square feet): _____;
    (iv)  Number of rooms (400-600 square feet): _____;
    (v)   Floor area of common spaces and wards (> 600 square feet): _____;
    (vi)  Square feet of floor area analyzed (total): _____; and
    (vii) Number of bathrooms and closets: _____.

Exhibit 3.16  Sample Worksheet XVI:  User Options to be Exercised

Enter the sequence within the control packet for this fire zone beside each option to be exercised.

(1) Major control options*:
    (i)    NEXT: _____;
    (ii)   LAST: _____;
    (iii) TEST: _____; and
    (iv)  FINAL: _____.

(2) Minor control options**:
    (i)    SOLVE: _____;
    (ii)   CHANGE: _____;
         (a) Building safety feature number: _____;
         (b) State number: _____; and
         (c) Transition cost: _____.
    (iii) REQUIR: _____;
         (a) Number of safety requirement: _____; and
         (b) Percent change desired: _____.

*May be used only once for each fire zone.

**May be used several times or in combination for each fire zone.  The influence on problem structure is cumulative.


## 3.3  HOW TO CONSTRUCT AN INPUT DECK

The worksheets discussed in the previous section were designed to facilitate the process of setting up a data file to critically analyze a building.  The relationship between the worksheets and the data file is summarized in Table 3.4.  The relationship is then illustrated schematically in figure 3.2.  Table 3.4 provides a crosswalk between the worksheets and the data file.  Figure 3.2 on the other hand consists of an exploded deck of cards[1] which are labeled so as to highlight the organization of a typical FSESCM data file.  The deck shown in figure 3.2 is constructed so that more than one building can be analyzed in a single run.  The discussion in this section will focus on how to set up a data file for a single building.  The generalization to two or more buildings batched together in a single run can then be understood as little more than replicating the process for a single building.  Guidelines for batching two or more buildings are given in chapter 5.

--------

[1]The term card image can be used without any loss of meaning if one were talking about a mass storage file.

Table 3.4  Sequencing for the FSESCM Data File

| Type of Data | Cross Reference to Figure 3.2 | Singleton or Group |
|---|---|---|
| 1 | Mailing Label | Group |
| 1 | Building Qualifiers | Singleton |
| 2 | Zone Qualifiers | Singleton |
| 2 | FSES Table 1 Qualifiers | Singleton |
| 2 | FSES Table 4 Qualifiers | Singleton |
| 3 | Construction | Group |
| 3 | Interior Finish [Corridors & Exits] | Group |
| 3 | Interior Finish [Rooms] | Group |
| 3 | Corridor Parttions/Walls | Group |
| 3 | Doors to Corridor | Group |
| 3 | Zone Length Qualifiers | Singleton |
| 3 | Zone Dimensions | Group |
| 3 | Vertical Openings | Group |
| 3 | Deficiency Qualifiers | Singleton |
| 3 | Hazardous Areas | Group |
| 3 | Smoke Control | Group |
| 3 | Emergency Movement Routes | Group |
| 3 | Manual Fire Alarm | Group |
| 3 | Smoke Detection & Alarm | Group |
| 3 | Sprinkler Qualifiers | Singleton |
| 3 | Sprinklers | Group |
| 4 | User Options | Group |

Figure 3.2  Organization of a Typical FSESCM Data File
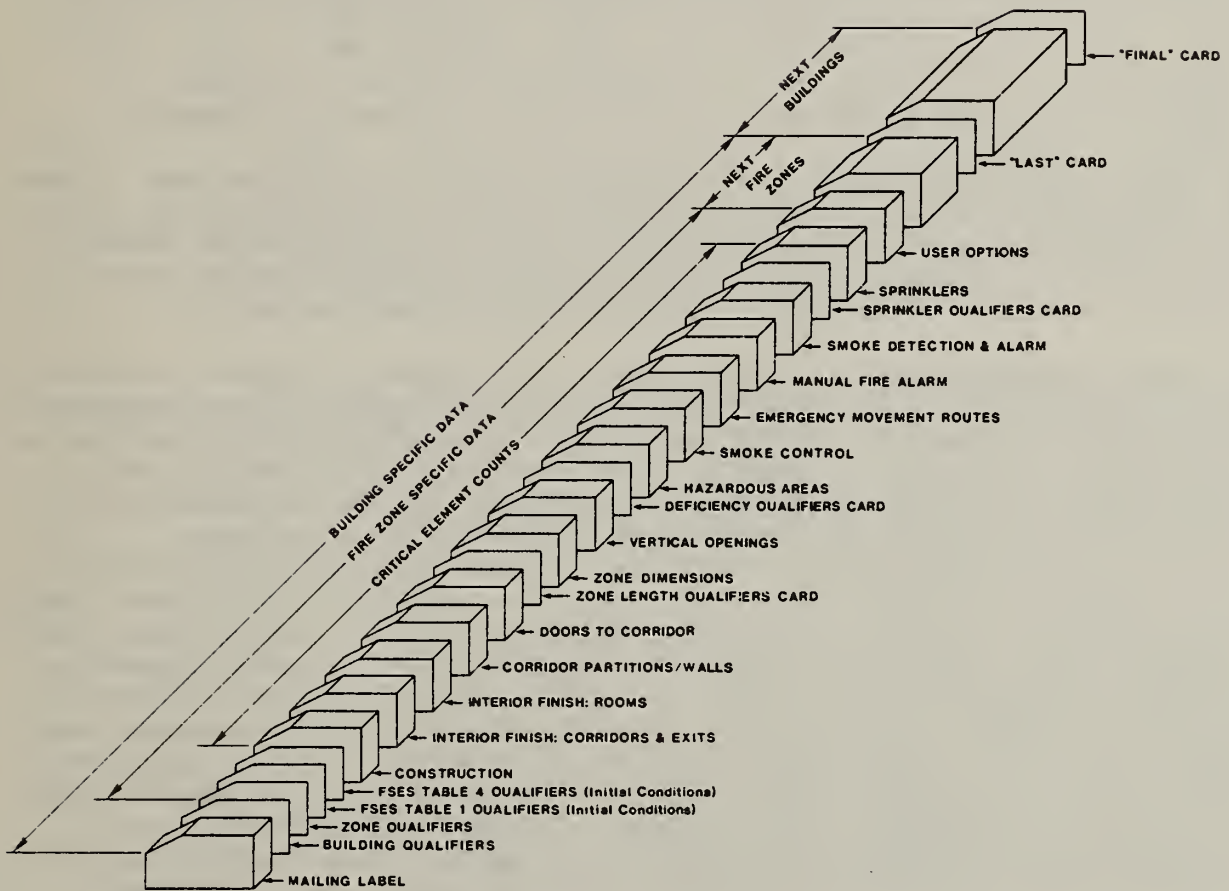
Two important points can easily be understood through reference to figure 3.2. First, all cards appear as either singletons or groups. Groups of cards are shown as a block to differentiate them from singletons. Second, cards for a particular building, just as the worksheets, are divided into four basic types[1] (see table 3.4).

The first type records background information on the building. These data are listed as "Mailing Label" and "Building Qualifiers" in table 3.4 and figure 3.2. This information remains constant during the course of the analysis irregardless of the number of fire zones in the building.

The second type records background information on a specific fire zone. These data are listed as "Zone Qualifiers", "FSES Table 1 Qualifiers", and "FSES Table 4 Qualifiers" in table 3.4 and figure 3.2. This information governs both the initial conditions within the fire zone and the structure of the application problem. Care should be exercised in setting up the values on these cards because recording errors on either the FSES Table 1 or 4 cards could render the interpretation of the problem meaningless or result in a termination of the analysis of the building under study. Techniques for finding and correcting input errors are discussed in detail in chapter 5.

The third type contains the critical element counts for the fire zone. These data are listed between the titles "Construction" and "Sprinklers" in table 3.4 and figure 3.2. They appear below the label "Critical Element Counts" on figure 3.2. The critical element counts define the feasibility of each retrofit as well as the means of estimating each transition cost.

The fourth type contains the user options. These cards are labeled as "User Options" in table 3.4 and figure 3.2. This control packet permits the user to redefine the problem structure by exercising the CHANGE and REQUIR options or to analyze the application problem by exercising the SOLVE option. Any combination of the three minor options just mentioned may be used within a particular fire zone. Users should note, however, that structural modifications are cumulative. Similarly, if modifications are made and the SOLVE option is used after each modification or groups of modifications, users should recognize that the output under the Total Building Summary Report will be based on the results of the analysis generated the first time the SOLVE option is exercised for each fire zone. Since each time the SOLVE option is exercised the model will generate a Fire Zone Summary Report, substitutions based on one of the subsequent uses of the SOLVE option could be made easily within the Total Building Summary Report. The last card of the user options group must be either NEXT, LAST or FINAL. If more fire zones are to be evaluated for the building under study, then the NEXT card should be used. If this is the last card for the building under study and a Total Building

---

[1] Type 1 data correspond to information recorded on FSESCM Worksheet I. Type 2 data correspond to information recorded on FSESCM Worksheet II. Type 3 data correspond to information recorded on FSESCM Worksheets III through XV. Type 4 data correspond to information recorded on FSESCM Worksheet XVI.

Summary Report is desired and one or more buildings follow, then the LAST card should be used. If this is the last card for the building under study and the user is performing data consistency checks, then the TEST card should be used. If the TEST option is exercised and one or more buildings are to be analyzed, then it should be followed by a NEXT card. In this case, the run will continue but the Total Building Summary Report will not be generated. If the TEST options is exercised and no more buildings are to be analyzed, then it should be followed by the FINAL card. In this case, the run will stop without generating the Total Building Summary Report. If this is the last card for the building under analysis and a Total Building Summary Report is desired and no other buildings follow, then the FINAL card should be used. The FINAL card will cause the Total Building Summary Report to be generated. The run will then stop.

The concepts just discussed are illustrated for a specific example in exhibit 3.17. This exhibit is a sample data file for the hospital discussed in section 3.1. The data file consists of four fire zones and 139 lines of input.

Two levels of descriptive detail will be used to systematically lay out the inputs of the model. The first level consists of a walk through of exhibit 3.17, relating each section of the file to a worksheet. This task will make use of a completed set of worksheets for the patient room floors of the building described in section 3.1. The format which governs the way in which the data file is read will then be discussed. The second level focuses on the input format for each singleton or group of cards.

A cursory review of exhibit 3.17 reveals a sequence of numbers going down the left hand side of the page. These line numbers show the position of each type of data within the file. The first six lines serve as a mailing label. They are the responses to questions 1.i through 1.vi on Worksheet I. The seventh line contains the responses to Worksheet I questions 2, 3, 4.i, 4.ii and 4.iii, respectively. Exhibit 3.18 presents the completed Worksheet I which corresponds to the entries on lines 1 through 7 of the data file.

Data on individual fire zones begin on line 8. The basement contains one fire zone and involves no patients. Its values are therefore recorded on line 8 as -1 (floor number) 1 (zone number) 0 (number of patients). The basement fire zone occupies lines 8 through 38 of the data file. The first floor also contains a single fire zone and involves no patients. This fire zone occupies lines 39 through 71 of the data file. The second floor consists of a single fire zone with 30 patients; it occupies lines 72 through 105 of the data file. The last group of data aggregates all fire zones on floors three through nine. It is treated as a single fire zone. Exhibits 3.19 through 3.33 contain completed worksheets which correspond to the entries on lines 106 through 139.

Exhibit 3.17 Sample Data File

```
 1      NORTH-WEST GENERAL HOSPITAL
 2      MAIN BUILDING
 3      ATTN: ROBERT E. CHAPMAN
 4      101 RESEARCH BLVD.
 5      MONTGOMERY, MARYLAND 20000
 6      TEL: (301)-921-3855
 7         1   4 1.15 1.00 1.00
 8        -1   1   0
 9         1   1   5   1   1
10         7   3   3   4   1   4   3   5   2   1   3   1   2
11         1
12         2
13         3
14         4
15         5       0       0       0       0      10      10       0       0
16         5       4       0       0       0      10      10       0       0
17         5       4       0       0       0      10      10       0       3
18         6     155       1
19         6       0       0       0       1       0       0       0
20         6       0       0       0       1       0       0       0
21         7       0       0       1       1
22         7       0       0       1       1
23         8   0   0   0
24         8
25         9      -1      -1      -1      -1
26        10      -1      -1      -1      -1      -1      -1      -1
27        10       0       0       0       1       0       0       0
28        10       0       0       0       1      40       0       0
29        10      -1      -1      -1      -1      -1      -1      -1
30        11
31        12     155       0    3000      15       4
32        12     155       0    3000      15       4
33        12     155       0    3000      15       4
34        12     155       0    3000      15       4
35        13   1   1
36        13       0       1       0       0       0    8300       4
37      SOLVE
38      NEXT
39         1   1   0
40         1   1   1   1   1
41         7   3   3   4   1   4   3   3   2   1   3   1   1
42         1
43         2
44         3
45         4
46         5       0       0       0       0       0       2       0       0
47         5      10       1       0       0       0       2      10       0
48         5      10       1       0       0       0       2      10       0
49         6     160       1
50         6       0       0       0       1       0       0       0
51         6       0       0       0       1       0       0       0
52         7       0       0       1       3
53         7       0       0       1       3
54         8   0   1   0
55         8      -1      -1      -1
56         8       0       1     100
57         9      -1      -1      -1      -1
```

Exhibit 3.17 Sample Data File (Continued)

```
58      10      -1      -1      -1      -1      -1      -1      -1
59      10       0       0       0       1       0       0       0
60      10       0       0       0       1      40       0       0
61      10      -1      -1      -1      -1      -1      -1      -1
62      11
63      12     160       0    1200      25      16
64      12     160       0    1200      25      16
65      12     160       0    1200      25      16
66      12     160       0    1200      25      16
67      13   1   1
68      13     160       0      25       0    1200   10000      16
69      13     160       0      25       0    1200   10000      16
70      SOLVE
71      NEXT
72           2    1   30
73          4   3   2   1   1
74          7   3   1   4   1   4   3   3   2   1   3   1   1
75          1
76          2
77          3       0       0     100
78          3       0       0     100
79          4
80          5       0       0       0       0      19       0       0       0
81          5       8       1       0       0      19       0       0       0
82          5       8       1       0       0      19       0       0       0
83          6     200       1
84          6       0       0       0       1       0       0       0
85          6       0       0       0       1       0       0       0
86          7       0       0       1       2
87          7       0       0       1       2
88          8   0   1   0
89          8      -1      -1      -1
90          8       0       1     100
91          9      -1      -1      -1      -1
92         10      -1      -1      -1      -1      -1      -1      -1
93         10       0       0       0       1       0       0       0
94         10       0       0       0       1      40       0       0
95         10      -1      -1      -1      -1      -1      -1      -1
96         11
97         12     200      14    1000      12      30
98         12     200      14    1000      12      30
99         12     200      14    1000      12      30
100        12     200      14    1000      12      30
101        13   1   1
102        13     200       5      21       0    1000   10000      30
103        13     200       5      21       0    1000   10000      30
104        SOLVE
105        NEXT
106            3    1  280
107           4   4   4   1   1
108           7   3   1   4   1   3   3   3   2   2   3   1   1
109           1
110           2
111           3       0       0     700
112           3       0       0     700
113           4
114           5       0       C       0       0      28      49       0       0
115           5      49       0       0       0      28      49       0       0
```

Exhibit 3.17 Sample Data File (Continued)

| | | | | | | | | |
|------|-------|-----|------|-----|-------|-------|-----|---|
| 116 | 5 | 49 | 0 | 0 | 0 | 28 | 49 | 0 | 0 |
| 117 | 6 | 210 | 1 | | | | | |
| 118 | 6 | 0 | 0 | 9 | 0 | 0 | 0 | 0 |
| 119 | 6 | 0 | 0 | 9 | 7 | 0 | 0 | 0 |
| 120 | 6 | 0 | 0 | 9 | 7 | 0 | 0 | 0 |
| 121 | 7 | 0 | 0 | 7 | 0 | | | |
| 122 | 7 | 0 | 0 | 7 | 0 | | | |
| 123 | 8 | 0 | 1 | 0 | | | | |
| 124 | 8 | -1 | -1 | -1 | | | | |
| 125 | 8 | 0 | 7 | 700 | | | | |
| 126 | 9 | -1 | -1 | -1 | -1 | | | |
| 127 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 128 | 10 | 0 | 0 | 0 | 7 | 280 | 0 | 0 |
| 129 | 10 | -1 | -1 | -1 | -1 | -1 | -1 | -1 |
| 130 | 11 | | | | | | | |
| 131 | 12 | 1540 | 154 | 7000 | 21 | 420 | | |
| 132 | 12 | 1540 | 154 | 7000 | 21 | 420 | | |
| 133 | 12 | 1540 | 154 | 7000 | 21 | 420 | | |
| 134 | 12 | 1540 | 154 | 7000 | 21 | 420 | | |
| 135 | 13 | 1 | 1 | | | | | |
| 136 | 13 | 1540 | 0 | 168 | 7 | 7000 | 77000 | 420 |
| 137 | 13 | 1540 | 0 | 168 | 7 | 7000 | 77000 | 420 |
| 138 | SOLVE | | | | | | | |
| 139 | FINAL | | | | | | | |

Exhibit 3.18 Completed Worksheet I:  Background Information

(1) Mailing label:
    (i)     Facility name:  <u>North-West General Hospital</u>;
    (ii)   Building name:  <u>Main Building</u>;
    (iii) Contact:  <u>Robert E. Chapman</u>;
    (iv)   Address:  <u>101 Research Blvd.</u>;
    (v)    City, state, zip code:  <u>Montgomery, Maryland  20000</u>; and
    (vi)   Telephone number:  <u>(301)-921-3855</u>.

(2) Building type designation:  <u>  1  </u>;
    (i)    Hosptal:  Designation = 1; and
    (ii)   Nursing Home:  Designation = 2.

(3) Building qualifier:  <u>  4  </u>;
    (i)    New single story:  Designation = 1;
    (ii)   New multi story:  Designation = 2;
    (iii) Existing single story:  Designation = 3; and
    (iv)   Existing multi story:  Designation = 4.

(4) Construction cost modifiers:
    (i)    Cost growth factor:  <u>1.15</u>
    (ii)   Labor cost differential:  <u>1.00</u>; and
    (iii) Material cost differential:  <u>1.00</u>.

The entries on line 106 correspond to the information recorded on Worksheet II (see exhibit 3.19) questions 1.i through 1.iii. The entries on lines 107 and 108 correspond to the information recorded on Worksheet II questions 2.i through 2.v and 3.i through 3.xiii, respectively. As mentioned earlier, these data serve to define the scope of the application problem.

Lines 109 through 137 of the data file contain the critical element counts for each building safety feature. The building safety feature number (see the entries at the top of Worksheets III through XV) is used to check sequencing. Data on all building safety features must begin with 1 and run through 13 with no gaps. If the building safety feature is already in the highest state, as is the one for construction (see line 109 and exhibit 3.20), the only entry on the card should be the building safety feature number. The next card would then contain critical element counts for the first retrofit state for the building safety feature which follows. If this building safety feature is also in the highest state (see line 110 and exhibit 3.21), then the only entry on the card should be the building safety feature number. There is no limit on how many building safety features can be entered in the highest state. If potential retrofits are possible, then the building safety feature number is followed by the critical element counts. For example interior finish [rooms] was in the "Class C" state implying retrofits to either "Class B" or "Class A" were possible. The entries on lines 111 and 112 contain the responses to Worksheet V (see exhibit 3.22) questions 1.a through 1.c and 2.1 through 2.c. In this case, both retrofits were deemed feasible.

Exhibit 3.23 indicates that the fourth building safety feature, corridor partitions/walls, is already in the highest state so no entry other than 4, the building safety feature number, is required on line 113.

Since doors to the corridor were listed as being in the "no door" state, three retrofit states are possible. The responses to Worksheet VII (see exhibit 3.24) questions 1, 2 and 3 indicate that retrofitting to the less than 20 minute fire rating state, greater than or equal to 20 minute fire rating state and greater than or equal to 20 minute fire rating with automatic closers state are feasible. In this case, normal closers are treated as being equivalent to automatic closers (see the discussion in section 3.2).

The entries on line 117 correspond to the answers to question 1.i and 1.ii on Worksheet VIII (see exhibit 3.25). In this case, the overall length of the fire zone is 210 feet and it is permissible to install a smoke partition to reduce the length of the fire zone. Lines 118, 119, and 120 correspond to the answers to questions 4.1 through 4.g, 5.a through 5.g, and 6.a through 6.g, respectively. Notice that since the fire zone was input in the third state, it was not necessary to respond to the entries under questions 2 and 3. Lines 121 and 122 correspond to the answers to questions 3.1 through 3.d and 4.a through 4.d on the vertical openings worksheet (see exhibit 3.26).

Exhibit 3.19 Completed Worksheet II:  Fire Zone Data

(1) General Information:
    (i)   Floor number:  __3__;
    (ii)  Zone number:  __1__; and
    (iii) Number of patients:  280.

(2) FSES Table 1:
    (i)   Patient mobility:  __4__;
    (ii)  Patient density:  __4__;
    (iii) Zone location:  __4__;
    (iv)  Ratio of Patients to attendants:  __1__; and
    (v)   Patient average age:  __1__.

(3) FSES Table 4:
    (i)    Construction:  __7__;
    (ii)   Interior finish [corridor and exits]:  __3__;
    (iii)  Interior finish [rooms]:  __1__;
    (iv)   Corridor partitions/walls:  __4__;
    (v)    Doors to corridor:  __1__;
    (vi)   Zone dimensions:  __3__;
    (vii)  Vertical openings:  __3__;
    (viii) Hazardous areas:  __3__;
    (ix)   Smoke control:  __2__;
    (x)    Emergency movement routes:  __2__;
    (xi)   Manual fire alarm:  __3__;
    (xii)  Smoke detection and alarm:  __1__; and
    (xiii) Automatic sprinklers:  __1__.

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Exhibit 3.20 Completed Worksheet III:  Construction (BSF=1)

Current state:  Fire resistive.

Note:  Do not complete this form if already in the fire resistive state.

Potential retrofits:
    (a) Resheath bearing walls and partitions: square feet;
    (b) Protect columns: linear feet;
    (c) Protect beams: linear feet; and
    (d) Protect decking: square feet.

(1) Element counts to move to protected state:
    (a) Square feet of bearing walls and partitions: _____;
    (b) Linear feet of columns: _____;
    (c) Linear feet of beams: _____; and
    (d) Square feet of decking: _____;

(2) Element counts to move to fire resistive state*:
    (a) Square feet of bearing walls and partitions: _____;
    (b) Linear feet of columns: _____;
    (c) Linear feet of beams: _____; and
    (d) Square feet of decking: _____;

*Complete this portion of the worksheet only if the building was classified as
non-combustible.

Exhibit 3.21 Completed Worksheet IV: Interior Finish [Corridors and Exit]
            (BSF=2)

Current state:  <u>Class A.</u>
Note:  Do not complete this form if already in the Class A state.

Potential retrofits
    (a) Install drywall: square feet;*
    (b) Coat walls with retardant: square feet;
    (c) Coat ceilings with retardant: square feet; and
    (d) Install carpet: square feet.

(1) Element counts to move to Class B:
    (a)* Square feet of paneling: _____;
    (b) Square feet of walls: _____;
    (c) Square feet of ceilings: _____; and
    (d) Square feet of carpet: _____.

(2) Element counts to move to Class A:
    (a)* Square feet of paneling: _____;
    (b) Square feet of walls: _____;
    (c) Square feet of ceilings: _____; and
    (d) Square feet of carpet: _____.

*To be installed only if the zone contains Class C (or worse) paneling.

Exhibit 3.22  Completed Worksheet V:  Interior Finish [Rooms] (BSF=3)

Current state: <u>Class C</u>.
Note:  Do not complete this form if already in the Class A state.

Potential retorfits:
     (a)  Install drywall:  square feet;*
     (b)  Coat walls with retardant: square feet; and
     (c)  Coat ceilings with retardant: square feet.

(1)  Element counts to move to Class B:
     (a)* Square feet of paneling:  <u>  0  </u>;
     (b)  Square feet of walls:  <u>  0  </u>; and
     (c)  Square feet of ceilings:  <u>700</u> .

(2)  Element counts to move to Class A:
     (a)* Square feet of paneling:  <u>  0  </u>;
     (b)  Square feet of walls:  <u>  0  </u>; and
     (c)  Square feet of ceilings:  <u>700</u> .

*To be installed only if the zone contains Class C (or worse) paneling.

Exhibit 3.23 Completed Worksheet VI: Corridor Partitions/Walls (BSF=4)

Current state: <u>> 1 hour.</u>
Note:  Do not complete this form if already in the > 1 hour state.

Potential retrofits:
    (a) Install partition slab-to-slab: linear feet;
    (b) Extend existing partition to slab: linear feet;
    (c) Replace windows (glass only): number;
    (d) Replace windows (glass only): are ($in^2$);
    (e) Replace windows (glass and frames): number;
    (f) Replace windows (glass and frames): area ($in^2$);
    (g) Sheath existing (< 1/3 hour) partition: linear feet; and
    (h) Sheath existing (1/3-1 hour) partition: linear feet.

(1) Element counts to move to < 1/3 hour state:
    (a) Linear feet of partition: _____;
    (b) Linear feet of extensiton: _____;
    (c) Number of windows (glass only): _____;
    (d) Square inches of windows (glass only): _____;
    (e) Number of windows (glass and frames): _____;
    (f) Square inches of windows (glass and frames): _____;
    (g) Linear feet of sheathing (>1/3 hour): _____; and
    (h) Linear feet of sheathing (1/3-1 hour): _____.

(2) Element counts to move to 1/3-1 hour state:

    (a) Linear feet of partition: _____;
    (b) Linear feet of extension: _____;
    (c) Number of windows (glass only): _____;
    (d) Square inches of windows (glass only): _____;
    (e) Number of windows (glass and frames): _____;
    (f) Square inches  of windows (glass and frames): _____;
    (g) Linear feet of sheathing (< 1/3 hour): _____; and
    (h) Linear feet of sheathing (1/3-1 hour): _____.

(3) Element counts to move to > 1 hour state:

    (a) Linear feet of partition: _____;
    (b) Linear feet of extension: _____;
    (c) Number of windows (glass only): _____;
    (d) Square inches of windows (glass only): _____;
    (e) Number of windows (glass and frames): _____;
    (f) Square inches of windows (glass and frames): _____;
    (g) Linear feet of sheathing (< 1/3 hour): _____; and
    (h) Linear feet of sheathing (1/3-1 hour): _____.

Exhibit 3.24   Completed Worksheet VII:   Doors to Corridor (BSF=5)

Current state:   <u>No door.</u>
Note:   Do not complete this form if already in the > 20 minute and automatic
        closers state.

Potential retrofits:
    (a) Replace doors and frames (single): number;
    (b) Replace doors and frames (double): number;
    (c) Replace doors (single): number;
    (d) Replace doors (double): number;
    (e) Replace latch: number;
    (f) Replace view panel: number;
    (g) Install closers (normal): number; and
    (h) Install closers (automatic): number.

(1) Element counts to move to < 20 minute fire rating state:
    (a) Number of doors and frames (single): ___0___;
    (b) Number of doors and frames (double): ___0___;
    (c) Number of doors (single): ___0___;
    (d) Number of doors (double): ___0___;
    (e) Number of latches: ___28___;
    (f) Number of view panels: ___49___;
    (g) Number of closers (normal): ___0___; and
    (h) Number of closers (automatic): ___0___.

(2) Element counts to move to > 20 minute fire rating state:
    (a) Number of doors and frames (single): ___49___;
    (b) Number of doors and frames (double): ___0___;
    (c) Number of doors (single): ___0___;
    (d) Number of doors (double): ___0___;
    (e) Number of latches: ___28___;
    (f) Number of view panels: ___49___;
    (g) Number of closers (normal): ___0___; and
    (h) Number of closers (automatic): ___0___.

(3) Element counts to move to > 20 minute fire rating with automatic closers
    state:
    (a) Number of doors and frames (single): ___49___;
    (b) Number of doors and frames (double): ___0___;
    (c) Number of doors (single): ___0___;
    (d) Number of doors (double): ___0___;
    (e) Number of latches: ___28___;
    (f) Number of view panels: ___49___;
    (g) Number of closers (normal): ___0___; and
    (h) Number of closers (automatic): ___0___.

Line 123 contains information on how the critical element counts for hazardous areas are to be aggregated. The three entries after the building safety feature number tell whether or not data on high hazard areas, single deficiency non-sprinklered areas, and single deficiency sprinklered areas are to be read in. A value of 0 implies that no data for that type of hazardous area are to be read; a value of 1 implies that element counts which represent the sum total for all hazardous areas of that type are to read in. Since the fire zone under consideration was initially in the single deficiency within the zone state, the only feasible retrofit was to go to the no deficiencies state. Since the model treats transitions to the single deficiency out of zone state as impossible, three values of −1 are recorded on line 124. Line 125 contains the responses to question 3 of Worksheet X (see exhibit 3.27). No other parts of this worksheet were completed because all single deficiency hazardous areas were of the non-sprinklered type.

Line 126 indicates that no transition to the smoke control by zone state is feasible (see exhibit 3.28). Recall that the mechanically assisted by zone state requires special costing not included within the FSESCM computer program. Values can be input, however, by exercising the CHANGE option.

Data on emergency movement routes are recorded on lines 127 through 129. These data correspond to the responses to questions 2.1 through 2.g and 3.a through 3.g on Worksheet XII (see exhibit 3.29). Since the direct exit state requires special costing, the critical element count entries on line 129 are coded as −1. The single entry on line 130 indicates that manual fire alarms are already in the highest state (see exhibit 3.30).

The entries on lines 131 through 134 correspond to the responses to Worksheet XIV (see exhibit 3.31) questions 1.i through 1.v, 2.i through 2.v, 3.i through 3.v, and 4.i through 4.v, respectively. These critical element counts are applied to a set of cost estimating relationships within subroutine CSMOKE. Just as for the other building safety features, if one or more of the retrofit states is infeasible, a value of −1 should be entered in the appropriate spaces on Worksheet XIV.

Lines 135 through 137 are concerned with automatic sprinklers. The two entries after the building safety feature number on line 135 correspond to the potential retrofit designation, Worksheet XV question 1 (see exhibit 3.32), and the water supply qualifier, Worksheet XV question 2. Lines 136 and 137 record the responses to questions 3.i through 3.vii and 4.i through 4.vii on Worksheet XV. As was the case for smoke detection and alarm retrofit states, if one or the other of the automatic sprinker retrofits is infeasible, a value of −1 should be coded into the spaces provided for the critical element counts.

The last two cards correspond to the sequences of each option within the control packet to be exercised for this fire zone. The sequence is declared on Worksheet XVI (see exhibit 3.33).

Exhibit 3.25  Completed Worksheet VIII:  Zone Dimensions (BSF=6)

Current state:  <u>Dead end 30-50'</u>.
Note:  Do not complete this form if already in the no dead ends state with a
       zone length less than 100 feet.

Potential retrofits:
     (a) Create a cross connection to a parallel corridor: linear feet;
     (b) Install interior stairway: number;
     (c) Install exterior stairway: number;
     (d) Install smoke partition: number;
     (e) Install partition slab-to-slab: linear feet;
     (f) Extend existing partition to slab: linear feet; and
     (g) Install smoke dampers: number.

(1) Design qualifiers
     (i)  What is the total length in feet of all zones currently being
          analyzed? __210__.
     (ii) Can a new smoke partition be installed to reduce the length of the
          fire zone? __1__. (0 implies no, 1 implies yes)

(2) Element counts to move to 50-100 feet Dead End state:
     (a) Linear feet of cross connection: _____;
     (b) Number of interior stairways: _____;
     (c) Number of exterior stairways: _____;
     (d) Number of smoke partitions: _____;
     (e) Linear feet of partition: _____;
     (f) Linear feet of extension: _____; and
     (g) Number of smoke dampers: _____.

(3) Element counts to mvoe to 30-50 foot dead end state:
     (a) Linear feet of cross connection: _____;
     (b) Number of interior stairways: _____;
     (c) Number of exterior stairways: _____;
     (d) Number of smoke partitions: _____;
     (e) Linear feet of partition: _____;
     (f) Linear feet of extension: _____; and
     (g) Number of smoke dampers: _____.

(4) Element counts to move to no dead ends and a zone length greater than
    150 feet state:
     (a) Linear feet of cross connection: __0__;
     (b) Number of interior stairways: __0__;
     (c) Number of exterior stairways: __9__;
     (d) Number of smoke partitions: __0__;
     (e) Linear feet of partition: __0__;
     (f) Linear feet of extension: __0__; and
     (g) Number of smoke dampers: __0__.

Exhibit 3.25 Completed Worksheet VIII:  Zone Dimensions (Continued)

(5) Element counts to move to no dead ends and a zone length between 100-150
    feet state:
    (a) Linear feet of cross connection: ___0___;
    (b) Number of interior stairways: ___0___;
    (c) Number of exterior stairways: ___9___;
    (d) Number of smoke partitions: ___7___;
    (e) Linear feet of partition: ___0___;
    (f) Linear feet of extension: ___0___; and
    (g) Number of smoke dampers: ___0___.

(6) Element counts to move to no dead ends and a zone length of less than 100
    feet state:
    (a) Linear feet of cross connection: ___0___;
    (b) Number of interior stairways: ___0___;
    (c) Number of exterior stairways: ___9___;
    (d) Number of smoke partitions: ___7___;
    (e) Linear feet of partition: ___0___;
    (f) Linear feet of extension: ___0___; and
    (g) Number of smoke dampers: ___0___.

Exhibit 3.26 Completed Worksheet IX:  Vertical Openings (BSF=7)

Current state:  < 1 hour .
Note:  Do not complete this form if already in the > 2 hour state.

Potential retrofits:
    (a) Frame and sheath enclosure: square feet;
    (b) Sheath existing enclosure: square feet;
    (c) Install doors and frames: number; and
    (d) Install doors: number.

(1) Element counts to move to the open 2 or 3 floors state:
    (a) Square feet of enclosure: _____;
    (b) Square feet of sheathing: _____;
    (c) Number of doors and frames: _____; and
    (d) Number of doors: _____.

(2) Element counts to move to enclosed with less than 1 hour fire rating
    state:
    (a) Square feet of enclosure: _____;
    (b) Square feet of sheathing: _____;
    (c) Number of doors and frames: _____; and
    (d) Number of doors: _____.

(3) Element counts to move to enclosed with 1 to 2 hour fire rating state:
    (a) Square feet of enclosure: ___0___;
    (b) Square feet of sheathing: ___0___;
    (c) Number of doors and frames: ___7___; and
    (d) Number of doors: ___0___.

(4) Element counts to move to enclosed with at least a 2 hour fire rating
    state:
    (a) Square feet of enclosure: ___0___;
    (b) Square feet of sheathing: ___0___;
    (c) Number of doors and frames: ___7___; and
    (d) Number of doors: ___0___.

Exhibit 3.27   Completed Worksheet X: Hazardous Areas (BSF=8)

Current state:  _Single deficiency in zone_ .
Note:  Do not complete this form if already in the no deficiencies state.

Potential retrofits:
    (a) Upgrade enclosure: square feet;
    (b) Install door: number; and
    (c) Install sprinklers: area in square feet.

Complete this section for _all_ high hazard areas.

(1) Element counts to move to the single deficiency state:
    (a) Square feet of enclosure: _____;
    (b) Number of doors: _____; and
    (c) Square feet of high hazard areas: _____.

(2) Element counts to move to the no deficiency state:
    (a) Square feet of enclosure: _____;
    (b) Number of doors: _____; and
    (c) Square feet of high hazard areas: _____.

Complete this section for _all_ non-sprinklered single deficiency areas.

(3) Element counts to move to no deficiency state:
    (a) Square feet of enclosure: ___0___;
    (b) Number of doors: ___7___; and
    (c) Square feet of all hazardous areas of this type: __700__.

Complete this section for _all_ sprinklered single deficiency areas.

(4) Element counts to move to no deficiency state
    (a) Square feet of enclosure: _____;
    (b) Number of doors: _____; and
    (c) Square feet of all hazardous areas of this type: _____.


Note:   FSESCM treats transitions to the double deficiency and single
        deficiency outside the fire zone as impossible.  Three values of minus
        one (-1) should therefore be used as the relevant element counts.

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Exhibit 3.28 Completed Worksheet XI:  Smoke Control (BSF=9)

Current state:  <u>Smoke partition.</u>
Note:  Do not complete this form if already in the smoke partition state.*

Potential retrofits:
    (a) Install smoke partition: number;
    (b) Install partition slab-to-slab: linear feet;
    (c) Extend existing partition to slab: feet; and
    (d) Install smoke dampers: number.

(1) Element counts to move to smoke partition state:
    (a) Number of smoke partitions: _____;
    (b) Linear feet of partition: _____;
    (c) Linear feet of extension: _____; and
    (d) Number of smoke dampers: _____.

*The mechanically assisted by zone state requiers special costing not included
within the FSESCM model.  Four values of minus one (-1) should therefore be
used as the relevant element counts.

Exhibit 3.29  Completed Worksheet XII:  Emergency Movement Routes (BSF=10)

Current state:  <u>Deficient capacity.</u>
Note:  Do not complete this form if already in the horizontal exit state.*

Potential retrofits:
    (a) Install interior stairway: number;
    (b) Install exterior stairway: number;
    (c) Install emergency light: number;
    (d) Install horizontal exist: number;
    (e) Install partition slab-to-slab: linear feet;
    (f) Extend existing partition to slab: linear feet; and
    (g) Install smoke dampers: number.

(1) Element counts to move to deficient capacity state:
    (a) Number of interior stairways: _____;
    (b) Number of exterior stairways: _____;
    (c) Number of emergency lights: _____;
    (d) Number of horizontal exits: _____;
    (e) Linear feet of partition: _____;
    (f) Linear feet of extension: _____;
    (g) Number of smoke dampers: _____.

(2) Element counts to move to no horizontal exit state:
    (a) Number of interior stairways: ___0___;
    (b) Number of exterior stairways: ___0___;
    (c) Number of emergency lights: ___0___;
    (d) Number of horizontal exits: ___0___;
    (e) Linear feet of partition: ___0___;
    (f) Linear feet of extension: ___0___;
    (g) Number of smoke dampers: ___0___.

(3) Element counts to move to horizontal exit state:
    (a) Number of interior stairways: ___0___;
    (b) Number of exterior stairways: ___0___;
    (c) Number of emergency lights: ___0___;
    (d) Number of horizontal exits: ___7___;
    (e) Linear feet of partition: _280_;
    (f) Linear feet of extension: ___0___;
    (g) Number of smoke dampers: ___0___.

*The direct exits state requires special costing not included with the FSESCM
 model.  Seven values of minus one (-1) should therefore be used as the
 relevant element counts.

Exhibit 3.30 Completed Worksheet XIII:   Manual Fire Alarm (BSF=11)

Current state:   Fire department connection.
Note:  Do not complete this form if already in the fire department connection
       state.

Potential retrofits:
    (a) Install control panel: number;
    (b) Install pull station: number; and
    (c) Connect zone(s) with fire department: number.

(1) Element counts to move to no fire department connection state:
    (a) Number of control panels: _____;
    (b) Number of pull stations: _____; and
    (c) Number of connections: _____.

(2) Element counts to move to fire department connection state:
    (a) Number of control panels: _____;
    (b) Number of pull stations: _____; and
    (c) Number of connections: _____.

Exhibit 3.31 Completed Worksheet XIV: Smoke Detection and Alarm (BSF=12)

Current state: <u>None</u>.
Note: Do not complete this form if already in the total space state.

Potential retrofit:
    (a) Install smoke detectors: number.

(1) Element counts to move to corridor only state:
    (i)    Linear feet of corridors:  <u>1540</u> ;
    (ii)   Number of patient rooms:  <u>154</u> ;
    (iii) Square feet of common areas:  <u>7000</u> ;
    (iv)   Number of non-patient rooms:  <u>21</u> ; and
    (v)    Number of bathrooms and closets:  <u>420</u> .

(2) Element counts to move to rooms only state:
    (i)    Linear feet of corridors:  <u>1540</u> ;
    (ii)   Number of patient rooms:  <u>154</u> ;
    (iii) Square feet of common areas:  <u>7000</u> ;
    (iv)   Number of non-patient rooms:  <u>21</u> ; and
    (v)    Number of bathrooms and closets:  <u>420</u> .

(3) Element counts to move to corridor and habitable space state:
    (i)    Linear feet of corridors:  <u>1540</u> ;
    (ii)   Number of patient rooms:  <u>154</u> ;
    (iii) Square feet of common areas:  <u>7000</u> ;
    (iv)   Number of non-patient rooms:  <u>21</u> ; and
    (v)    Number of bathrooms and closets:  <u>420</u> .

(4) Element counts to move to total space state:
    (i)    Linear feet of corridors:  <u>1540</u> ;
    (ii)   Number of patient rooms:  <u>154</u> ;
    (iii) Square feet of common areas:  <u>7000</u> ;
    (iv)   Number of non-patient rooms:  <u>21</u> ; and
    (v)    Number of bathrooms and closets:  <u>420</u> .

Exhibit 3.32  Completed Worksheet XV:  Automatic Sprinklers (BSF=13)

Current state: __None__ .
Note:  Do not complete this form if already in the total space state.

(1) Potential retrofit designation: ____1____ ;
    (a) Wet exposed: Designation = 1;
    (b) Wet concealed: Designation = 2;
    (c) Dry exposed: Designation = 3; and
    (d) Dry concealed: Designation = 4.

(2) Water supply qualifier: ____1____ ;
    (i)   Adequate: Designation = 1;
    (ii)  Not Adequate: Designation = 2; and
    (iii) Unknown: Designation = 3.

(3) Element counts to move to corridor and habitable space state:
    (i)   Linear feet of corridors: __15400__ ;
    (ii)  Number of rooms (< 200 square feet): ____0____ ;
    (iii) Number of rooms (200-400 square feet): __168____ ;
    (iv)  Number of rooms (400-600 square feet): ____7____ ;
    (v)   Floor area of common spaces and wards (> 600 square feet): __7000__ ;
    (vi)  Square feet of floor area analyzed (total): __77000__ ; and
    (vii) Number of bathrooms and closets: __420____ .

(4) Element counts to move to total space state:
    (i)   Linear feet of corridors: __1540____ ;
    (ii)  Number of rooms (< 200 square feet): ____0____ ;
    (iii) Number of rooms (200-400 square feet): ___168____ ;
    (iv)  Number of rooms (400-600 square feet): ____7____ ;
    (v)   Floor area of common spaces and wards (> 600 square feet): __7000__ ;
    (vi)  Square feet of floor area analyzed (total): __77000__ ; and
    (vii) Number of bathrooms and closets: __420____ .

Exhibit 3.33 Completed Worksheet XVI:  User Options to be Exercised

Enter the sequence within the control packet for this fire zone beside each option to be exercised.

(1) Major control options*:
    (i)    NEXT: _____;
    (ii)   LAST: _____;
    (iii) TEST: _____; and
    (iv)  FINAL: ___2___ .

(2) Minor control options**:
    (i)    SOLVE: ___1___;
    (ii)   CHANGE: _____;
           (a) Building safety feature number: _____;
           (b) State number: _____; and
           (c) Transition cost: _____.
    (iii) REQUIR: _____;
           (a) Number of safety requirement: _____; and
           (b) Percent change desired: _____.

*May be used only once for each fire zone.

**May be used several times or in combination for each fire zone.  The influence on problem structure is however cumulative.

The remainder of this section consists of a set of tables. These tables summarize the input format for each singleton or group of cards. Cross reference to the FSESCM Worksheet is given as well as a description of the associated routines. Within the tables, reference to each input variable is handled in five ways. First, the critical element will be named. Second, the variable will be tied to a specific response on the worksheet. Third, the type of variable will be declared. Fourth, the first column available for recording information on the targeted input variable will be given. Finally, the name of the internal variable used to store the input data for this variable will be given. This step is necessary to simplify reference to the relevant sections of the Programmer's Manual where technical issues are discussed (e.g., modifications to the source code due to pecularities of the operating system). The titles of the tables are cross referenced to the entries in figure 3.2. The information presented in tables 3.5 through 3.26 is therefore in the same sequence as in figure 3.2.

The column number of the table which has "Section of Worksheet" as its title refers to the question number - subsection number of the appropriate FSESCM Worksheet. The worksheet number is given beneath the table number. Thus 1.i refers to subsection i of question 1 of the previously declared worksheet. If several different questions are relevant due to the existence of two or more retrofit states, then all possibilities will be listed. For example, if the fire zone were initially in the "no door" state and we were recording the number of single-width doors and frames which would require replacement to move to a higher state, the entries would be 1.a, 2.a, 3.a.

FSESCM uses integer, single precisison real, and character variables as inputs. All variables which appear in tables 3.5 through 3.26 are defined as: (1) In, refers to an n-digit integer; (2) Fj.k, refers to a j-digit single precision real number with k digits to the right of the decimal point; and (3) Ap, refers to a character string of p characters. Two points should be kept in mind when examining the tables which follow. First, all integer variables must be right justified (i.e., the units digit must be in the right-most column of the field). Second, if a decimal is not entered in an F field, it is implied by the value of k, and occupies no space in the field. If a decimal point is entered in an F field, it is used as entered (overriding the value of k) but it occupies one space in the field. Since the position of the decimal overrides the specification declared on the read statement, there is no need to right justify real variables if a decimal point is entered. Regardless of the type of variable to be entered, the user should exercise some care to insure that all columns are properly aligned. It is important to note that the variable specifications shown in tables 3.5 through 3.26 do not include "fillers". Thus if a FORMAT statement within the program contains an nX entry which corresponds to a filler, the first column specification is shifted n spaces to the right. Similarly, if a variable has a maximum value less than 100 and is read according to an I3 specification, it is listed as I2 with the first column shifted one space to the right. This approach was taken in order to focus attention on the relationship between the file and the worksheets rather than on technical details.

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Two points should be understood when attempting to interpret the information given under the "Internal Variable" heading. First, some internal variables are arrays. In this case, one of the array dimensions may correspond to the state number whereas the other corresponds to a specific critical element. In order to differentiate the state number from the critical element, the following convention is used: critical elements will be numbered sequentially whereas state numbers will be denoted by asterisks (*). It is worth noting that the maximum state number is equal to the number of entries on the appropriate row of FSES Table 4. This value is recorded internally in the vector IT4M(I), I=1,13. Second, the number of critical elements associated with each building safety feature read within the MAIN program is determined by the entries in the vector LCV(I), I=1,13. (LCV refers to the length of the cost vector.) Thus although the INELT arry is referenced frequently in the tables which follow, data on the Ith building safety feature are read into it according to the entries in IT4M(I) and LCV(I). The number of critical elements is determined within the appropriate special purpose subroutine for building safety features 1, 6, 8, and 12 and 13.

Table 3.5  Mailing Label

Routine:  MAIN          Worksheet:  I
Card classification:  Group
Examples within exhibit 3.17:  Lines 1 through 6.
Note:  Each row of the table refers to a single card.

| Variable Name | Section of Worksheet | Variable Type | First Column | Internal Variable |
|---|---|---|---|---|
| Facility | 1.i | A40 | 1 | HBLDG(1) |
| Building | 1.ii | A40 | 1 | HBLDG(2) |
| Contact | 1.iii | A40 | 1 | HBLDG(3) |
| Address | 1.iv | A40 | 1 | HBLDG(4) |
| City, State, Zip | 1.v | A40 | 1 | HBLDG(5) |
| Telephone | 1.vi | A40 | 1 | HBLDG(6) |

Table 3.6  Building Qualifiers

Routine:  MAIN          Worksheet:  I
Card classification:  Singleton
Examples within exhibit 3.17:  Line 7

| Variable Name | Section of Worksheet | Variable Type | First Column | Internal Variable |
|---|---|---|---|---|
| Building Type | 2 | I1 | 3 | ITYPE |
| Building Age | 3 | I1 | 6 | IBLDG |
| Cost Growth | 4.i | F5.2 | 7 | CMODT |
| Labor Factor | 4.ii | F5.2 | 12 | CMODL |
| Material Factor | 4.iii | F5.2 | 17 | CMODM |

Table 3.7  Zone Qualifiers

Routine:  MAIN          Worksheet:  I
Card classification:  Singleton
Examples within exhibit 3.17:  Lines 8, 39, 72 and 106.

| Variable<br>Name | Section of<br>Worksheet | Variable<br>Type | First<br>Column | Internal<br>Variable |
|---|---|---|---|---|
| Floor Number | 1.i | I2 | 3 | IFLOR |
| Zone Number | 1.ii | I2 | 7 | IZONE |
| Number of Patients | 1.iii | I4 | 9 | IPATS |


Table 3.8  FSES Table 1 Qualifiers

Routine:  MAIN          Worksheet:  II
Card classification:  Singleton
Examples within exhibit 3.17:  Lines 9, 40, 73 and 107.

| Variable<br>Name | Section of<br>Worksheet | Variable<br>Type | First<br>Column | Internal<br>Variable |
|---|---|---|---|---|
| Patient Mobility | 2.i | I1 | 3 | IT1X(1) |
| Patient Density | 2.ii | I1 | 6 | IT1X(2) |
| Zone Location | 2.iii | I1 | 9 | IT1X(3) |
| Patients/Attendants | 2.iv | I1 | 12 | IT1X(4) |
| Average Age | 2.v | I1 | 15 | IT1X(5) |

## Table 3.9  FSES Table 4 Qualifiers

Routine:  MAIN          Worksheet:  II
Card classification:  Singleton
Examples within exhibit 3.17:  Lines 10, 41, 74 and 108.

| Variable Name | Section of Worksheet | Variable Type | First Column | Internal Variable |
|---|---|---|---|---|
| Construction | 3.i | I1 | 3 | IT4X(1) |
| Interior Finish [Corridor] | 3.ii | I1 | 6 | IT4X(2) |
| Interior Finish [Rooms] | 3.iii | I1 | 9 | IT4X(3) |
| Corridor Partitions/Walls | 3.iv | I1 | 12 | IT4X(4) |
| Doors to Corridor | 3.v | I1 | 15 | IT4X(5) |
| Zone Dimensions | 3.vi | I1 | 18 | IT4X(6) |
| Vertical Openings | 3.vii | I1 | 21 | IT4X(7) |
| Hazardous Areas | 3.viii | I1 | 24 | IT4X(8) |
| Smoke Control | 3.ix | I1 | 27 | IT4X(9) |
| Emergency Movement | 3.x | I1 | 30 | IT4X(10) |
| Manual Fire Alarms | 3.xi | I1 | 33 | IT4X(11) |
| Smoke Detection | 3.xii | I1 | 36 | IT4X(12) |
| Sprinklers | 3.xiii | I1 | 39 | IT4X(13) |


## Table 3.10  Construction

Routine:  CCONST          Worksheet: III
Building safety feature:  1
Card classification:  Group
Examples within exhibit 3.17:  Lines 11, 42, 75 and 109.

| Variable Name | Section of Worksheet | Variable Type | First Column | Internal Variable |
|---|---|---|---|---|
| BSF Number | Title | I2 | 2 | K |
| Walls and Partitions | 1.a,2.a | I6 | 4 | IECCON(1,*) |
| Columns | 1.b,2.b | I6 | 10 | IECCON(2,*) |
| Beams | 1.c,2.c | I6 | 16 | IECCON(3,*) |
| Decking | 1.d,2.d | I6 | 22 | IECCON(4,*) |

Table 3.11  Interior Finish [Corridors and Exits]

Routine:  MAIN          Worksheet:   IV
Building safety feature:  2
Card classification:  Group
Examples within exhibit 3.17:  Lines 12, 43, 76 and 110.

| Variable Name | Section of Worksheet | Variable Type | First Column | Internal Variable |
|---|---|---|---|---|
| BSF Number | Title | I2 | 2 | J |
| Drywall | 1.q,2.q | I6 | 4 | INELT(*,1) |
| Walls | 1.b,2.b | I6 | 10 | INELT(*,2) |
| Ceiling | 1.c,2.c | I6 | 16 | INELT(*,3) |
| Carpet | 1.d,2.d | I6 | 22 | INELT(*,4) |


Table 3.12  Interior Finish  [Rooms]

Routine:  MAIN          Worksheet:  V
Building safety feature:  3
Card classification:  Group
Examples within exhibit 3.17:  Lines 13, 44, 77, 78, 111 and 112.

| Variable Name | Section of Worksheet | Variable Type | First Column | Internal Variable |
|---|---|---|---|---|
| BSF Number | Title | I2 | 2 | J |
| Drywall | 1.q,2.q | I6 | 4 | INELT(*,1) |
| Walls | 1.b,2.b | I6 | 10 | INELT(*,2) |
| Ceiling | 1.c,2.c | I6 | 16 | INELT(*,3) |

## Table 3.13   Corridor Partitions/Walls

Routine:  MAIN            Worksheet:  VI
Building safety feature:  4
Card classification:  Group
Examples within exhibit 3.17:  Lines 14, 45, 79 and 113.

| Variable Name | Section of Worksheet | Variable Type | First Column | Internal Variable |
|---|---|---|---|---|
| BSF Number | Title | I2 | 2 | J |
| Install Partition | 1.a,2.a,3.a | I6 | 4 | INELT(*,1) |
| Extend Partition | 1.b,2.b,3.b | I6 | 10 | INELT(*,2) |
| Replace Glass: Number | 1.c,2.c,3.c | I6 | 16 | INELT(*,3) |
| Replace Glass: Area | 1.d,2.d,3.d | I6 | 22 | INELT(*,4) |
| Replace Window: Number | 1.e,2.e,3.e | I6 | 28 | INELT(*,5) |
| Replace Window: Area | 1.f,2.f,3.f | I6 | 34 | INELT(*,6) |
| Sheath (< 1/3 Hour) | 1.g,2.g,3.g | I6 | 40 | INELT(*,6) |
| Sheath (1/3-1 Hour) | 1.h,2.h,3.h | I6 | 46 | INELT(*,8) |


## Table 3.14   Doors to Corridor

Routine:  MAIN            Worksheet:  VII
Building safety feature:  5
Card classification:  Group
Examples within exhibit 3.17:  Lines 15, 16, 17, 46, 47, 48, 80, 81, 82, 114, 115 and 116.

| Variable Name | Section of Worksheet | Variable Type | First Column | Internal Variable |
|---|---|---|---|---|
| BSF Number | Title | I2 | 2 | J |
| Doors & Frames (Single) | 1.a,2.a,3.a | I6 | 4 | INELT(*,1) |
| Doors & Frames (Double) | 1.b,2.b,3.b | I6 | 10 | INELT(*,2) |
| Doors (Single) | 1.c,2.c,3.c | I6 | 16 | INELT(*,3) |
| Doors (Double) | 1.d,2.d,3.d | I6 | 22 | INELT(*,4) |
| Latch | 1.e,2.e,3.e | I6 | 28 | INELT(*,5) |
| View Panel | 1.f,2.f,3.f | I6 | 34 | INELT(*,6) |
| Closers (Normal) | 1.g,2.g,3.g | I6 | 40 | INELT(*,6) |
| Closers (Automatic) | 1.h,2.h,3.h | I6 | 46 | INELT(*,8) |

Table 3.15  Zone Length Qualifiers

Routine:  CZODIM        Worksheet:  VIII
Building safety feature:  6
Card classification:  Singleton
Examples within exhibit 3.17:  Lines 18, 49, 83 and 117.

| Variable Name | Section of Worksheet | Variable Type | First Column | Internal Variable |
|---|---|---|---|---|
| BSF Number | Title | I2 | 2 | K |
| Zone Length | 1.i | I6 | 4 | LZONE |
| Partition Qualifier | 1.ii | I1 | 15 | IPART |

Table 3.16  Zone Dimensions

Routine:  CZODIM        Worksheet:  VIII
Building safety feature:  6
Card classification:  Group
Examples within exhibit 3.17:  Lines 19, 20, 50, 51, 84, 85, 118, 119 and 120.

| Variable Name | Section of Worksheet | Variable Type | First Column | Internal Variable |
|---|---|---|---|---|
| BSF Number | Title | I2 | 2 | K |
| Cross Connection | 2.a,3.a,4.a,5.a,6.a | I6 | 4 | IECZDM(1,*) |
| Interior Stairwell | 2.b,3.b,4.b,5.b,6.b | I6 | 10 | IECZDM(2,*) |
| Exterior Stairwell | 2.c,3.c,4.c,5.c,6.c | I6 | 16 | IECZDM(3,*) |
| Smoke Partition | 2.d,3.d,4.d,5.d,6.d | I6 | 22 | IECZDM(4,*) |
| Install Partition | 2.e,3.e,4.e,5.e,6.e | I6 | 28 | IECZDM(5,*) |
| Extend Partition | 2.f,3.f,4.f,5.f,6.f | I6 | 34 | IECZDM(6,*) |
| Smoke Dampers | 2.g,3.g,4.g,5.g,6.g | I6 | 40 | IECZDM(7,*) |

Table 3.17   Vertical Openings

Routine:  MAIN            Worksheet:  IX
Building safety feature:  7
Card classification:  Group
Examples within exhibit 3.17: Lines 21, 22, 52, 53, 86, 87, 121, and 122.

| Variable Name | Section of Worksheet | Variable Type | First Column | Internal Variable |
|---|---|---|---|---|
| BSF Number | Title | I2 | 2 | J |
| Frame and Sheath | 1.a,2.a,3.a,4.a | I6 | 4 | INELT(*,1) |
| Sheath | 1.b,2.b,3.b,4.b | I6 | 10 | INELT(*,2) |
| Doors and Frames | 1.c,2.c,3.c,4.c | I6 | 16 | INELT(*,3) |
| Doors | 1.d,2.d,3.d,4.d | I6 | 22 | INELT(*,4) |


Table 3.18   Deficiency Qualifiers

Routine:  CHAZAR        Worksheet:  X
Building safety feature:  8
Card classification:  Singleton
Examples within exhibit 3.17:  Lines 23, 54, 88, and 123.

| Variable Name | Section of Worksheet | Variable Type | First Column | Internal Variable |
|---|---|---|---|---|
| BSF Number | Title | I2 | 2 | K |
| Double Deficiency Qualifier | 1,2 | I1 | 6 | K1 |
| Single Deficiency (Non Sprinklered) | 3 | I1 | 9 | K2 |
| Single Deficiency (Sprinklered) | 4 | I1 | 12 | K3 |

## Table 3.19  Hazardous Areas

Routine:  CHAZAR          Worksheet:  X
Building safety feature:  8
Card classification:  Group
Examples within exhibit 3.17:  Lines 24, 55, 56, 89, 90, 124, and 125.

| Variable Name | Section of Worksheet | Variable Type | First Column | Internal Variable |
|---|---|---|---|---|
| BSF Number | Title | I2 | 2 | K |
| Enclosure | 1.a,2.a,3.a,4.a | I6 | 4 | see footnote 1 |
| Doors | 1.b,2.b,3.b,4.b | I6 | 10 | see footnote 1 |
| Area | a.c,2.c,3.c,4.c | I6 | 16 | see footnote 1 |

[1]The appropriate internal variable is as follows, where J=1 implies enclosures, J=2 implies doors and J=3 implies area:

(i)    IECDBL(J,*)  if the data is for a high hazard area;
(ii)   IECNOS(J,*)  if the data is for a single deficiency non-sprinklered area; and
(iii)  IECYES(J,*)  if the data is for a single deficiency sprinklered area.


## Table 3.20  Smoke Control

Routine:  MAIN          Worksheet:  XI
Building safety feature:  9
Card classification:  Group
Examples within exhibit 3.17:  Lines 25, 57, 91 and 126.

| Variable Name | Section of Worksheet | Variable Type | First Column | Internal Variable |
|---|---|---|---|---|
| BSF Number | Title | I2 | 2 | J |
| Smoke Partition | 1.a | I6 | 4 | INELT(*,1) |
| Install Partition | 1.b | I6 | 10 | INELT(*,2) |
| Extend Partition | 1.c | I6 | 16 | INELT(*,3) |
| Smoke Dampers | 1.d | I6 | 22 | INELT(*,4) |

Table 3.21   Emergency Movement Routes

Routine:  MAIN              Worksheet:  XII
Building safety feature:  10
Card classification:  Group
Examples within exhibit 3.17:  Lines 26, 27, 28, 29, 58, 59, 60, 61, 92, 93,
        94, 95, 127, 128, and 129.

| Variable Name | Section of Worksheet | Variable Type | First Column | Internal Variable |
|---|---|---|---|---|
| BSF Number | Title | I2 | 2 | J |
| Interior Stair | 1.a,2.a,3.a | I6 | 4 | INELT(*,1) |
| Exterior Stair | 1.b,2.b,3.b | I6 | 10 | INELT(*,2) |
| Emergency Light | 1.c,2.c,3.c | I6 | 16 | INELT(*,3) |
| Horizontal Exit | 1.d,2.d,3.d | I6 | 22 | INELT(*,4) |
| Install Partition | 1.e,2.e,3.e | I6 | 28 | INELT(*,5) |
| Extend Partition | 1.f,2.f,3.f | I6 | 34 | INELT(*,6) |
| Smoke Dampers | 1.g,2.g,3.g | I6 | 40 | INELT(*,7) |


Table 3.22   Manual Fire Alarm

Routine:  MAIN              Worksheet:  XIII
Building safety feature:  11
Card classification:  Group
Examples within exhibit 3.17:  Lines 30, 62, 96, and 130.

| Variable Name | Section of Worksheet | Variable Type | First Column | Internal Variable |
|---|---|---|---|---|
| BSF Number | Title | I2 | 2 | 3 |
| Panel | 1.a,2.a | I6 | 4 | INELT(*,1) |
| Pull Station | 1.b,2.b | I6 | 10 | INELT(*,2) |
| Connection | 1.c,2.c | I6 | 16 | INELT(*,3) |

Table 3.23   Smoke Detection and Alarm

Routine:  CSMOKE          Worksheet:  XIV
Building safety feature:  12
Card classification:  Group
Examples within exhibit 3.17:  Lines 31, 32, 33, 34, 63, 64, 65, 66, 97, 98,
    99, 100, 131, 132, 133 and 134.

| Variable Name | Section of Worksheet | Variable Type | First Column | Internal Variable |
|---|---|---|---|---|
| BSF Number | Title | I2 | 2 | K |
| Corridors | 1.i,2.i,3.i,4.i | I6 | 4 | IECSMO(1,*) |
| Patient Rooms | 1.ii,2.ii,3.ii,4.ii | I6 | 10 | IECSMO(2,*) |
| Common Areas | 1.iii,2.iii,3.iii,4.iii | I6 | 16 | IECSMO(3,*) |
| Non-Patient Rooms | 1.iv,2.iv,3.iv,4.iv | I6 | 22 | IECSMO(4,*) |
| Bathrooms & Closets | 1.v,2.v,3.v,4.v | I6 | 28 | IECSMO(5,*) |


Table 3.24   Sprinkler Qualifiers

Routine:  CSPRNK          Worksheet:  XV
Building safety feature:  13
Card classification:  Singleton
Examples within exhibit 3.17:  Lines 35, 67, 101 and 135.

| Variable Name | Section of Worksheet | Variable Type | First Column | Internal Variable |
|---|---|---|---|---|
| BSF Number | Title | I2 | 2 | K |
| Sprinkler Type | 1 | I1 | 6 | I2 |
| Water Supply | 2 | I1 | 9 | I3 |

Table 3.25   Sprinklers

Routine:  CSPRNK          Worksheet:  XV
Building safety feature:  13
Card classification:  Group
Examples within exhibit 3.17:  Lines 36, 68, 69, 102, 103, 136 and 137.

| Variable Name | Section of Worksheet | Variable Type | First Column | Internal Variable |
|---|---|---|---|---|
| BSF number | Title | I2 | 2 | K |
| Corridors | 3.i,4.i | I6 | 4 | IECSPR(1,*) |
| Rooms ($<200$ ft$^2$) | 3.ii,4.ii | I6 | 10 | IECSPR(2,*) |
| Rooms (200-400 ft$^2$) | 3.iii,4.iii | I6 | 16 | IECSPR(3,*) |
| Rooms (400-600 ft$^2$) | 3.iv,4.iv | I6 | 22 | IECSPR(4,*) |
| Common Areas & Wards | 3.v,4.v | I6 | 28 | IECSPR(5,*) |
| Total Floor Area | 3.vi,4.vi | I6 | 34 | IECSPR(6,*) |
| Bathrooms & Closets | 3.vii,4.vii | I6 | 40 | IECSPR(7,*) |


Table 3.26   User Options

Routine:  MAIN          Worksheet:  XVI
Card classification:  Group
Examples within exhibit 3.17:  Lines 37, 38, 70, 71, 104, 105, 138, and 139.
Note:  Entries between dashed lines (---) refer to a single card.

| Variable Name | Section of Worksheet | Variable Type | First Column | Internal Variable |
|---|---|---|---|---|
| NEXT | 1.i | A6 | 1 | HIN |
| LAST | 1.ii | A6 | 1 | HIN |
| TEST | 1.iii | A6 | 1 | HIN |
| FINAL | 1.iv | A6 | 1 | HIN |
| SOLVE | 2.i | A6 | 1 | HIN |
| CHANGE | 2.ii | A6 | 1 | HIN |
| BSF Number | 2.ii.a | I2 | 8 | I1 |
| State Number | 2.ii.b | I1 | 12 | I2 |
| Cost | 2.ii.c | I7 | 13 | I3 |
| REQUIR | 2.iii | A6 | 1 | HIN |
| Safety Requirement | 2.iii.a | I1 | 9 | I1 |
| Percent Change | 2.iii.b | I3 | 10 | I2 |

# 4. A DISCUSSION OF PROGRAM OUTPUTS

The model's output reports can be classified into three basic categories. These output reports contain background information, reference data and solutions for each fire zone, and design solutions which specify the best post-retrofit strategies for the entire building. All output reports described in this chapter will be based on the example presented in chapter 3. For easy reference, each of the ten exhibits shown in this chapter is divided into two parts. Part A is a sample output and Part B is an interpretation of the information provided by the model. The descriptions given throughout this chapter are aimed at analyzing each output report on an item-by-item basis. It is important for users to recognize that some interpretation and qualification is necessary when analyzing the solutions produced by the model. The description presented in this chapter will attempt to address these issues for the case example. Readers should treat this as illustrative but not limit the interpretation of their own studies to the topics discussed in this chapter. In order to provide guidance for analyzing the solutions produced by the model in a general setting, the next chapter will establish criteria based on experience in model building and consultation among user groups for setting up and critiquing the model's results. It is important to point out that the data on the first three fire zones are not summarized in this chapter. Consequently, if the user were to run the case study from chapter 3, reports on the first three fire zones would be output. Similarly, in order to conserve on space, several of the Total Building Summary Reports have been omitted. Since the tape which contains the FSESCM source code also contains the chapter 3 data file and a complete set of output reports, it is not expected that the omission of several output reports will result in confusion or misinterpretation of the part of users. The file containing the model's output reports is provided both for user convenience and as a check of software portability across operating systems. Users are encouraged to run this case prior to conducting any analytical studies of their own.

## 4.1  BACKGROUND INFORMATION

The two exhibits contained in this section serve as a separator among buildings under analysis, a mailing label for the completed analysis, and a summary of the relevant information from FSES Tables 1, 6 and 4. The information presented as exhibit 4.1 is based on the responses to question 1 of Worksheet I (exhibit 3.1). These responses correspond to the first six lines of the data file or the first six lines for the data on each building if more than one facility is to be analyzed. This output report is produced through a call to a subroutine once the mailing label has been read into a character array. Information on the building type designation, building qualifier and construction cost modifiers are then read in (questions 2, 3 and 4 of Worksheet I). The building type designator determines whether the facility under analysis is a hospital or nursing home (i.e, it specifies the appropriate values of FSES Table 6). In this case, the facility is a hospital. The building qualifier specifies the appropriate entries in FSES Table 6 which are then used as performance requirements. The outputs of FSES Tables 1, 6 and 4 are based on internally stored arrays (both character and real).

Exhibit 4.1  Sample Title Page

Part A:  Printout

```
NORTH-WEST GENERAL HOSPITAL
MAIN BUILDING
ATTN: ROBERT E. CHAPMAN
101 RESEARCH BLVD.
MONTGOMERY, MARYLAND 20000
TEL: (301)-921-3855
```

Exhibit 4.1   Sample Title Page

Part B:   Discussion


The title page is produced through a call to subroutine PRTBAC.  The character
array HBLDG is passed as an argument.  The subroutine prints the contents of
HBLDG (i.e., the mailing label and the contact person).  The carriage returns
within subroutine PRTBAC also serve as a separator between runs for different
facilities.  Subroutine PRTBAC is called immediately after it has read into
HBLDG the facility ID, name of the contact person and facility address.

Exhibit 4.2  Sample FSES Tables

Part A:  Printout

## OCCUPANCY RISK FACTORS

1.  PATIENT
    MOBILITY    1.0   1.6   3.2   4.5

2.  PATIENT
    DENSITY     1.0   1.2   1.5   2.0

3.  ZONE
    LOCATION    1.1   1.2   1.4   1.6   1.6

4.  RATIO OF
    PT TO AT    1.0   1.1   1.2   1.5   4.0

5.  AVERAGE
    AGE         1.0   1.2

## MANDATORY SAFETY REQUIREMENTS FOR HOSPITALS

| | CONTAINMENT SA | | EXTINGUISHMENT SB | | PEOPLE MOVEMENT SC | |
|---|---|---|---|---|---|---|
| ZONE LOCATION | NEW | EXIST | NEW | EXIST | NEW | EXIST |
| FIRST FLOOR | 9.0 | 5.0 | 4.0 | 4.0 | 4.0 | 1.0 |
| ABOVE 1ST FLOOR | 14.0 | 9.0 | 6.0 | 6.0 | 7.0 | 3.0 |

## PARAMETER VALUES

1.  CONSTRUCTION

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| FIRST FLOOR | -2.0 | .0 | -2.0 | .0 | .0 | 2.0 | 2.0 |
| SECOND FLOOR | -7.0 | -2.0 | -4.0 | -2.0 | -2.0 | 2.0 | 4.0 |
| THIRD FLOOR | -9.0 | -7.0 | -9.0 | -7.0 | -7.0 | 2.0 | 4.0 |
| 4TH & ABOVE | -13.0 | -7.0 | -13.0 | -7.0 | -9.0 | -7.0 | 4.0 |

| | | | | | |
|---|---|---|---|---|---|
| 2.  INTERIOR FINISH CORR AND EXIT | -5.0 | .0 | 3.0 | | |
| 3.  INTERIOR FINISH ROOMS | -3.0 | 1.0 | 3.0 | | |
| 4.  CORRIDOR PARTITIONS AND WALLS | -10.0 | .0 | 1.0 | 2.0 | |
| 5.  DOORS TO CORRIDOR | -10.0 | .0 | 1.0 | 2.0 | |
| 6.  ZONE DIMENSIONS | -6.0 | -4.0 | -2.0 | -2.0 | .0 | 1.0 |
| 7.  VERTICAL OPENINGS | -14.0 | -10.0 | .0 | 2.0 | 3.0 | |
| 8.  HAZARDOUS AREAS | -11.0 | -5.0 | -6.0 | -2.0 | .0 | |
| 9.  SMOKE CONTROL | -5.0 | .0 | 3.0 | | |
| 10.  EMERGENCY MOVEMENT ROUTES | -8.0 | -2.0 | .0 | 3.0 | 5.0 | |
| 11.  MANUAL FIRE ALARM | -4.0 | 1.0 | 2.0 | | |
| 12.  SMOKE DETECTION AND ALARM | .0 | 2.0 | 3.0 | 4.0 | 5.0 | |
| 13.  AUTOMATIC SPRINKLERS | .0 | 8.0 | 10.0 | | |

Exhibit 4.2  Sample FSES Tables

Part B:  Discussion


This report is generated by the MAIN program.  The labels for FSES Table 1
stored in the character array HT1 are first printed followed by the occupancy
risk factors stored in the T1 array.  Next, depending on the value of ITYPE,
the mandatory safety requirements for the problem under analysis are output.
The value of ITYPE determines whether this is a hospital (T6A) or a nursing
home (T6B).  FSES Table 4 is then printed out; it consists of three parts.
First, the labels stored in the character array HPAR are printed out.  Next,
the state values for the four rows associated with the construction building
safety feature stored in array T4A are printed out.  Finally, the state values
associated with the remaining 12 building safety features, which are stored in
the G array, are printed out.

## 4.2  REFERENCE DATA AND SOLUTIONS

As mentioned earlier, the data from the FSESCM Worksheets for each fire zone (exhibit 3.2) and each building safety feature (exhibits 3.3 through 3.15) are pieced together until they roughly resemble the retrofits specified at the top of each building safety feature worksheet.  The data are then used to set up the problem for solution by the FSESCM computer program.  Three types of output information are shown as as exhibits 4.3 through 4.5.  The Input Summary Report (exhibit 4.3) provides the user with a concise statement of the data used in setting up the problem for solution.  It provides the user an opportunity to check the correctness of any values input as well as a means of differentiating among several runs for the same fire zone.  This report shows the location of the fire zone, the number of patients and the appropriate set of occupancy risk factors for the fire zone under study.  Data on each of the 13 building safety features are then printed out.  These data show the input and prescriptive state and the number of elements which must be upgraded in order to move to a higher state.

The summary of Estimated Retrofit Costs Report (exhibit 4.4) is then presented.  This report includes the location of the fire zone and three types of construction cost modifiers.  The modifiers are needed because all costs used within the FSESCM computer program reflect the cost of installing a particular retrofit in the Washington, D.C. area during the summer of 1981.  Thus it is not only necessary to adjust for regional price differences in the markets for labor services and building materials, but also to adjust for cost growth over time.  All three of these cost factors are readily available from construction industry publications.  Each of the 13 building safety features is then output.  The data show the input and prescriptive state and the estimated cost of going to each potential retrofit.  The cost of prescriptive compliance for the fire zone is also shown as a basic reference point.

The Fire Zone Summary Report (exhibit 4.5) is then output.  This report shows each distinct solution generated as a line of output.  In order to easily identify a particular solution and for ease in differentiating among solutions, the state name is printed beneath each of the 13 building safety feature solumn headings.  The order in which the solutions are output is based on the 40 design classifications listed in table 2.4.  All solutions are ranked from least costly to most costly within a design classification; so if more than one solution was generated, the least costly is printed first followed by the second, until all solutions for that design classification are output.  The program then outputs the solution(s) for the next design classification for which at least one solution was generated until the list is exhausted.  The prescriptive compliance solution is then output.  Three other groups of solutions are also output.  They are:  (1) solutions which have no deficiencies in hazardous areas but do not belong to one of the design classifications; (2) solutions which have a single deficiency in a hazardous area; and (3) solutions which have a double deficiency in a hazardous area.

It is important to point out that exhibits 4.3 through 4.5 are samples selected to illustrate specific points and as such do not constitute the complete output for the building being analyzed. For example, exhibits 4.3 through 4.5 are the outputs associated with the patient room floors (floors 3 through 9) and hence do not contain laboratories, heavy equipment areas, or other areas which may call for special treatment.

## 4.3  DESIGN SOLUTIONS

For purposes of illustration, the Total Building Summary Reports presented as exhibits 4.6 throgh 4.10 will be analyzed in some detail. The relative costs, as a percentage of the prescriptive compliance costs, are shown in figure 4.1. This figure shows that the range of cost savings is quite dramatic, with the best solution from among the 40 design classifications costing only 10 percent of the prescriptive compliance solution. The solutions shown in figure 4.1 were selected to illustrate another point, namely that the requirement for the inclusion of a high cost option (e.g., the installation of an exit stairwell to remove a dead end corridor charge) can be accomplished at a significant savings in overall compliance costs. This result is due to the way in which the procedure upgrades the building safety features not constrained by the design variable qualifiers. There are circumstances under which the additional cost of compliance can be traced to a particular option, however. For example, the best solution for the building, presented as exhibit 4.6 (bar A on figure 4.1), costs slightly over $30,000. If we now require smoke detection and alarm in all corridors and habitable spaces, hold all other design variable qualifiers constant, and let the remaining building safety features be upgraded in the most cost-effective manner, the total cost for the building rises to around $110,000 (see exhibit 4.7 and bar B on figure 4.1). In this case, the additional cost of compliance is due almost entirely to the installation of smoke detection and alarm equipment. Requiring smoke detection and alarm in the total space (see exhibit 4.8 and bar C on figure 4.1) has a similar effect. This implies some care should be exercised in deciding on whether to cover corridors and habitable spaces only or to go for covering the total space. A similar conclusion results if automatic sprinkler systems are considered. In exhibit 4.9 (bar D in figure 4.1), the dead end corridor charge on floors 3 through 9 is removed through the installation of an exit stairwell. In this case, the cost of compliance is $215,000 or approximately 30 percent less expensive than the prescriptive compliance solution (compare exhibits 4.9 and 4.10 and bars D and E on figure 4.1). Another important factor concerns the surpluses over the four safety requirements. In almost all cases the fire zones within a design classification exceed the requirements by several points. The surpluses therefore serve both as a buffer against future changes in safety requirements and provide information which may be useful in choosing among retrofit packages which are close in cost to each other.

INPUT SUMMARY

FLOOR 3   ZONE 1   PATIENTS 280   TABLE 1 INDICES   4 4 4 1 1

| BUILDING SAFETY FEATURE | INPUT | PRESC | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | NCOM•R | NCOM•R | C•WF•U | C•WF•P | C•OR•U | C•OR•P | NCOM•U | NCOM•P | NCOM•R |
| 1. CONSTRUCTION | AAAA | BBBB | CCCC | BBBB | AAAA | ..... | ..... | ..... | 0 |
| 2. INTERIOR FINISH CORR AND EXIT | BBBB | BBBB | CCCC | BBBB | AAAA | AAAA | 0 | | 0 |
| 3. INTERIOR FINISH ROOMS | CCCC | CCCC | BBBB | BBBB | AAAA | AAAA | 0 | 700 | 700 |

| | INPUT | PRESC | | | | |
|---|---|---|---|---|---|---|
| | GE 1HR | 1/3-1H | NON/IN | LT1/3H | 1/3-1H | GE 1HR |
| 4. CORRIDOR PARTITIONS AND WALLS | GE 1HR | 1/3-1H | ..... | ..... | ..... | 0 |

| | INPUT | PRESC | | | | |
|---|---|---|---|---|---|---|
| | NODOOR | GE 20M | NODOOR | LT 20M | GE 20M | GE20AC |
| 5. DOORS TO CORRIDOR | NODOOR | GE 20M | 0 | 0 | 49 | 49 |
| | | | 0 | 0 | 0 | 0 |
| | | | 0 | 28 | 28 | 28 |
| | | | 0 | 49 | 49 | 49 |
| | | | 0 | 0 | 0 | 0 |

| | INPUT | PRESC | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | DED•30 | NO+100 | DED100 | DED•50 | DED•30 | NO+150 | NO+100 | NO•100 |
| 6. ZONE DIMENSIONS | DED•30 | NO+100 | ..... | ..... | 0 | 0 | 0 | 0 |
| | | | ..... | ..... | 0 | 0 | 0 | 0 |
| | | | ..... | ..... | 0 | 0 | 0 | 0 |
| | | | ..... | ..... | 0 | 9 | 9 | 9 |
| | | | ..... | ..... | 0 | 0 | 7 | 7 |
| | | | ..... | ..... | 0 | 0 | 0 | 0 |
| | | | ..... | ..... | 0 | 0 | 0 | 0 |
| | | | | | 0 | 0 | 0 | 0 |

| | INPUT | PRESC | | | | | |
|---|---|---|---|---|---|---|---|
| | ENC-1H | ENC-2H | OP•GE4 | OP•2-3 | ENC-1H | ENC-2H | ENC+2H |
| 7. VERTICAL OPENINGS | ENC-1H | ENC-2H | ..... | ..... | 0 | 0 | 0 |
| | | | ..... | ..... | 0 | 0 | 0 |
| | | | ..... | ..... | 0 | 7 | 7 |
| | | | ..... | ..... | 0 | 0 | 0 |

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Exhibit 4.3   Sample Output Summarizing the Data Input for a
              Typical Fire Zone

Part B:   Description


The purpose of the Input Summary Report is to characterize the data used in
setting up the problem for solution.  It is also useful in distinguishing
among runs when a sensitivity analysis is performed.  The first descriptive
line shows the location of the fire zone, the number of patients and the state
numbers for Table 1 of the FSES.  In this case the zone aggregates data on
floors 3 through 9 of the facility.  Each of the 13 building safety features
is then listed.  The two columns to the right of the building safety feature
name show the input and prescriptive states.  Up to 7 columns are then used to
show the number of elements which must be upgraded in order to move to a
higher state.  The actual element counts consist of from 1 to 8 rows depending
on the building safety feature and its condition.  If the building safety
feature was not in the highest state, then each row corresponds to a
particular element.  For example, the two rows associated with interior finish
in rooms correspond to the square feet of walls and ceilings which would have
to be coated with retardant in order to move to Class B or Class A flame
spread ratings.  In interpreting the values, it is necessary to note that the
symbol ***** indicates that the state whose name appears above it not a
permissible retrofit.  This may result because the state is below the input
and hence would result in a regression in score (e.g., construction is already
in the highest state) or it is precluded on engineering grounds.  The states
which are permissible have either a value of zero or some positive integer
recorded.  For example, 0 square feet of walls and 700 square feet of ceilings
must be coated with retardant in order to move to either the Class B or Class
A flame spread rating for interior finishes in rooms.  The second page of the
printout consists of data on building safety features 8 through 13.  These
data are not reproduced since their interpretation is the same as given
above.

Part A:  Printout

SUMMARY OF ESTIMATED RETROFIT COSTS

FLOOR  3    ZONE  1    COST GROWTH FACTOR 1.15    LOCATION MODIFIERS:  LABOR 1.00    MATERIALS 1.00

| BUILDING SAFETY FEATURE | INPUT | PRESC | C*WF*U | C*WF*P | C*OR*U | C*OR*P | NCOM*U | NCOM*P | NCOM*R |
|---|---|---|---|---|---|---|---|---|---|
| 1. CONSTRUCTION | NCOM*R | NCOM*R | | | | | | | |
|    ESTIMATED RETROFIT COST | | | ****** | ****** | ****** | ****** | ****** | ****** | O |
| 2. INTERIOR FINISH CORR AND EXIT | BBBB | BBBB | CCCC | BBBB | AAAA | AAAA | AAAA | | |
|    ESTIMATED RETROFIT COST | | | ****** | ****** | 0 | 644 | | | |
| 3. INTERIOR FINISH ROOMS | BBBB | BBBB | CCCC | BBBB | AAAA | AAAA | | | |
|    ESTIMATED RETROFIT COST | | | ****** | 604 | 0 | | | | |
| 4. CORRIDOR PARTITIONS AND WALLS | 1/3-1H | 1/3-1H | NON/IN | LT1/3H | 1/3-1H | GE 1HR | | | |
|    ESTIMATED RETROFIT COST | | | ****** | ****** | ****** | 0 | | | |
| 5. DOORS TO CORRIDOR | GE 20M | GE 20M | NODOOR | LT 20M | GE 20M | GE2OAC | NO+100 | NO-100 | |
|    ESTIMATED RETROFIT COST | | | 0 | 5233 | 39043 | 39043 | 207230 | 207230 | |
| 6. ZONE DIMENSIONS | NO+100 | NO+100 | DED*30 | DED*50 | DED100 | DED*30 | NO+150 | NO-100 | |
|    ESTIMATED RETROFIT COST | | | 0 | ****** | ****** | ****** | 1B6300 | 207230 | |
| 7. VERTICAL OPENINGS | ENC-2H | ENC-1H | ENC-1H | OP*2-3 | OP*GE4 | ENC-2H | ENC+2H | | |
|    ESTIMATED RETROFIT COST | | | 0 | ****** | ****** | 5635 | 6440 | | |
| 8. HAZARDOUS AREAS | SGL IN | NO DEF | SGL IN | DBLOUT | DBL IN | SGLOUT | NO DEF | | |
|    ESTIMATED RETROFIT COST | | | 0 | ****** | ****** | ****** | 1610 | | |
| 9. SMOKE CONTROL | PARTTN | PARTTN | PARTTN | PARTTN | NO CTL | MECZON | | | |
|    ESTIMATED RETROFIT COST | | | 0 | ****** | ****** | ****** | | | |
| 10. EMERGENCY MOVEMENT ROUTES | DEFCAP | W/OH*E | DEFCAP | W/OH*E | LT2RTS | H*EXIT | DIRECT | | |
|    ESTIMATED RETROFIT COST | | | 0 | ****** | ****** | 49106 | 49106 | | |
| 11. MANUAL FIRE ALARM | FD CON | FD CON | FD CON | W/OCON | NO ALR | FD CON | | | |
|    ESTIMATED RETROFIT COST | | | 0 | ****** | 0 | 0 | | | |
| 12. SMOKE DETECTION AND ALARM | NONE | NONE | NONE | CORDOR | ROOMS | CORHAB | TTLZON | | |
|    ESTIMATED RETROFIT COST | | | 0 | 1416B | 42504 | 64615 | 122575 | | |
| 13. AUTOMATIC SPRINKLERS | NONE | NONE | NONE | CORHAB | TTLBLD | | | | |
|    ESTIMATED RETROFIT COST | | | 0 | 137B23 | 22234B | | | | |

THE COST OF PRESCRIPTIVE COMPLIANCE FOR THIS FIRE ZONE IS:  254122

Exhibit 4.4    Sample Output Showing the Estimated Cost for Each Potential
               Retrofit for a Typical Fire Zone

                          Part B:    Description


This Summary of Estimated Retrofit Costs Report presents the estimated costs
for all potential retrofits.  The first descriptive line shows the zone
location and the values of each of the three construction cost modifiers.  For
this case, costs have increased 15 percent over those experienced during the
summer of 1981 in the Washington, D.C. area.  Each of the 13 building safety
features is then listed.  The two columns to the right of the building safety
feature name show the input and prescriptive states.  Up to 7 columns are then
used as labels for each possible state within a building safety feature.  The
line immediately beneath the building safety feature name bears the title
"Estimated Retrofit Cost"; it lists the estimated cost for each potential
retrofit.  In interpreting the values, it is necessary to note that the symbol
****** indicates that the state whose name appears above is not a permissible
retrofit; it is assigned an arbitrarily high cost to prevent its occurrence.
This may result because the state is below the input and hence would result in
a regression in score (e.g., construction is already in the highest state) or
it is precluded on engineering grounds (e.g., mechanically assisted smoke
control by zone).  Those states which are permissible have either a value of
zero of some positive integer recorded.  In each case, the cost of remaining
in the input state is recorded as zero.  If desired, this assumption can be
modified through use of the CHANGE option.  It may also be possible to move to
a higher state for zero cost if the change is not construction related.  The
remainder of the costs are based on the expected cost of upgrading all
critical elements recorded in the previous exhibit.  The bottom line of the
printout is the estimated cost of prescriptive compliance.  Since some states
may already exceed their prescriptive level, no cost is incurred for that
building safety feature.  For all other cases, the cost is the sum of the
costs of the prescriptive compliance state listed under the heading "PRESC".

Exhibit 4.5  Sample Output Showing the Solutions Generated for a Typical Fire Zone

Part A:  Printout

FIRE ZONE SUMMARY REPORT

FLOOR 3   ZONE 1

| CONSTR | FINISH COR&EX | FINISH ROOMS | CORDOR PT&WLS | DOORS TO COR | ZONE DIMENS | VERTIC OPENNG | HAZARD AREAS | SMOKE CONTROL | EMERGE MOVMNT | MANUAL ALARM | SMOKE DET&ALM | SPRNKLR | CON S1 | EXT S2 | MOV S3 | GEN SG | COST TO COMPLY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NCOM*R | AAAA | BBBB | GE 1HR | LT 20M | NO+100 | ENC-1H | NO DEF | PARTTN | H*EXIT | FD CON | NONE | NONE | 1 | 0 | 3 | 5 | 242B44 |
| NCOM*R | AAAA | BBBB | GE 1HR | LT 20M | DED*30 | ENC-1H | NO DEF | PARTTN | H*EXIT | FD CON | NONE | NONE | 1 | 0 | 1 | 4 | 56544 |
| NCOM*R | AAAA | BBBB | GE 1HR | LT 20M | NO+150 | ENC-2H | NO DEF | PARTTN | H*EXIT | FD CON | NONE | NONE | 3 | 0 | 0 | 3 | 199374 |
| NCOM*R | AAAA | BBBB | GE 1HR | LT 20M | NO-100 | ENC-1H | NO DEF | PARTTN | W/OH*E | FD CON | NONE | NONE | 1 | 0 | 0 | 3 | 214669 |
| NCOM*R | AAAA | BBBB | GE 1HR | LT 20M | NO-100 | ENC-1H | NO DEF | PARTTN | W/OH*E | FD CON | NONE | NONE | 1 | 0 | 1 | 4 | 214669 |
| NCOM*R | AAAA | BBBB | GE 1HR | LT 20M | DED*30 | ENC-2H | NO DEF | PARTTN | W/OH*E | FD CON | NONE | NONE | 3 | 0 | D | 4 | 13074 |
| NCOM*R | AAAA | AAAA | GE 1HR | LT 20M | DED*30 | ENC-1H | NO DEF | PARTTN | W/OH*E | FD CON | NONE | NONE | 5 | 0 | 0 | 5 | 13115 |
| NCOM*R | AAAA | CCCC | GE 1HR | LT 20M | DED*30 | ENC-2H | NO DEF | PARTTN | W/OH*E | FD CON | NONE | NONE | 0 | 0 | 0 | 0 | 13274 |
| NCOM*R | AAAA | BBBB | GE 1HR | LT 20M | DED*30 | ENC+2H | NO DEF | PARTTN | W/OH*E | FD CON | NONE | NONE | 4 | D | 1 | 4 | 13B79 |
| NCOM*R | AAAA | BBBB | GE 1HR | GE20AC | DED*30 | ENC+2H | NO DEF | PARTTN | W/OH*E | FD CON | NONE | NONE | 3 | 0 | D | 4 | 41249 |
| NCOM*R | AAAA | AAAA | GE 1HR | GE 20M | DED*30 | ENC-2H | NO DEF | PARTTN | W/OH*E | FD CON | NONE | NONE | 4 | 0 | 1 | 4 | 46BB5 |
| NCOM*R | AAAA | AAAA | GE 1HR | LT 20M | NO+100 | ENC-1H | NO DEF | PARTTN | H*EXIT | FD CON | CORHAB | NONE | 3 | 4 | 7 | 12 | 307499 |
| NCOM*R | AAAA | AAAA | GE 1HR | LT 20M | DED*30 | ENC-1H | NO DEF | PARTTN | H*EXIT | FD CON | CORHAB | NONE | 3 | 4 | 5 | 10 | 121199 |
| NCOM*R | AAAA | AAAA | GE 1HR | LT 20M | NO+150 | ENC-1H | NO DEF | PARTTN | W/OH*E | FD CON | CORHAB | NONE | 3 | 4 | 2 | 7 | 25B394 |
| NCOM*R | AAAA | CCCC | GE 1HR | LT 20M | DED*30 | ENC-1H | NO DEF | PARTTN | H*EXIT | FD CON | NONE | NONE | 3 | 4 | 2 | 7 | 72095 |
| NCOM*R | AAAA | CCCC | GE 1HR | LT 20M | NO+100 | ENC-1H | NO DEF | PARTTN | H*EXIT | FD CON | NONE | CORHAB | 5 | 8 | 7 | 10 | 3B0063 |
| NCOM*R | AAAA | CCCC | GE 1HR | LT 20M | DED*30 | ENC-1H | NO DEF | PARTTN | W/OH*E | FD CON | NONE | CORHAB | 5 | 8 | 2 | 8 | 193763 |
| NCOM*R | AAAA | CCCC | GE 1HR | LT 20M | NO+150 | ENC-1H | NO DEF | PARTTN | W/OH*E | FD CON | NONE | CORHAB | 5 | 8 | 2 | 5 | 330958 |
| NCOM*R | AAAA | AAAA | GE 1HR | LT 20M | DED*30 | ENC-1H | NO DEF | PARTTN | W/OH*E | FD CON | NONE | CORHAB | 5 | B | 2 | 5 | 14465B |
| NCOM*R | AAAA | AAAA | GE 1HR | LT 20M | NO+100 | ENC-1H | NO DEF | PARTTN | H*EXIT | FD CON | TTLZON | NONE | 3 | 8 | 8 | 13 | 365459 |
| NCOM*R | AAAA | AAAA | GE 1HR | LT 20M | DED*30 | ENC-1H | NO DEF | PARTTN | H*EXIT | FD CON | TTLZON | NONE | 3 | 6 | 6 | 11 | 179159 |
| NCOM*R | AAAA | CCCC | GE 1HR | LT 20M | NO+150 | ENC-1H | NO DEF | PARTTN | W/OH*E | FD CON | TTLZON | NONE | 3 | 5 | 3 | 8 | 316354 |
| NCOM*R | AAAA | CCCC | GE 1HR | LT 20M | DED*30 | ENC-1H | NO DEF | PARTTN | W/OH*E | FD CON | NONE | NONE | 3 | 5 | 3 | 8 | 130054 |
| NCOM*R | AAAA | CCCC | GE 1HR | LT 20M | NO+100 | ENC-1H | NO DEF | PARTTN | H*EXIT | FD CON | NONE | TTLBLD | 7 | 10 | B | 12 | 4645BB |
| NCOM*R | AAAA | CCCC | GE 1HR | LT 20M | DED*30 | ENC-1H | NO DEF | PARTTN | W/OH*E | FD CON | NONE | TTLBLD | 7 | 10 | 3 | 10 | 27B2BB |
| NCOM*R | AAAA | AAAA | GE 1HR | GE 20M | NO+150 | ENC-1H | NO DEF | PARTTN | W/OH*E | FD CON | NONE | TTLBLD | 7 | 1D | 3 | 7 | 4154B3 |
| NCOM*R | AAAA | BBBB | GE 1HR | LT 20M | DED*30 | ENC-1H | NO DEF | PARTTN | W/OH*E | FD CON | NONE | TTLBLD | 7 | 10 | 3 | 7 | 2291B3 |
| NCOM*R | AAAA | AAAA | GE 1HR | GE 20M | NO+100 | ENC-1H | NO DEF | PARTTN | W/OH*E | FD CON | NONE | NONE | 4 | 0 | 3 | 7 | 254122 |
| NCOM*R | AAAA | BBBB | GE 1HR | LT 20M | DED*30 | ENC-2H | NO DEF | PARTTN | W/OH*E | FD CON | CORDOR | NONE | 3 | 2 | 0 | 5 | 21646 |
| NCOM*R | AAAA | AAAA | GE 1HR | LT 20M | DED*30 | ENC+2H | NO DEF | PARTTN | DEFCAP | FD CON | CORDOR | NONE | 4 | 2 | 1 | 4 | 2B04B |
| NCOM*R | AAAA | AAAA | GE 1HR | LT 20M | DED*30 | ENC-1H | NO DEF | PARTTN | W/OH*E | FD CON | ROOMS | NONE | 3 | 3 | 1 | 6 | 499B4 |
| NCOM*R | AAAA | BBBB | GE 1HR | NODOOR | DED*30 | ENC+2H | SGL IN | PARTTN | H*EXIT | FD CON | CORHAB | CORHAB | 2 | 12 | 2 | 9 | 26022B |
| NCOM*R | AAAA | AAAA | GE 1HR | LT 20M | DED*30 | ENC-1H | SGL IN | PARTTN | W/OH*E | FD CON | NONE | CORHAB | 3 | 2 | 3 | 3 | 143652 |
| NCOM*R | AAAA | AAAA | GE 1HR | LT 20M | DED*30 | ENC-1H | SGL IN | PARTTN | W/OH*E | FD CON | CORDOR | CORHAB | 5 | 4 | 3 | 7 | 157B60 |
| NCOM*R | AAAA | BBBB | GE 1HR | LT 20M | DED*30 | ENC-1H | SGL IN | PARTTN | W/OH*E | FD CON | NONE | TTLBLD | 5 | 4 | 3 | 5 | 22B177 |

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Exhibit 4.5  Sample Output Showing the Solutions Generated for a
              Typical Fire Zone

                        Part B:   Description


The Fire Zone Summary Report records all of the distinct solutions generated
for the fire zone under study.  The first descriptive line shows the fire zone
location.  Each of the 13 building safety features are then listed followed by
the 4 safety requirements.  The estimated cost to comply is presented in the
last column.  The name of the post-retrofit state for each of the 13 building
safety features are listed beneath the appropriate column heading.  Each
solution takes up one line of the output.  The surpluses over the required
score for Containment, Extinguishment, People Movement and General Safety are
then recorded.  The order in which the solutions are output is based on the 40
design classifications.  The following buildng safety features are used to
define the design classifications:  (1) construction; (2) zone dimensions; (3)
hazardous areas; (4) emergency movement routes; (5) smoke detection and alarm;
and (6) automatic sprinklers.  All solutions are ranked and printed out in
ascending order of cost.  The program then outputs the solution(s) for the
next design classification for which at least one solution was generated until
the list is exhausted.  The prescriptive solution is then output.  Note that
in this case, the prescriptive solution shows surplus scores on all 4 safety
requirements; the estimated cost of prescriptive compliance is $275,052.  The
score surpluses are due to some of the input states already exceeding their
prescriptive values.  Solutions which do not fit a design classification are
then ranked and printed out according to whether they have no deficiencies, a
single deficiency, or a double deficiency in hazardous areas.

Exhibit 4.6 Sample Output Showing the Best Combination of Design
Equivalent Solutions

Part A: Printout

TOTAL BUILDING SUMMARY REPORT

THE DESIGN VARIABLE QUALIFIERS FOR THIS CLASS ARE AS FOLLOWS

| HAZARD AREAS | CONSTR RESIST | ZONE DIMENS | EMERGE MOVMNT | SMOKE DT+ALM | SPRNKLR |
|---|---|---|---|---|---|
| NO DEF | RESIST | DED*30 | NO H*E | INPUT | INPUT |

THE TOTAL COST OF RETROFITTING THE BUILDING FOR THIS DESIGN CLASSIFICATION IS: 30839
THE TOTAL COST OF PRESCRIPTIVE COMPLIANCE FOR THIS BUILDING IS: 302527

BUILDING SAFETY FEATURE NAME

| FL Z OR N | CONSTR | FINISH COR+EX | FINISH ROOMS | CORDOR PT+WLS | DOORS TO COR | ZONE DIMENS | VERTIC OPENNG | HAZARD AREAS | SMOKE CONTROL | EMERGE MOVMNT | MANUAL ALARM | SMOKE DET+ALM | SPRNKLR | SURPLUS CN EX MV GN / S1 S2 S3 SG | COST TO COMPLY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -1 1 | NCOM*R | AAAA | AAAA | GE 1HR | LT 20M | NO+150 | ENC-1H | NO DEF | PARTTN | W/OH*E | FD CON | NONE | CORHAB | 11 8 2 19 | 5462 |
| 1 1 | NCOM*R | AAAA | AAAA | GE 1HR | LT 20M | NO+150 | ENC-1H | NO DEF | PARTTN | W/OH*E | FD CON | NONE | NONE | 5 0 D 9 | 4369 |
| 2 1 | NCOM*R | AAAA | BBBB | GE 1HR | LT 20M | NO+150 | ENC-2H | NO DEF | PARTTN | W/OH*E | FD CON | NONE | NONE | 3 0 0 7 | 7934 |
| 3 1 | NCOM*R | AAAA | BBBB | GE 1HR | LT 20M | DED*30 | ENC-2H | NO DEF | PARTTN | W/OH*E | FD CON | NONE | NONE | 3 0 0 3 | 13074 |

Exhibit 4.6   Sample Output Showing the Best Combination of Design
              Equivalent Solutions

              Part B:   Description


This Total Building Summary Report records the best solution for the entire
building from among the 40 design classifications.  The first descriptive
heading shows the design variable qualifiers for this design classification.
The total cost of retrofitting the entire building to this design
classification is then given followed by the cost of prescriptive compliance.
In this case the total cost is approximately 10 percent of that associated
with prescriptive compliance.  Information on the location of the fire zone,
the post-retrofit state for each of the 13 building safety features, the
surplus over each of the 4 safety requirements, and the estimated cost to
comply are then printed out.  Each fire zone takes up one line of output.  The
solutions for the fire zones are based on the least-cost solution from within
the design classification under consideration.  If, as in this case, one of
the design variable qualifiers entered in a state above that which appears in
the heading, an artificial solution is created.  Thus although the qualifier
for zone dimensions is a dead end greater than 30 feet, since the first three
fire zones entered with no dead ends, they are included as an artificial
solution within this design classification.  This approach is taken because
the objective of the design classifications is to have a compatible set of
retrofits.  Since the existing condition within the building was acceptable
(i.e., a mixture of dead ends on floors 3 through 9 and no dead ends in the
basement, first and second floors), not changing one of the building safety
features across all zones should not affect the acceptability of the design.
The classifications are, however, based on a worst-case scenario.  Thus if a
dead end resulted in any fire zone, no artificial solution would be generated
indicating a "no dead end" situation.

Part A:  Printout

TOTAL BUILDING SUMMARY REPORT

THE DESIGN VARIABLE QUALIFIERS FOR THIS CLASS ARE AS FOLLOWS

| HAZARD AREAS | CONSTR RESIST | ZONE DIMENS | EMERGE MOVMNT | SMOKE DT+ALM | SPRNKLR |
|---|---|---|---|---|---|
| NO DEF | | DED*30 | NO H*E | CORHAB | INPUT |

THE TOTAL COST OF RETROFITTING THE BUILDING FOR THIS DESIGN CLASSIFICATION IS:   112459
THE TOTAL COST OF PRESCRIPTIVE COMPLIANCE FOR THIS BUILDING IS:   302527

|  |  |  |  |  | BUILDING SAFETY FEATURE NAME | | | | | | | | | | SURPLUS | | | | COST |
| FL OR | Z N | CONSTR | FINISH COR+EX | FINISH ROOMS | CORDOR P::+WLS | DOORS TO COR | ZONE DIMENS | VERTIC OPENNG | HAZARD AREAS | SMOKE CONTROL | EMERGE MOVMNT | MANUAL ALARM | SMOKE DET+ALM | SPRNKLR | CN S1 | EX S2 | MV S3 | GN SG | TO COMPLY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -1 | 1 | NCOM*R | AAAA | AAAA | GE 1HR | LT 20M | NO+150 | ENC-1H | NO DEF | PARTN | W/OH*E | FD CON | CORHAB | CORHAB | 11 | 12 | 6 | 23 | 11948 |
| 1 | 1 | NCOM*R | AAAA | AAAA | GE 1HR | LT 20M | NO+150 | ENC-1H | NO DEF | PARTN | W/OH*E | FD CON | CORHAB | NONE | 5 | 4 | 4 | 13 | 13109 |
| 2 | 1 | NCOM*R | AAAA | AAAA | GE 1HR | LT 20M | NO+150 | ENC-1H | NO DEF | PARTN | W/OH*E | FD CON | CORHAB | NONE | 3 | 4 | 2 | 11 | 15307 |
| 3 | 1 | NCOM*R | AAAA | AAAA | GE 1HR | LT 20M | DED*30 | ENC-1H | NO DEF | PARTN | W/OH*E | FD CON | CORHAB | NONE | 3 | 4 | 2 | 7 | 72095 |

Exhibit 4.7   Sample Output Showing Design Equivalent Solutions Based
on Smoke Detection and Alarm in Corridors and Habitable Spaces

Part B:   Description

This printout shows the best solutions for each fire zone when smoke detection
and alarm are required in all corridors and habitable spaces.  The total cost
of retrofitting the entire building to this design classification is
approximately one third that of prescriptive compliance.  As in the previous
case, an artificial solution has been created for the fire zones in the
basement, first and second floors which were input without any dead ends.  In
addition, the basement floor was input with sprinklers in all corridors and
habitable spaces.

TOTAL BUILDING SUMMARY REPORT

THE DESIGN VARIABLE QUALIFIERS FOR THIS CLASS ARE AS FOLLOWS

| HAZARD AREAS | CONSTR RESIST | ZONE DIMENS | EMERGE MOVMNT | SMOKE DT+ALM | SPRNKLR |
|---|---|---|---|---|---|
| NO DEF | | DED*30 | NO H.*E | TTLZON | INPUT |

THE TOTAL COST OF RETROFITTING THE BUILDING FOR THIS DESIGN CLASSIFICATION IS:   176283
THE TOTAL COST OF PRESCRIPTIVE COMPLIANCE FOR THIS BUILDING IS:   302527

| FL OR | Z N | CONSTR | FINISH COR+EX | FINISH ROOMS | CORDOR PT+WLS | DOORS TO COR | ZONE DIMENS | VERTIC OPENNG | HAZARD AREAS | SMOKE CONTROL | EMERGE MOVMNT | MANUAL ALARM | SMOKE DET+ALM | SPRNKLR | SURPLUS CN EX MV GN S1 S2 S3 SG | COST TO COMPLY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | NCOM*R | AAAA | AAAA | GE 1HR | LT 20M | NO+150 | ENC-1H | NO DEF | PARTTN | W/OH*E | FD CON | TTLZON | CORHAB | 11 13 7 24 | 12500 |
| 1 | 1 | NCOM*R | AAAA | AAAA | GE 1HR | LT 20M | NO-100 | ENC-1H | NO DEF | PARTTN | LT2RTS | FD CON | TTLZON | NONE | 5 5 0 9 | 14282 |
| 2 | 1 | NCOM*R | AAAA | AAAA | GE 1HR | LT 20M | NO+150 | ENC-1H | NO DEF | PARTTN | W/OH*E | FD CON | TTLZON | NONE | 3 5 3 12 | 19447 |
| 3 | 1 | NCOM*R | AAAA | AAAA | GE 1HR | LT 20M | DED*30 | ENC-1H | NO DEF | PARTTN | W/OH*E | FD CON | TTLZON | NONE | 3 5 3 8 | 130054 |

Exhibit 4.8   Sample Output Showing Design Equivalent Solutions Based
on Smoke Detection and Alarm in the Total Space

Part B:   Description


This printout shows the best solution for each fire zone when smoke detection
and alarm are required throughout the total space.  The total cost of
retrofitting the entire building to this design classification is somewhat
more than one half that of prescriptive compliance.  Through reference to FSES
Table 4, it can be seen that this movement increases the state value from 4
points to 5 points over the previous case (smoke detection and alarm in all
corridors and habitable spaces).  An examination of the surplus scores over
each safety requirement reveals an average increase of one point.  In this
case, the additional cost of compliance is due almost entirely to the
installation of smoke detection and alarm equipment.  If one were to examine
the two design classifications where automatic sprinklers were interchanged
with smoke detection and alarm, a similar result would occur.  Thus careful
consideration should be given to any decision which would require detectors or
sprinklers in the total space rather than in all corridors and habitable
spaces.

TOTAL BUILDING SUMMARY REPORT

THE DESIGN VARIABLE QUALIFIERS FOR THIS CLASS ARE AS FOLLOWS

| HAZARD AREAS | CONSTR CONSTR RESIST | ZONE DIMENS NO DED | EMERGE MOVMNT NO H*E | SMOKE DT+ALM INPUT | SPRNKLR INPUT |
|---|---|---|---|---|---|
| NO DEF | | | | | |

THE TOTAL COST OF RETROFITTING THE BUILDING FOR THIS DESIGN CLASSIFICATION IS: 217139
THE TOTAL COST OF PRESCRIPTIVE COMPLIANCE FOR THIS BUILDING IS: 302527

| FL ZON OR N | CONSTR | FINISH COR+EX | FINISH ROOMS | CORRDOR PT+WLS | DOORS TO COR | ZONE DIMENS | VERTIC OPENNG | HAZARD AREAS | SMOKE CONTROL | EMERGE MOVMNT | MANUAL ALARM | SMOKE DET+ALM | SPRNKLR | SURPLUS CN EX MV GN S1 S2 S3 SG | COST TO COMPLY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -1 1 | NCOM*R | AAAA | AAAA | GE 1HR | LT 20M | NO+150 | ENC-1H | NO DEF | PARTTN | W/OH*E | FD CON | NONE | CORHA8 | 11 8 -2 19 | 5462 |
| 1 1 | NCOM*R | AAAA | AAAA | GE 1HR | LT 20M | NO+150 | ENC-1H | NO DEF | PARTTN | W/OH*E | FD CON | NONE | NONE | 5 0 0 9 | 4369 |
| 2 1 | NCOM*R | AAAA | BBBB | GE 1HR | LT 20M | NO+150 | ENC-2H | NO DEF | PARTTN | W/OH*E | FD CON | NONE | NONE | 3 0 0 7 | 7934 |
| 3 1 | NCOM*R | AAAA | BBBB | GE 1HR | LT 20M | NO+150 | ENC-2H | NO DEF | PARTTN | W/OH*E | FD CON | NONE | NONE | 3 0 0 3 | 199374 |

Exhibit 4.9  Sample Output Showing Design Equivalent Solutions Based
on No Dead Ends in Corridors

Part B:  Description


This printout shows the best solution for each fire zone when no dead ends are
permitted.  (Recall that a dead end greater than 30 feet existed on floors 3
through 9.)  Although the installation of an exit stairwell is quite
expensive, the solution produced by the FSESCM program costs about 30 percent
less than that associated with prescriptive compliance.  This is because the
procedure upgrades all building safety features which are not constrained by
the design variable qualifiers in the most cost effective manner.

Part A: Printout

TOTAL BUILDING SUMMARY REPORT

PRESCRIPTIVE COMPLIANCE SOLUTION

THE TOTAL COST OF RETROFITTING THE BUILDING FOR THIS DESIGN CLASSIFICATION IS: 302527
THE TOTAL COST OF PRESCRIPTIVE COMPLIANCE FOR THIS BUILDING IS: 302527

| FL Z OR N | CONSTR | FINISH COR+EX | FINISH ROOMS | CORDOR PT+WLS | DOORS TO COR | ZONE DIMENS | VERTIC OPENNG | HAZARD AREAS | SMOKE CONTROL | EMERGE MOVMNT | MANUAL ALARM | SMOKE DET+ALM | SPRNKLR | SURPLUS CN EX MV GN S1 S2 S3 SG | COST TO COMPLY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -1 1 | NCOM*R | AAAA | AAAA | GE 1HR | GE 20M | NO+100 | ENC-2H | NO DEF | PARTTN | W/OH*E | FD CON | NONE | CORHAB | 14 8 7 25 | 12593 |
| 1 1 | NCOM*R | AAAA | AAAA | GE 1HR | GE 20M | NO+100 | ENC-2H | NO DEF | PARTTN | W/OH*E | FD CON | NONE | NONE | 6 0 3 13 | 18078 |
| 2 1 | NCOM*R | AAAA | BBBB | GE 1HR | GE 20M | NO+100 | ENC-2H | NO DEF | PARTTN | W/OH*E | FD CON | NONE | NONE | 4 0 3 11 | 17734 |
| 3 1 | NCOM*R | AAAA | BBBB | GE 1HR | GE 20M | NO+100 | ENC-2H | NO DEF | PARTTN | W/OH*E | FD CON | NONE | NONE | 4 0 3 7 | 254122 |

(BUILDING SAFETY FEATURE NAME)

ALTHOUGH THIS IS THE PRESCRIPTIVE COMPLIANCE SOLUTION, IT MAY SHOW A SURPLUS IN ONE OR MORE OF THE SAFETY REQUIREMENTS. IF A SURPLUS IN EITHER OF THE CONTAINMENT, EXTINGUISHMENT OR PEOPLE MOVEMENT SAFETY REQUIREMENTS OCCURS, IT IS BECAUSE ONE OR MORE OF THE BUILDING SAFETY FEATURES ALREADY EXCEEDED ITS PRESCRIPTIVE STATE. IF A SURPLUS IN THE GENERAL SAFETY REQUIREMENT OCCURS, IT IS DUE TO THE WAY IN WHICH R IS CALCULATED IN TABLES 1 THROUGH 3 OF THE FSES

Exhibit 4.10  Sample Output Showing the Details of the Prescriptive
              Compliance Solution

Part B:  Description

This printout shows the prescriptive compliance solution for each fire zone.
It is included as a baseline against which all solutions generated by the
FSESCM program can be compared objectively.  Note that surplus scores are
shown for all of the safety requirements.  This is because each fire zone as
input exceeded one or more of the prescriptive requirements.  Although no
credit was given for exceeding a requirement prior to the incorporation of the
Fire Safety Evaluation System into the Life Safety Code, score surpluses are
possible if the evaluation procedure of the Fire Safety EValaution System is
used.  The values of the surpluses are presented because it is felt that they
will promote a more meaningful comparison against those solutions based solely
on the Fire Safety Evaluation System.

Figure 4.1  Alternative Retrofit Packages for the Case Study Building



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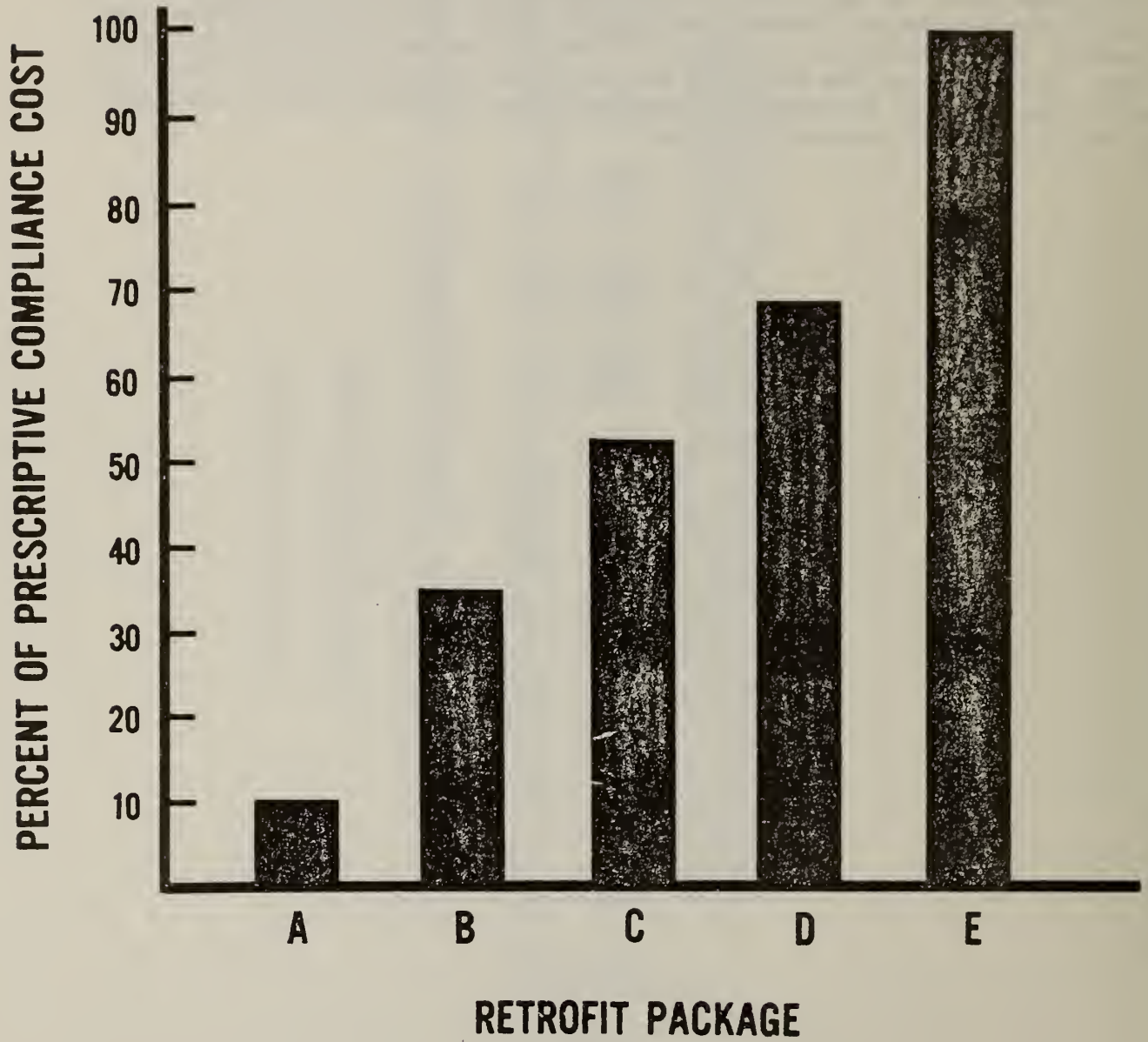
5. SOME COMMENTS ON USING THE FSESCM COMPUTER PROGRAM


The purpose of this chapter is to provide guidance for making intelligent use of the model. The previous chapters dealt with the technical underpinnings of the model and the mechanics of setting up and interpreting a case study. This chapter aims at ways in which these basic approaches can be tailored to specific objectives. Specific topics discussed in this chapter include: (1) when and how to use a particular combination of options; (2) how to batch runs so that more than one facility can be analyzed; and (3) how to find and correct input errors.

Once all data have been collected and prior to an analysis with the model, a series of important questions must be answered. As an initial step, the user must carefully define the objectives of the study and attempt to relate them to the data recorded on the worksheets. Some typical objectives which senior management might wish to analyze involve: (a) the time phasing of the project; (b) the affects on services and revenues; (c) the costs of a highly desired option; or (d) the opportunity to anticipate future changes in the requirements of the Life Safety Code.

In performing any of the analyses mentioned above, it is essential that sufficient detail be incorporated into the data file so meaningful tradeoffs can be made. For example, a baseline run exercising a minimum number of options can be used to establish a "straw man" scenario. The CHANGE and REQUIR options can then be used to modify the problem so that it more closely follows the pecularities of the building under analysis. A series of "what-if" questions can then be addressed by systematically changing key input values and rerunning the model. These results can then be compared against the "straw man" scenario to weigh the benefits of alternative courses of action.

There are several practical considerations which govern the amount of detail for a given case study. First, all topics should be ranked according to their importance to the decision maker. This implies that greater effort should be made to obtain more precise information on selected "high visibility" items, rather than spending an inordinate amount of time on relatively unimportant data. Second, care should be exercised when precluding retrofits. This is because certain design variable qualifiers may be affected which govern the output provided under the Total Building Summary Report.

Suppose an initial run has been performed and several targets of opportunity for further analysis can be identified. For example, one may wish to require a higher level of Containment Safety than currently specified under the Life Safety Code. Similarly, one may wish to increase the cost of installing an exit stairwell. The two cases mentioned above relate to the use of the REQUIR and CHANGE options, respectively. If the Containment Safety requirment were to be increased by 20 percent, then the following card sequence would be needed:

```
REQUIR      1     20
SOLVE
```

where REQUIR occupies columns 1 through 6 of the card, 1 (Containment Safety)
occupies column 9, and 20 occupies columns 11 and 12, respectively.  The next
card tells the program to solve the application problem with the increased
Containment Safety requirement.  If this option were to be exercised and the
cost of installing and exit stairwell to move to the no dead end zone length
less than 100 feet state were increased from slightly under 230,000 to
250,000, then the card sequence would be:

```
REQUIRE     1     20
CHANGE      6      6     250000
SOLVE
```

where CHANGE occupies columns 1 through 6, the building safety feature number
(6) is in column 9, the state number (6) is in column 12, and the transition
cost (250000) occupies columns 14 through 19.  If one also wished to examine
the impact of excluding two or more retrofits, say horizontal exits and
sprinklers in corridor and habitable spaces, then the card sequence would be

```
REQUIR      1     20
CHANGE      6      6     250000
CHANGE     10      4       -1
CHANGE     13      2       -1
SOLVE
```

To examine how the various effects are related, one may choose the following
sequence:

```
REQUIR      1     20
SOLVE
CHANGE      6      6     250000
SOLVE
CHANGE     10      4       -1
SOLVE
CHANGE     13      2       -1
SOLVE
```

In making use of the options provided, one should note that they are
cumulative and they have an impact on all output reports which follow.  For
example if the following sequence were input.

```
REQUIR      1     20
REQUIR      1     20
```

The Containment Safety requirement would be increased by 44 percent.
Similarly, by precluding horizontal exits and sprinklers in corridor and
habitable spaces <u>all</u> cases where these retrofits are referenced as design

variable qualifiers under the Total Building Summary Report will be
suppressed. This is true even if they are only precluded in one fire zone
within the buildng. Thus if these retrofit types are desired, it would be
necessary to restore the precluded cost with one which is deemed reasonable.
For example, the following sequence would permit the consequences of both
courses of action to be assessed:

```
CHANGE      10      4         -1
CHANGE      13      2         -1
SOLVE
CHANGE      10      4       50000
CHANGE      13      2      140000
SOLVE
```

If buildings are to be batched together, the only sequences which are
recommended are:

```
SOLVE
LAST
```

or

```
SOLVE
FINAL
```

or

```
TEST
NEXT
```

or

```
TEST
FINAL
```

The first group of controls tells the program to solve the application
problem, generate the Total Building Summary Report and proceed to the data on
the next building which follows immediately. The second group of controls
tells the program to proceed as above but to stop after the Total Building
Summary Report is output.

The third group of controls tells the program that the testing option has been
exercised and to proceed to the data on the next building without outputting
the Total Building Summary Report. The last group of controls indicates that
the testing option has been exercised and no buildings follow. The program
stops without outputting the Total Building Summary Report.

In analyzing the results produced by the model, users should ask the following questions. Are the answers meaningful? If not, what appears to be inconsistent? Are all objectives satisfied? If not, how were they formulated and related to the data on the worksheets? Have new problems been identified? If so, do they shed light on the problem? By probing into the model's results and through careful critique, users should build both technical skills and confidence in exercising the model. One should always recognize that counter intuitive results may lead to genuine insights into the problem when the assumptions upon which a model is based are critically analyzed.

The remainder of this section will deal with error messages. In order to address the everyday problems of incorrect formatting, recording and sequencing, FSESCM has an elaborate system for edit-checking the values of key input variables. If an error is encountered, then a message is printed out which should help to locate and correct the error. There are two basic types of error messages: (1) those which FSESCM treats as fatal for the building under analysis; and (2) those which result in the setting of default values.

The discussion of FSESCM generated error messages which follows is designed to be reasonably comprehensive but should not be considered exhaustive. The diagnostic associated with each error message is presented first. The routine which generated the message is then identified. This information serves as a cross walk to the Programmer's Manual should a modification to the source code be required due to pecularities of the operating system. The action taken by the program and the data output are then given. Recommendations for ways in which the problem may be corrected are also given.

It is important to point out that the discussion which follows is limited to first-order effects. If a non-fatal error (type 2), in which a default value is set, is followed by a fatal error (type 1), then both errors should be analyzed carefully for a possible relationship. In particular, a default setting to correct for an earlier error may result in a sequencing problem which triggers a fatal error. In every case where a fatal error is encountered, there should be sufficient information to easily locate the card which caused the problem. Non-fatal errors which do not require treatment should be subjected to close scrutiny to insure that the interpretation of the problem is not rendered meaningless.

<div align="center">Type 1 Errors</div>

| | |
|---|---|
| Diagnostic: | NO SATISFACTORY SOLUTIONS ENCOUNTERED |
| Routine: | MAIN |
| Action: | Analysis of current building terminates. Subroutine SEARCH is called to locate where data on the next building starts. |
| Data Output: | None |
| Remedy: | Output from the revised simplex (RVSMPX) is abnormal. Check application problem and input data. |

<div align="center">118</div>

| | |
|---|---|
| Diagnostic: | SAFETY REQUIREMENT OUT OF RANGE |
| Routine: | MAIN |
| Action: | Analysis of current building terminates.  Subroutine SEARCH is called to locate where data on the next building starts. |
| Data Output: | None |
| Remedy: | Check the value of the first integer variable (see table 3.26) after the command REQUIR on this control card.  The number of the safety requirement must take on a value between 1 and 4. |

| | |
|---|---|
| Diagnostic: | USER MOD INCORRECT |
| Routine: | MAIN |
| Action: | Analysis of current building terminates.  Subroutine SEARCH is called to locate where data on the next building starts. |
| Data Output: | Command on control card (HIN) plus option qualifiers (I1,I2,I3). |
| Remedy: | Check the value of the command on this control card against those given in table 2.2. |

| | |
|---|---|
| Diagnostic: | PARAMETER CARD ___ INCORRECT |
| Routine: | MAIN |
| Action: | Analysis of current building terminates.  Subroutine SEARCH is called to locate where data on the next building starts. |
| Data Output: | Building safety feature number as read. |
| Remedy: | Check application problem and input data.  An improper setting of the input state for a building safety feature can cause this problem.  Check for missing cards. |

| | |
|---|---|
| Diagnostic: | THE VALUES ON CARD ___ AFTER THE ERROR ARE: ___ ___ |
| Routine: | SEARCH |
| Action: | Analysis of current building terminates.  Subroutine SEARCH is called to locate where data on the next building starts. |
| Data Output: | Card number in sequence (1-20) and its values in alphanumeric (A6, A72) formats. |
| Remedy: | Use output to locate the card which caused the error. Additional diagnostics will also be available. |

## Type 2 Errors

| | |
|---|---|
| Diagnostic: | AN ATTEMPT TO RELAX A SAFETY REQUIREMENT IS BEING MADE |
| Routine: | MAIN |
| Action: | None |
| Data Output: | None |
| Remedy: | None is required but it would be advisible to verify that relaxing (reducing) the safety requirement was the intent. |

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| | |
|---|---|
| Diagnostic: | BUILDING SAFETY FEATURE OUT OF RANGE |
| Routine: | MAIN |
| Action: | The incorrect value is set to a default value of either 1 or 13. |
| Data Output: | None |
| Remedy: | Check the value on the first integer variable (see table 3.26) after the command CHANGE on this control card. The building safety feature declared must take on a value between 1 and 13. |

| | |
|---|---|
| Diagnostic: | RETROFIT STATE OUT OF RANGE |
| Routine: | MAIN |
| Action: | The incorrect value is set to a default value of either 1 or IT4M(I), where I is the building safety feature number. |
| Data Output: | None |
| Remedy: | Check the initial settings of the state variables read into IT4X(I). Check the value of the second integer variable, I2 after the command CHANGE on this control card. Both I2 and IT4X(I) must take on values between 1 and IT4M(I). |

| | |
|---|---|
| Diagnostic: | BUILDING TYPE QUALIFER OUT OF RANGE |
| Routine: | MAIN |
| Action: | The incorrect value is set to a default value of either 1 (hospitals) or 2 (nursing homes). |
| Data Output: | None |
| Remedy: | Check the value on the seventh card for this building in the data file. ITYPE must be either 1 or 2 (see table 3.6). |

| | |
|---|---|
| Diagnostic: | BUILDING AGE QUALIFIER OUT OF RANGE |
| Routine: | MAIN |
| Action: | The incorrect value is set to a default value of either 1 (new single story) or 4 (existing multistory). |
| Data Output: | None |
| Remedy: | Check the value on the seventh card for this building in the data file. IBLDG must be either 1 or 4 (see table 3.6). |

| | |
|---|---|
| Diagnostic: | PARTITION QUALIFIER OUT OF RANGE |
| Routine: | CZODIM |
| Action: | The incorrect value is set to a default value of 0. |
| Data Output: | None |
| Remedy: | Check the value on the first card for the sixth building safety feature (zone dimensions) for this fire zone. IPART must be either 0 or 1 (see table 3.15). |

| | |
|---|---|
| Diagnostic: | DEFICIENCY QUALIFIER OUT OF RANGE |
| Routine: | CHAZAR |
| Action: | The incorrect value is set to a default value of 0. |
| Data Output: | None |
| Remedy: | Check the value on the first card for the eighth building safety feature (hazardous areas) for this fire zone. Each of three deficiency qualifiers must take on values of either 0 or 1 (see table 3.18). |

```
Diagnostic:      SPRINKLER DESIGNATION OUT OF RANGE
Routine:         CSPRNK
Action:          The incorrect value is set to a default value of 2 (wet
                 concealed).
Data Output:     None
Remedy:          Check the value on the first card for the thirteenth building
                 safety feature (sprinklers) for this fire zone.  The
                 allowable values are 1 through 4 (see table 3.24).


Diagnostic:      WATER SUPPLY DESIGNATION OUT OF RANGE
Routine:         CSPRNK
Action:          The incorrect value is set to a default value of 3
                 (unknown).
Data Output:     None
Remedy:          Check the value on the first card for the thirteenth building
                 safety feature (sprinklers) for this fire zone.  The
                 allowable values are 1 through 3 (see table 3.24).
```

As an aid in building skills at troubleshooting, readers are encouraged to experiment with the example from chapter 3. A useful strategy might be as follows. First, run the model with all data as shown in chapter 3. Second, make several copies of the file for use in subsequent runs. Third, create an error in each of the duplicated files (e.g., delete a line, duplicate a line, change the column alignment on a card, exceed the maximum or minimum value, etc.). Fourth, run the model and examine the diagnostics. Fifth, determine what steps you would take to fix the problem based only on the information provided. Would these steps correct the problem? If the answer is no, then it will be necessary to study the relationship between the error you created and the diagnostics produced by the program to determine the source of the difficulty.

## REFERENCES

American Nation Standards Institute, <u>American National Standard Programming Language FORTRAN</u>, ANSI X3.9-1978, New York, 1978.

Chapman, R.E., and W. G. Hall, <u>Programmer's Manual for the Fire Safety Evaluation System Cost Minimizer Computer Program</u>, National Bureau of Standards, NBSIR 83-2749, Washington, D.C., 1983.

Lathrop, J.K., editor, <u>Life Safety Code Handbook</u>, National Fire Protection Association, Quincy, Mass., 1981.

National Fire Protection Association, <u>Code for Safety to Life from Fire in Buildings and Structures</u>, NFPA 101-1981, Quincy, Mass., 1981.

Nelson, H.E., and A. J. Shibe, <u>A System for Fire Safety Evaluation of Health Care Facilities</u>, National Bureau of Standards, NBSIR 78-1555, Washington, D.C., 1980.

U.S. Congress, House, Select Committee on Aging, Subcommittee on Long-Term Care, <u>Tragedy of Multiple Death Nursing Home Fires:  The Need for a National Commitment to Safety</u>, 1976.

# FEDERAL INFORMATION PROCESSING STANDARD SOFTWARE SUMMARY

| 01. Summary date | | | 02. Summary prepared by *(Name and Phone)* | 03. Summary action | | |
|---|---|---|---|---|---|---|
| Yr. | Mo. | Day | Robert E. Chapman    (301) 921-3855 | New | Replacement | Deletion |

01. Summary date: Yr. 8 3 Mo. 0 7 Day 1 9

02. Summary prepared by *(Name and Phone)*: Robert E. Chapman    (301) 921-3855

03. Summary action: New [x]   Replacement [ ]   Deletion [ ]

05. Software title: FIRE SAFETY EVALUATION SYSTEM COST MINIMIZER (FSESCM)

04. Software date: Yr. 8 3 Mo. 0 7 Day 1 9

Previous Internal Software ID

06. Short title:

07. Internal Software ID: NA

**08. Software type**
Automated Data System [ ]
Computer Program [x]
Subroutine/Module [ ]

**09. Processing mode**
Interactive [ ]
Batch [x]
Combination [ ]

**10. Application area**

*General*
Computer Systems Support/Utility [ ]
Scientific/Engineering [x]
Bibliographic/Textual [ ]
Management/Business [ ]
Process Control [ ]
Other [ ]

*Specific*
Fire Safety in Health Care Facilities

**11. Submitting organization and address**

Operations Research Division
Center for Applied Mathematics
National Bureau of Standards
Washington, D.C.   20234

**12. Technical contact(s) and phone**

Robert E. Chapman (301) 921-3855

William G. Hall    (301) 921-3855

**13. Narrative**

This program minimizes the cost to hospitals and nursing homes of complying with the Life Safety Code.  The model uses the Fire Safety Evaluation System developed by the Center for Fire Research at the National Bureau of Standards as a means for identifying alternatives to prescriptive compliance to the Life Safety Code.  A linear programming algorithm is then used to define compliance strategies which, for a given set of constraints, are optimal in terms of minimum cost.

**14. Keywords**

Building codes; building economics; economic analysis; fire safety; health care facilities; hospitals; life safety; mathematical programming; nursing homes; renovation.

| 15. Computer manuf'r and model | 16. Computer operating system | 17. Programing language(s) | 18. Number of source program statements |
|---|---|---|---|
| Sperry Univac | 1100/82 | FORTRAN 77 | APPX 4000 |

| 19. Computer memory requirements | 20. Tape drives U9V/UPS | 21. Disk/Drum units | 22. Terminals |
|---|---|---|---|
| Less than 256 K Bytes | (9 Track 1600 or 6250 FPI) | | |

**23. Other operational requirements**

**24. Software availability**
Available [x]   Limited [ ]   In-house only [ ]

**25. Documentation availability**
Available [x]   Inadequate [ ]   In-house only [ ]

**26. FOR SUBMITTING ORGANIZATION USE**

| U.S. DEPT. OF COMM. **BIBLIOGRAPHIC DATA SHEET** (See instructions) | 1. PUBLICATION OR REPORT NO. NBSIR 83-2797 | 2. Performing Organ. Report No. | 3. Publication Date December 1983 |
|---|---|---|---|

**4. TITLE AND SUBTITLE**

User's Manual for the Fire Safety Evaluation System Cost Minimizer Computer Program

**5. AUTHOR(S)**

Robert E. Chapman and William G. Hall

| 6. PERFORMING ORGANIZATION (If joint or other than NBS, see instructions) NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON, D.C. 20234 | 7. Contract/Grant No. |
|---|---|
| | 8. Type of Report & Period Covered |

**9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS (Street, City, State, ZIP)**

Center for Fire Research
National Engineering Laboratory
National Bureau of Standards
Washington, D.C. 20234

Department of Health and
Human Services
Washington, D.C. 20201

**10. SUPPLEMENTARY NOTES**

[x] Document describes a computer program; SF-185, FIPS Software Summary, is attached.

**11. ABSTRACT** (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

The Fire Safety Evaluation System Cost Minimizer (FSESCM) computer program integrates engineering and economic considerations with a linear programming algorithm which permits the least-cost means of upgrading health care facilities to compliance with the Life Safety Code to be identified. This report is designed as a reference document for a nonprogramming FSESCM user. A description of the philosophy and methodology behind FSESCM is given first, followed by a discussion of the data requirements, the various options available to the user, as well as some of the limitations of the program. A detailed example in which all inputs to the FSESCM computer program are described is then given. The output associated with the example is then analyzed rigorously. The report concludes with a set of guidelines for making efficient use of the FSESCM computer program.

**12. KEY WORDS** (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

Building codes; building economics; economic analysis; fire safety; health care facilities; hospitals; life safety; mathematical programming; nursing homes; renovation

**13. AVAILABILITY**

[x] Unlimited

[ ] For Official Distribution. Do Not Release to NTIS

[ ] Order From Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

[x] Order From National Technical Information Service (NTIS), Springfield, VA. 22161

**14. NO. OF PRINTED PAGES**

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