



U.S. Department of Commerce  
Technology Administration  
National Institute of Standards and Technology

Office of Applied Economics  
Building and Fire Research Laboratory  
Gaithersburg, MD 20899

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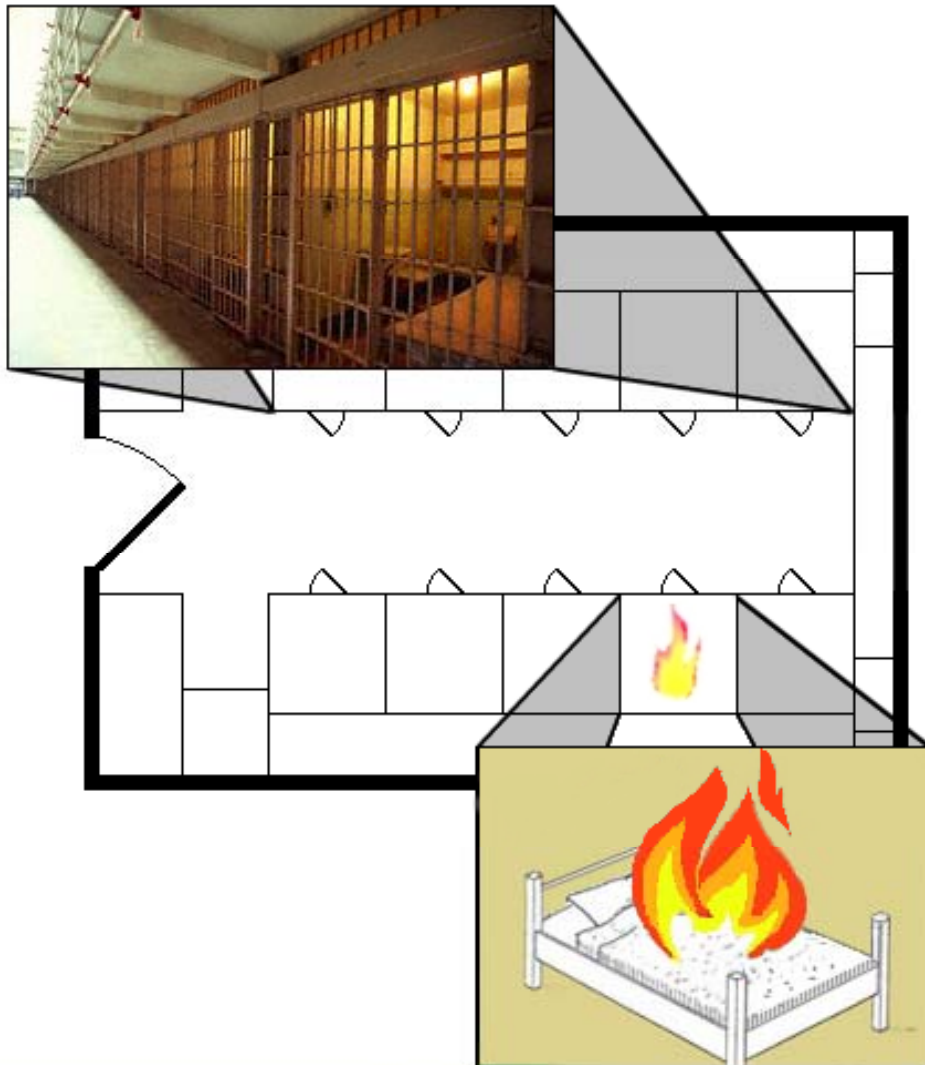
# **ALARM 2.0 User Manual**

## **Minimizing Compliance Costs of the Life Safety Code for Prisons**

Stephen F. Weber and Laura I. Schultz

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**U.S. DEPARTMENT OF COMMERCE**

Donald L. Evans, Secretary

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Karen H. Brown, Acting Director



## **Abstract**

***ALARM***, Alternative Life Safety Analysis for Retrofit Cost Minimization, is a software tool that helps prison facility managers and fire safety engineers achieve cost-effective compliance with the widely-used *Life Safety Code*<sup>®</sup> of the National Fire Protection Association. The latest version of the software (2.0) supports analysis of Detention and Correctional Occupancies. Through a special provision of the code, ***ALARM*** implements a goal-oriented, or performance-based approach to code compliance. The user specifies the current safety level of the facility for each of 13 life safety parameters and then enters quantity and size data on each of the safety improvements to be explored. The software indicates whether the current safety level is in compliance with the code and, if not, quickly finds the least-cost compliance strategy and its estimated construction cost. The software takes into account the special conditions in the code that preclude finding solutions by hand. A practice file with data from a sample facility, extensive help with a step-by-step tutorial, a report utility for viewing and printing results, and a comprehensive file manager are included. The optimization method used in ***ALARM*** has been field tested in 89 hospitals (17,898 beds). For this sample the least-cost solution identified by the software was on average 41 % less expensive than the prescriptive solution. This represents a potential cost savings of \$2,116 per bed or over \$37 million in total.

**Keywords:** building codes; building economics; correctional facilities; cost minimization, fire safety; life safety code; linear programming; mathematical programming; optimization, prisons.

## Acknowledgments

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The authors greatly appreciate the permission granted by Dennis Berry, Associate General Counsel for the National Fire Protection Association (NFPA), to reprint material from the *Life Safety Code*<sup>®</sup> in the User Manual and software help system. Users should note that the reprinted material found in this publication is not the complete and official position of NFPA on the referenced subject, which is represented only by the standard in its entirety.

Special thanks are owed to Walter J. Jones of NIST for developing the comprehensive help system; designing the graphics for the welcome screen and the software icon, and conducting extensive tests on early versions of the software. Thanks is also extended to Robert Chapman of NIST, who developed the original linear programming model and software application on which the cost minimization method is based. Credit is also due to Michel Berkelaar of Eindhoven University of Technology (Netherlands) for putting into the public domain his efficient software code, *lp\_solve*, which includes the module for solving zero-one integer programming problems that we adapted for *ALARM 2.0*.

We are indebted to Harold Nelson, Edward Budnick, and Shivani Mehta of Hughes Associates, Inc. of Columbia MD for supplying detailed construction specifications as well as cost estimation algorithms and data for the improvements in fire safety levels. Harold Nelson is the major force behind development of the Fire Safety Evaluation Systems for various building occupancies found in NFPA 101A. He also provided many useful comments on early versions of the software and developed the case study for the sample file used in the tutorial.

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**Disclaimer on the use of non-metric units:**

The policy of the National Institute of Standards and Technology is to use metric units of measurement in all its publications. This publication, however, is intended for the fire safety engineering and construction industries in the United States, where certain non-metric units are so widely used instead of metric units that it is more practical and less confusing to present construction dimensions, costs, and safety level definitions in customary units.

**Disclaimer on trade names:**

Trade names are mentioned in this publication to specify products used in the software. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology.

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Material in the help file and the Project Window of the software, appearing also as screen shots in this User Manual, is reprinted with permission from NFPA 101A-2001, *Guide on Alternative Approaches to Life Safety*, Copyright ©, National Fire Protection Association. This reprinted material is not the complete and official position of NFPA on the referenced subject, which is represented only by the standard in its entirety.





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## 1.0 Introduction

### 1.1 Purpose

The Fire Safety Evaluation System (FSES) for Detention and Correctional Facilities, specified in Chapter 5 of the *Guide on Alternative Approaches to Life Safety* (NFPA 101A), provides the managers and fire safety engineers of these facilities with many alternative compliance solutions that are equivalent in safety to the prescriptive version of the *Life Safety Code*<sup>®</sup> found in NFPA 101<sup>®</sup>, *Code for Safety to Life in Buildings and Structures*. The flexibility provided by the FSES allows for major cost savings in achieving compliance with the *Life Safety Code*. The wide range of acceptable compliance solutions and the many exceptions and interdependencies introduced by the footnotes combine to make it virtually impossible to find the least-cost solution using trial and error methods.

**ALARM 2.0**, Alternative Life Safety Analysis for Retrofit Cost Minimization, is a software tool that helps prison facility managers, fire safety engineers, and architects quickly find the most cost-effective plan to achieve compliance with the *Life Safety Code*. **ALARM 2.0** is a user-friendly, 32-bit Windows software program designed to help users take full advantage of the flexibility offered by NFPA 101A. The **ALARM** tool allows users to enter data about the physical dimensions of their facilities through an interface that mirrors the main worksheet of NFPA 101A. The program then applies its cost algorithms and unit cost data to estimate the cost of each safety improvement to be considered. The cost estimates automatically vary by facility location using the built-in geographic area cost factors of the nearest major city. Finally, the software quickly finds the most cost-effective construction plan for achieving compliance with the *Life Safety Code*.

### 1.2 History

The first version of **ALARM** was developed in the Building and Fire Research Laboratory at the National Institute of Standards and Technology. The software generated a set of alternative compliance strategies and their estimated construction costs for the NFPA 101A for health care occupancies. The software used an optimization method that has since been tested in 89 hospitals and compared to the cost of strict compliance with the prescriptive code of the NFPA. Research done after the development of the first version of **ALARM** showed a potential cost savings of \$2,116 per bed for almost 18,000 beds, resulting in a total savings of over \$37 million.

### 1.3 New Features

This latest version of **ALARM** (2.0) has integrated many improvements in modeling techniques, interface design, and usability. Version 1.0 was a DOS program limited by its

text only, 16-bit platform. *ALARM 2.0* takes full advantage of the 32 bit, graphical Windows platform. This has allowed for speedier optimization and improvements in user-friendliness. The main Project screen is directly based on the design and layout of the key worksheet of the *Life Safety Code*. The more powerful platform has also facilitated the use of the new optimization algorithm included in this version.

Another significant feature of *ALARM 2.0* is that almost all of the descriptive text, safety parameter definitions, code and point requirements, and cost data are contained in data files that are independent of the executable program. As a result, a new set of data files is all that is needed to efficiently incorporate changes in code requirements and cost data. In addition, this software design will enable rapid development of new releases of *ALARM* that cover occupancies other than Correctional Facilities, such as Business, Health Care, and Board and Care occupancies.

## 1.4 Overview

This manual provides instructions on getting started with *ALARM 2.0* and setting up new projects for analysis. To show the many features of *ALARM*, a demonstration case is included with the software as a sample project file. To learn to use the software, practice each instruction in Chapters 2 through 6 of this manual using the sample project file, State Penn.fse. Chapter 7 provides information on the economic and mathematical methods the software uses to determine the least-cost safety improvement plan. Chapter 8 discusses the fire safety improvements and cost data and cost estimating algorithms used in the software.

## 2.0 Getting Started

### 2.1 Installing *ALARM 2.0*

To install *ALARM 2.0*, insert the CD-ROM into your drive and close the CD drawer. Wait a few seconds for the AutoRun feature to execute the Setup.exe installation program. You will be asked to confirm the drive and installation folder for *ALARM*. Click on the OK button to begin the process of copying all the files to the installation folder on your hard drive. Once the files are copied you are ready to start the *ALARM* software. If the AutoRun feature is disabled on your computer, simply click on the Start button and select Run. Then type the command “d:\setup.exe,” substituting for “d” the letter assigned to your CD-ROM drive, to execute the Setup.exe installation program directly from the CD-ROM drive.

### 2.2 Starting *ALARM 2.0*

To start *ALARM 2.0*, use the My Computer icon to open the *ALARM* folder and double click on the file labeled Alarm.exe. In a few seconds, the *ALARM* welcome window will appear.



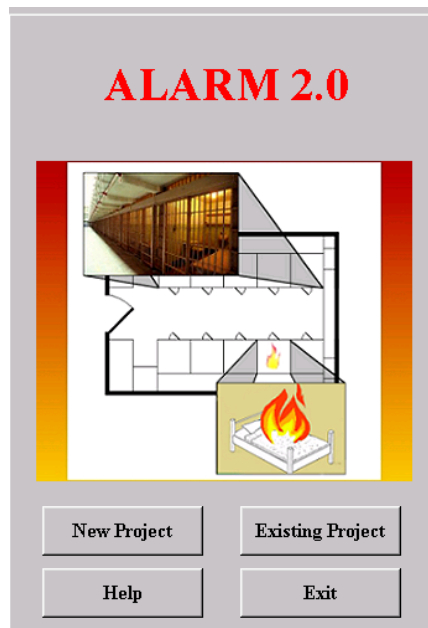
*ALARM* Welcome Window

The welcome screen presents the user with four options: New Project, Existing Project, Help and Exit. New Project and Existing Project are discussed in the following section. Help will open the Help Window to *ALARM*'s Online Tutorial. The help system also provides users with information on the *Life Safety Code* and instructions on using the software. Complete documentation of the Help system can be found below. The final button, **Exit**, shuts down *ALARM*.

Note on Screen Resolution: Due to the large amount of information displayed on the main screen, *ALARM*, runs best at a screen resolution of 800x600 or higher. If the program does not fully display on your desktop, the resolution is probably set too low. To increase the resolution, press the **Start** button and select **Settings and Control Panel**. Select the **Display** icon in the control panel. The Settings tab will allow you to reset the resolution. In the box titled **Desktop Area** move the pointer to the right until it reads 800 by 600 resolution. To accept the new resolution, press the **OK** button. You may need to reboot for the settings to take effect.

### 2.3 Help System

The help system was designed to provide the user with a reference on running *ALARM* and a resource for looking up the definitions of safety parameters and safety levels taken from the NFPA documentation on the *Life Safety Code*. Help can be accessed from several places in *ALARM*, starting with the Welcome Screen, where the user can press the Help button.



**The Help Button**

Help may also be found in the Menu Bar by selecting Help and then Contents, or by pressing the **F1** key.



### Help Menu

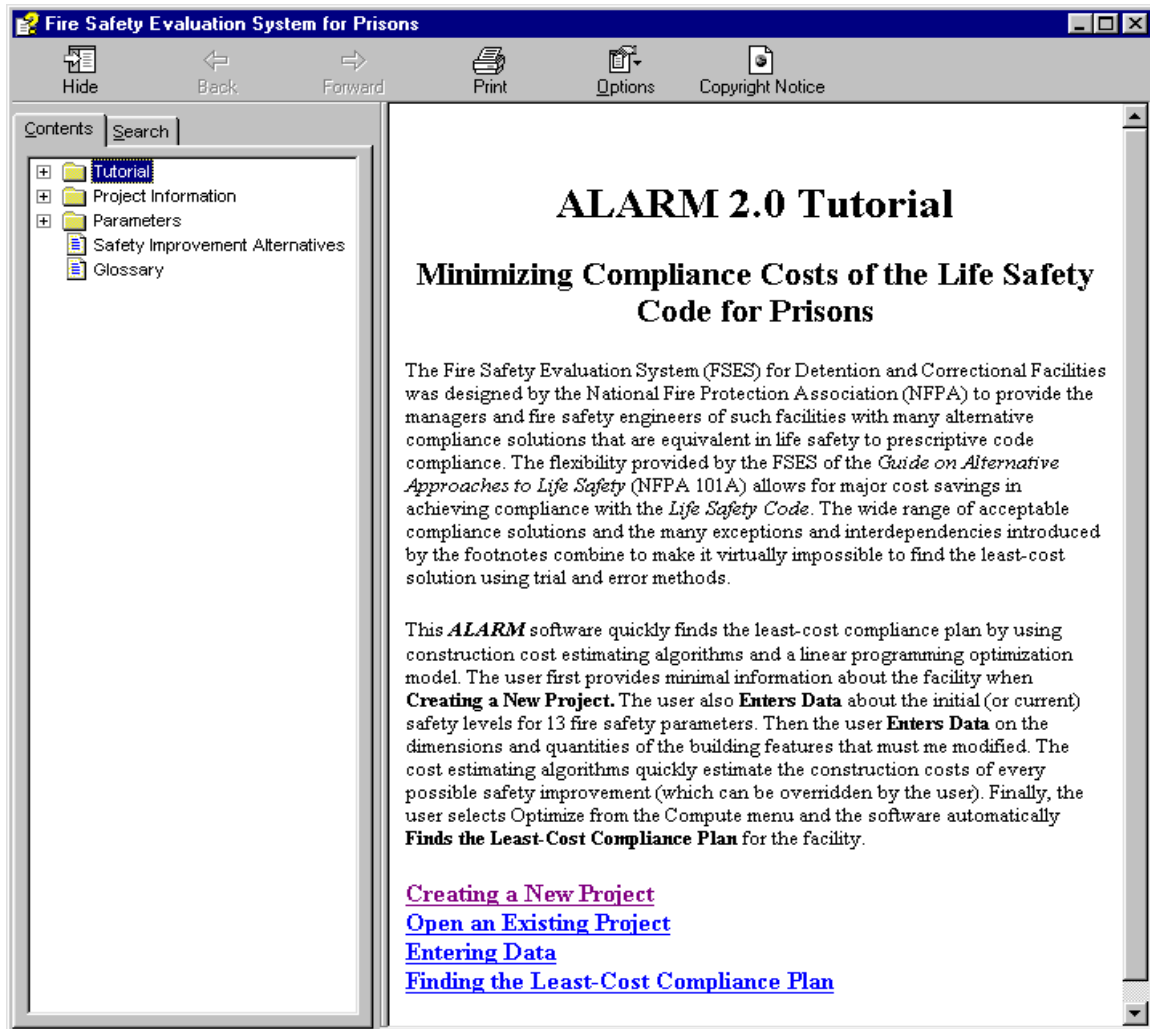
The above methods open the main help page which describes the *ALARM* software and accesses the tutorial.

The other method of accessing the help system is to use the context sensitive feature by selecting **Help** from the drop down menu of a safety level.

Sprinklers		\$ 24536	\$ 26491	0	0	0	0
6 Interior Finish (Corridor)	Class C	Class B	Class A	0	0	0	0
7 Interior Finish (Other Areas)	Class C		Class A \$ 15256	-1	0	0	-2
8 Cell/Sleeping Room Enclosure	Cells face on Corridor		Space in Resid. Housing Area Resistant <1 hour	0	0	0	0
9 Separation of Residential	Incomplete		>1 Hour Fire Resistance \$ 16645	2	1	2	2

### Safety Level Specific Help

When help is accessed with this method, the help system takes you directly to the documentation on the specific safety parameter that was clicked. From there, documentation on choosing the correct safety level can be viewed.



### The Help System

The Help system includes a tutorial that is designed to help a new user learn how to operate *ALARM*. The documentation for the tutorial is based on this manual. The Project Information section of the help system provides documentation about the data needed to start a new project, such as use condition and number of stories. The parameters section is based on NFPA documentation regarding the 13 safety parameters. This section should be used to help select the Initial Safety level and the safety levels to be considered for analysis for each safety parameter.

The help system can be navigated by browsing through the outline in the contents panel on the left side of the help window. The help documentation itself also contains links to information relevant to the displayed topic.

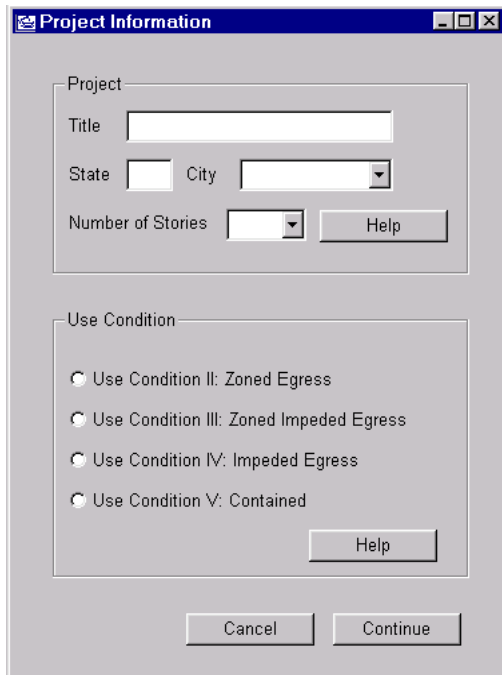
The help system may also be searched for a specific keyword or term. To search, select the Search Tab on the left side of the window, and enter the term. All references to the key term will be listed. Double clicking on a reference displays that topic.



## 3.0 Starting a Project

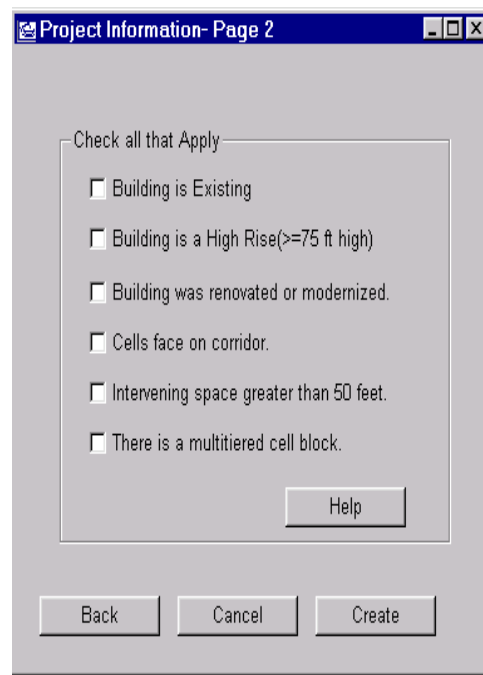
### 3.1 Creating a New Project

A new project can be created by either pressing the New Project button on the Welcome Window or by selecting File menu on the menu bar and then New on the drop-down menu. To create a new project you need to answer several questions about the facility to be analyzed using the two Project Information Windows:



The screenshot shows a window titled "Project Information". It contains two main sections. The first section, labeled "Project", includes a text box for "Title", a "State" dropdown menu, a "City" dropdown menu, and a "Number of Stories" dropdown menu. A "Help" button is located to the right of the "Number of Stories" dropdown. The second section, labeled "Use Condition", contains four radio button options: "Use Condition II: Zoned Egress", "Use Condition III: Zoned Impeded Egress", "Use Condition IV: Impeded Egress", and "Use Condition V: Contained". A "Help" button is located to the right of these options. At the bottom of the window are "Cancel" and "Continue" buttons.

Window 1



The screenshot shows a window titled "Project Information- Page 2". It contains a section labeled "Check all that Apply" with five checkbox options: "Building is Existing", "Building is a High Rise(>=75 ft high)", "Building was renovated or modernized.", "Cells face on corridor.", and "Intervening space greater than 50 feet.". A sixth checkbox option, "There is a multitiered cell block.", is located below the main list. A "Help" button is located to the right of the checkboxes. At the bottom of the window are "Back", "Cancel", and "Create" buttons.

Window 2

### Project Information

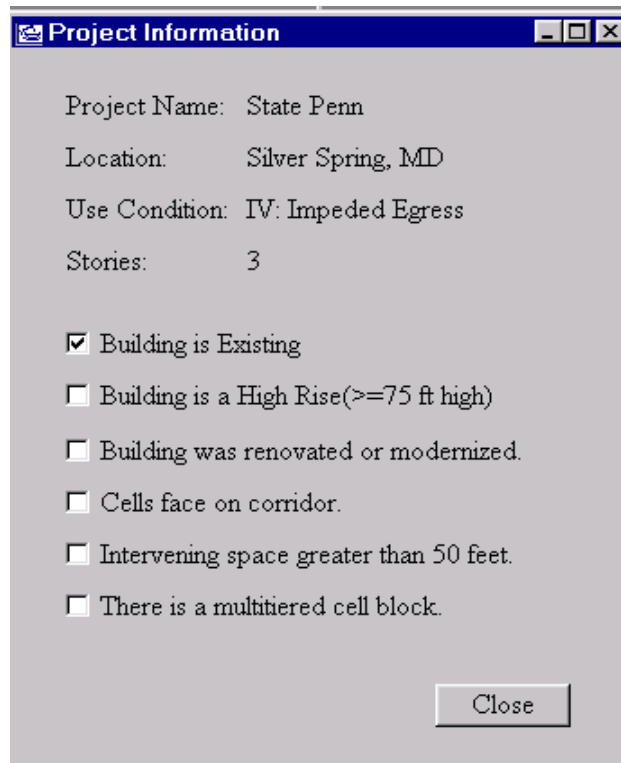
The first section of Window 1 asks for background information about the project. You may use any convenient name for the project title. **ALARM** uses your title as the file name plus an "FSE" (Fire Safety Evaluation) extension for storing the project data. Enter the state where the facility is located, and a list of cities will appear to the right. The construction cost estimates developed by **ALARM** are based on geographic location factors to provide the most accurate cost estimates. Select the city that most closely resembles the facility location in terms of construction costs. The final listbox asks the user for the number of stories. Number of Stories is the number of floors that are occupied by inmates. For a more precise definition and help in determining the number of stories in your facility, press the Help button. A help screen will appear providing the NFPA's definition of Stories.

Next enter the Use Condition of the facility. As before, the Help button opens a page in the help file designed to assist in determining the proper Use Condition as defined by the NFPA.

After all information has been entered press the Continue button to move to the second Project Information Window. If a message box appears warning of missing data, press OK and recheck the previous entries to make sure all data were entered correctly.

The second Window lists a set of statements that may be true about the facility. The Help button provides definitions of all the statements to assist the user in choosing the correct options. Mark the check boxes that apply to the facility. The Back button allows the user to change any data entered on the first page if necessary. Once all data have been entered correctly in both Project Information screens, press the Create button to finish creating the new project.

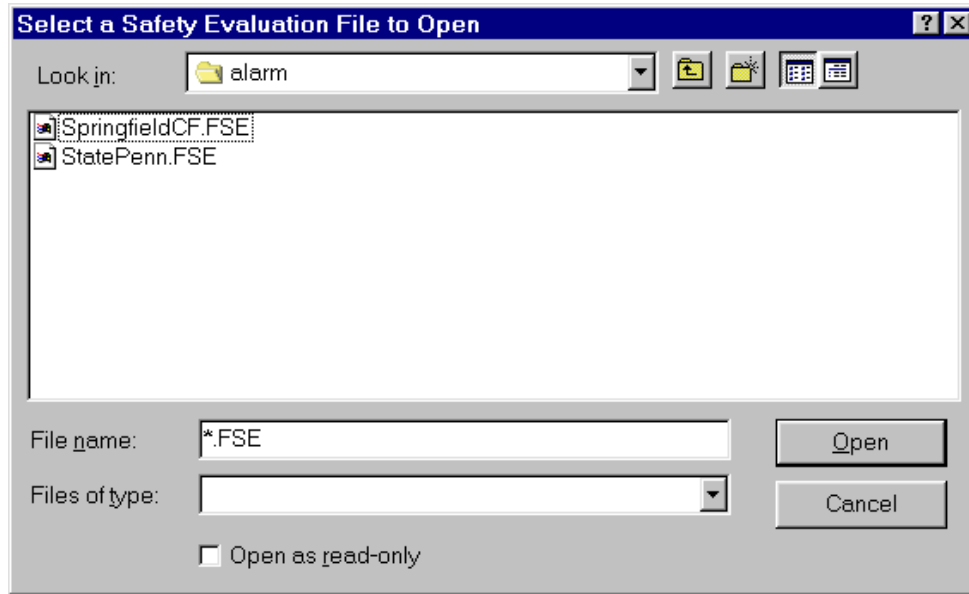
Once the project has been created, the data entered in the Project Information screens cannot be changed without creating a new project file. The user may view the project information data at any time after creation by selecting the Edit item on the menu bar, and then choosing the View Project Information option from the drop-down menu.



**Project Information Window**

### 3.2 Opening an Existing Project

There are two methods of opening existing projects. You may select the Existing Project from the Welcome Window or the Open option from the File menu. Both methods will display the dialog window, Select a Safety Evaluation File to Open.



#### Selecting an Existing File to Open

This dialog window lets you select any one of your project files. They all have the extension \*.FSE (Fire Safety Evaluation).



## 4.0 Understanding the Project Window

### 4.1 Layout

Once a new project is started or an existing file is opened, a new window appears called the **Project Window**. For a new project, the window appears as a clean slate, with no safety level boxes color coded and no construction costs or points displayed.

Project: New Project								S1	S2	S3	S4	
1. Construction	V(000)	V(111)	IV(2HH)	III(200)	III(211)	II(000)	II(111)	II(222) or I(ANY)	0	0	0	0
2. Hazardous Areas	Within Residential Housing Area			Outside Residential Housing Area			No Deficiencies		0	0	0	0
	Double Deficiency		Single Deficiency	Double Deficiency		Single Deficiency						
3. Fire Alarm	No Alarm		No FD Notification		With F.D. Notification							
					No Manual Alarm		Manual Alarm	0	0	0	0	
4. Smoke Detection	None	Residential Housing Area			Total Building							
		Large Sleeping Rooms		All Sleeping Rooms	Full Coverage			0	0	0	0	
5. Automatic Sprinklers	None		Residential Housing Areas		Entire Building			0	0	0	0	
6. Interior Finish (Corns/Egress)	Class C		Class B		Class A			0	0	0	0	
7. Interior Finish (Other Areas)	Class C		Class B		Class A			0	0	0	0	
8. Cell/Sleeping Room Enclosure	Cells face on Corridor		Intervening Common Space in Resid. Housing Area									
			Open	Smoke Resistant <1 hour	Fire Resistant >1 hour		0	0	0	0		
9. Separation of Residential	Incomplete		Smoke Resistant <1 hour		>1 Hour Fire Resistance			0	0	0	0	
10. Exit System	<2 Routes		Multiple Routes									
			Deficient	No Deficiencies	Direct Room Exits		0	0	0	0		
11. Exit Access	Dead Ends		No Dead Ends >50ft and Travel is:			<= 150 ft						
	>100 ft	>50 ft	>200 ft	<=200 ft	>150 ft	<=150 ft	0	0	0	0		
12. Vertical Openings	Open or Incomplete Enclosures				Enclosed							
	Thru 4>= Floors	2-3 Floors	1 Floor	Smoke Resistant	Fire Resistant		0	0	0	0		
13. Smoke Control	No Control		Smoke Compartments			Heat + Smoke Vent System						
			Passive	Mechanically Assisted				0	0	0	0	
								Points Earned:	0	0	0	0
								Points Needed:	9	12	10	14
								Deficit:	-9	-12	-10	-14

### New Project Window

The Project Window is designed to mirror Worksheet 5.5.3: Safety Parameter Values, from NFPA 101A. At the top of the window the title of the current project is displayed. There are 13 rows in the worksheet, each representing a safety parameter. Each parameter row has a set of labeled boxes, representing all the safety levels possible for that parameter.

The right side of the window provides a tally of the points earned in the project. The four columns are titled “S1,” “S2,” “S3,” and “S4.” These are derived from the weighting factors in Worksheet 5.5.4 of the NFPA 101A and represent the four safety evaluation goals, Fire Control (S1), Egress (S2), Refuge (S3) and General Fire Safety (S4). The

box at the end of each safety parameter shows the points earned by that parameter for each of the point evaluations. The points are tallied at the bottom of each column.

Points Earned:	0	0	0	0
Points Needed:	9	12	10	14
Deficit:	-9	-12	-10	-14

### Point Tally

The Point Tally consists of three rows. The first is Points Earned, which displays the sum of all the points earned from the selected Initial Safety levels. Because this is a new project the points earned are initially zero. The next row, Points Needed, displays the points required to achieve compliance with the *Life Safety Code*, based on the Mandatory Safety Requirements specified in Worksheet 5.5.5. The final row shows the point **Deficit**, computed by subtracting the Points Needed from the Points Earned. Once all the minimum point requirements are achieved the final row will show a **Surplus**.

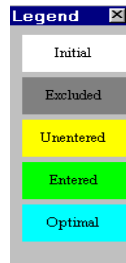
### 4.2 Color Coding

Once data have been entered, the appearance of the Project Window changes to reflect the new information. Below is an image of an Existing Project with some data entered.

Project: State Penn								S1	S2	S3	S4	
1. Construction	V(000)	V(111)	IV(2HH)	III(200)	III(211)	II(000)	II(111)	II(222) or I(ANY)	0	0	0	0
2. Hazardous Areas	Within Residential Housing Area			Outside Residential Housing Area			No Deficiencies		-4	-2	-4	-4
	Double Deficiency	Single Deficiency	Double Deficiency	Single Deficiency \$ 7772								
3. Fire Alarm	No Alarm		No FD Notification		With F.D. Notification			1	1	0	1	
					No Manual Alarm	Manual Alarm \$ 3698						
4. Smoke Detection	None		Residential Housing Area			Total Building \$ 4519		2	4	0	4	
			Large Sleeping Rooms	All Sleeping Rooms	Full Coverage							
5. Automatic Sprinklers	None		Residential Housing Areas \$ 24636		Entire Building \$ 86491			0	0	0	0	
6. Interior Finish (Corns/Egress)	Class C		Class B			Class A		0	0	0	0	
7. Interior Finish (Other Areas)	Class C		Class B \$ 15256		Class A \$ 15256			-1	0	0	-2	
8. Cell/Sleeping Room Enclosure	Cells face on Corridor		Intervening Common Space in Resid. Housing Area				0	0	0	0		
			Open	Smoke Resistant <1 hour	Fire Resistant >1 hour							
9. Separation of Residential	Incomplete		Smoke Resistant <1 hour		>1 Hour Fire Resistance \$ 16645			2	1	2	2	
10. Exit System	<2 Routes		Multiple Routes			Direct Room Exits \$ 15214		0	0	0	0	
			Deficient		No Deficiencies							
11. Exit Access	Dead Ends		No Dead Ends >50ft and Travel is:				<= 150 ft		0	-2	0	-2
	>100 ft	>50 ft	>200 ft	<=200 ft	>150 ft	<=150 ft \$ 1019						
12. Vertical Openings	Open or Incomplete Enclosures				Enclosed			0	0	0	0	
	Thru 4>= Floors	2-3 Floors	1 Floor	Smoke Resistant		Fire Resistant \$ 26142						
13. Smoke Control	No Control		Smoke Compartments			Heat + Smoke Vent System \$		0	2	2	2	
			Passive	Mechanically Assisted \$								
								Points Earned:	-1	4	0	1
								Points Needed:	7	10	8	11
								Deficit:	-8	-6	-8	-10

Existing Project Window

The colors on the screen, allow you to quickly interpret data in the box. **ALARM** provides a convenient reference to understanding the color scheme in the Legend Window.



### Legend Window

To view the Legend Window, select Edit from the menu bar and choose Show Legend. The Legend Window explains the color-coding on the main window. A safety level marked white is the Initial, or current safety level of the facility. Dark gray safety levels have been Excluded from the analysis. **ALARM** automatically marks safety levels as Excluded if they have a lower point value than the Initial level or if there is no feasible way to improve safety from the Initial to the Excluded level. You may also mark as Excluded any safety level that you do not want to consider in your safety improvement plan. Yellow safety levels are achievable from the Initial safety level, but are missing quantity and cost. Green safety levels contain data and will be considered in the analysis when the project is optimized. Aqua levels signify the optimum safety levels and will only appear after the Optimize function under the Compute Menu finds the least-cost compliance plan.

In addition to providing a comprehensive overview of the facility's status, the Project Window is also used for data entry. To see how the window is used to collect data about your facility continue to the next chapter.





## 5.0 Data Entry

### 5.1 Selecting an Initial Level

A sample project file with most of the necessary data already entered has been provided to assist you in the data entry process described in this chapter. Open the file “State Penn.FSE” to display the tutorial in the Project Window.

ALARM 2.0								S1	S2	S3	S4				
Project: State Penn															
1. Construction	V(000)	V(111)	IV(2HH)	III(200)	III(211)	II(000)	II(111)	II(222) or I(ANY)	0	0	0	0			
2. Hazardous Areas	Within Residential Housing Area			Outside Residential Housing Area			No Deficiencies		-4	-2	-4	-4			
	Double Deficiency		Single Deficiency	Double Deficiency		Single Deficiency \$ 7772									
3. Fire Alarm	No Alarm		No FD Notification		With F.D. Notification					1	1	0	1		
					No Manual Alarm		Manual Alarm \$ 3698								
4. Smoke Detection	None		Residential Housing Area			Total Building \$ 4519				2	4	0	4		
			Large Sleeping Rooms	All Sleeping Rooms	Full Coverage										
5. Automatic Sprinklers	None		Residential Housing Areas \$ 84636		Entire Building \$ 86491					0	0	0	0		
6. Interior Finish (Corns/Egress)	Class C		Class B		Class A					0	0	0	0		
7. Interior Finish (Other Areas)	Class C		Class B \$ 15256		Class A \$ 15256					-1	0	0	-2		
8. Cell/Sleeping Room Enclosure	Cells face on Corridor		Intervening Common Space in Resid. Housing Area								0	0	0	0	
			Open	Smoke Resistant <1 hour	Fire Resistant >1 hour										
9. Separation of Residential	Incomplete		Smoke Resistant <1 hour		>1 Hour Fire Resistance \$ 16645					2	1	2	2		
10. Exit System	<2 Routes		Multiple Routes				Direct Room Exits \$ 15214				0	0	0	0	
			Deficient	No Deficiencies											
11. Exit Access	Dead Ends		No Dead Ends >50ft and Travel is:				<= 150 ft				0	-2	0	-2	
	>100 ft	>50 ft	>200 ft	<=200 ft	>150 ft	<=150 ft \$ 1019									
12. Vertical Openings	Open or Incomplete Enclosures				Enclosed							0	0	0	0
	Thru 4+ Floors	2-3 Floors	1 Floor	Smoke Resistant		Fire Resistant \$ 26142									
13. Smoke Control	No Control		Smoke Compartments			Heat + Smoke Vent System \$						0	2	2	2
			Passive	Mechanically Assisted \$											
								Points Earned:	-1	4	0	1			
								Points Needed:	7	10	8	11			
								Deficit:	-8	-6	-8	-10			

### Project Window

To mark the initial safety level, you may either right click or double click on the desired safety level box. Double clicking immediately sets the initial safety level. Right clicking leads to a menu allowing the initial safety level to be set.

Sprinklers		\$ 84636	\$ 86491	0	0	0	0
6 Interior Finish (ConsEgress)	Class C	Class B	Class A	0	0	0	0
7 Interior Finish (Other Areas)	Class C		Class A \$ 15256	-1	0	0	-2
8 Cell/Sleeping Room Enclosure	Cells face on Corridor		Space in Resid. Housing Area Resistant <1 hour      Fire Resistant >1 hour	0	0	0	0
9 Separation of Residential	Incomplete		>1 Hour Fire Resistance \$ 16645	2	1	2	2

### Setting an Initial Level

Another choice on the drop-down menu is Help. Help can assist you in identifying and selecting the Initial safety level. When selecting Help the help window displays documentation on the relevant safety parameter. The documentation includes tips on identifying your Initial safety level and definitions relevant to the safety levels of that parameter. The documentation directly quotes relevant parts of the NFPA codes.

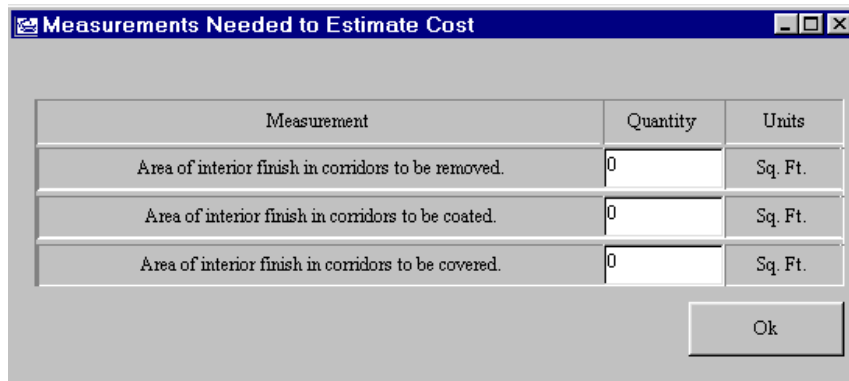
Once a Initial safety level has been set for a parameter, you will notice changes in the boxes for all safety levels of that parameter. Double click now on the Class B box for Parameter 6. The Class B box has turned white to indicate its status as the Initial or current safety level. The Class C level has been disqualified because it has a lower point value than the Initial level. The Class A is yellow indicating that it is possible to improve safety from Class B to Class A, but that quantity and cost data have not yet been entered. The points columns at the far right have been updated. Now instead of zeros, four numbers are displayed representing the point values earned toward the four safety goals (S1: Fire Control, S2: Egress, S3: Refuge, and S4: General Fire Safety) as a result of being at the selected Initial safety level. The change is also reflected in the totals for Points Earned and Deficit/Surplus at the bottom right of the screen.

6 Interior Finish (ConsEgress)	Class C	Class B	Class A \$	0	-1	0	-1
--------------------------------	---------	---------	---------------	---	----	---	----

### Initial Level Set

## 5.2 Data Entry

Once the Initial safety levels have been marked, data on the scale of the safety improvements are needed to complete the optimization. As mentioned above, yellow safety levels are those awaiting data. To enter data, right click on the safety level to activate the drop down menu and select the **Enter Data** option. The box will temporarily turn red to identify it as the safety level being worked on, and a window titled Measurements Needed to Estimate Cost will appear.



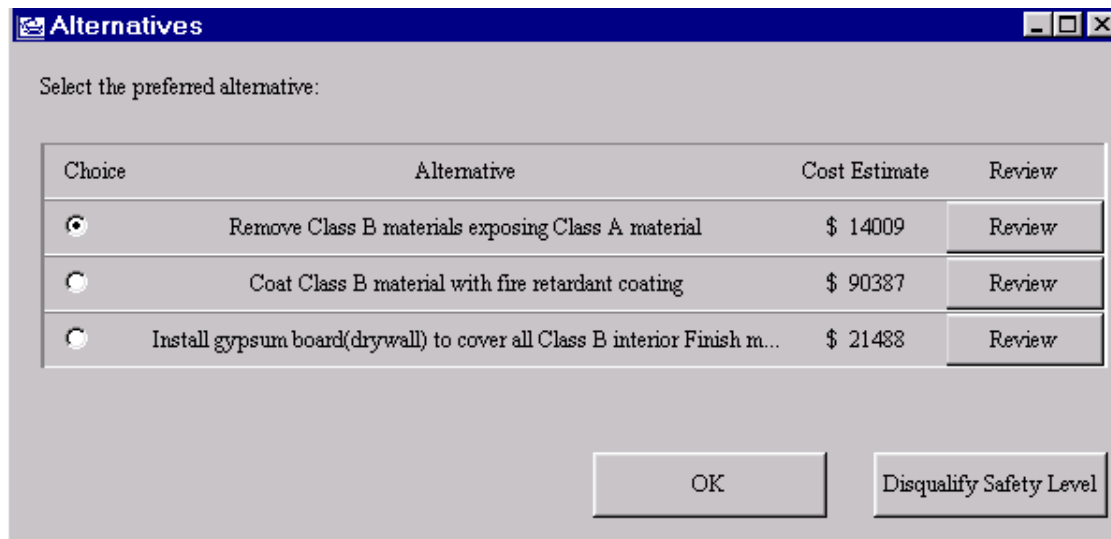
The image shows a software window titled "Measurements Needed to Estimate Cost". It contains a table with three rows and three columns: Measurement, Quantity, and Units. Each row has a description of a measurement, a quantity field with the value "0", and the unit "Sq. Ft.". An "Ok" button is located at the bottom right of the window.

Measurement	Quantity	Units
Area of interior finish in corridors to be removed.	0	Sq. Ft.
Area of interior finish in corridors to be coated.	0	Sq. Ft.
Area of interior finish in corridors to be covered.	0	Sq. Ft.

### Measurements Window

This window lists all measurements needed to estimate the costs of safety improvements. Enter the Area of interior finish in corridors to be removed, the area to be coated and the area to be covered. In this case the initial quantity is zero, but if there is another number in the quantity slot, it is based on information entered earlier, possibly for another safety level whose cost depended on the same measurements. **A warning: If you change such pre-existing data, previously computed cost estimates will also change.** For this tutorial, enter 33,000 for all three of the quantities.

Once the data have been entered, press OK to display the Alternatives Window, which lists all the construction alternatives to improve the Initial safety level to the new, higher, safety level.

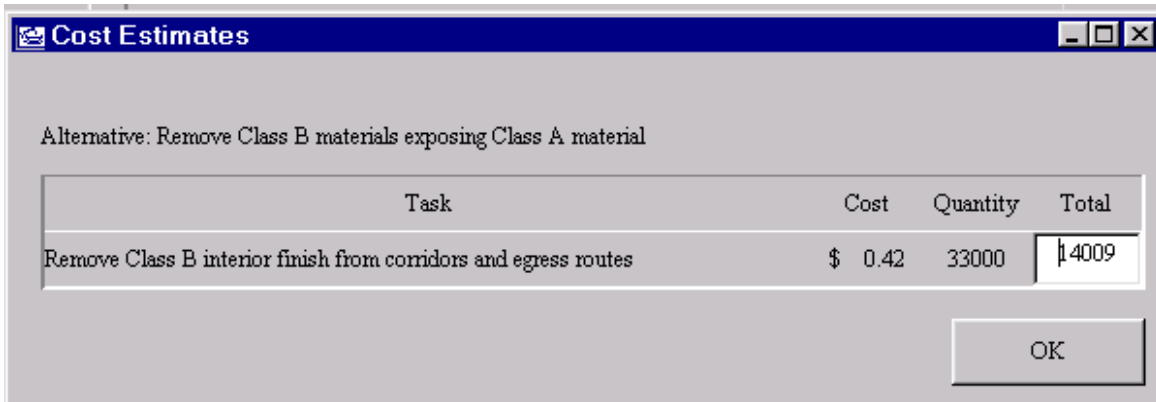


The image shows a software window titled "Alternatives". It prompts the user to "Select the preferred alternative:" and displays a table with three rows. Each row has a radio button for selection, a description of the alternative, a cost estimate, and a "Review" button. At the bottom, there are "OK" and "Disqualify Safety Level" buttons.

Choice	Alternative	Cost Estimate	Review
<input checked="" type="radio"/>	Remove Class B materials exposing Class A material	\$ 14009	Review
<input type="radio"/>	Coat Class B material with fire retardant coating	\$ 90387	Review
<input type="radio"/>	Install gypsum board(drywall) to cover all Class B interior Finish m...	\$ 21488	Review

### Alternatives Window

The Alternatives Window shows a description of each alternative with its estimated cost. To see more information about any alternative and its cost estimate, click on the **Review** button to display the Cost Estimates Window.



### Cost Estimates Window

The Cost Estimates Window offers an itemized description of all tasks needed to complete the alternative. This example has only one task, but alternatives can be more involved. There is a unit cost and quantity breakdown for each task. You may override the total cost of the alternative. Once you are satisfied with the cost estimates, click the OK button to return to the Alternative window. If the estimate was overridden, the change will be reflected in the Alternative window. The cost estimates provided by *ALARM* take the geographic location of the facility into account.

Once back in the Alternatives Window you should select which alternative is to be used in the analysis. Once the alternative is selected, click the **OK** button. The box of the safety level will change from red to green, and the cost estimate of the selected alternative will be displayed in the box. If you chose the least-cost alternative, “Remove Class B materials...” the Interior Finish safety parameter will look like this:

6 Interior Finish (ConsEgress)	Class C	Class B	Class A \$ 14009	0	-1	0	-1
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### Data is Entered and Cost is Displayed

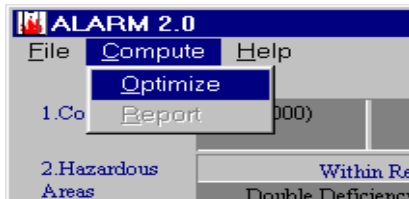
If, on the other hand, you reviewed the alternatives and decided that none were feasible for the project, you may select **Disqualify State**. This will turn the safety level box dark gray and remove that safety level from consideration in the optimization.

Now select an initial state and enter data for safety Parameter 8. At this point all thirteen of the Initial safety levels have been marked, and data have been entered for all the safety levels to be considered. The next step is optimization to find the least cost improvement plan.

## 6.0 Finding the Least-Cost Improvement Plan

### 6.1 Optimizing

Optimizing is the mathematical procedure that **ALARM** uses to find the least-cost method of achieving compliance with the *Life Safety Code*. The software will not allow you to optimize until all thirteen Initial safety levels have been marked. The optimization procedure considers all green safety levels as possible improvements from the Initial safety levels. The program interprets yellow levels as disqualified because there are no cost estimates for implementing those safety levels. To start the optimization procedure, click on the **Compute** menu and select the **Optimize** item.



How to Optimize

The screen refreshes and the answer is displayed using color-coded safety level boxes.

ALARM 2.0								S1	S2	S3	S4	
File Compute Edit Help												
Cost of Optimal Solution: \$ 70902												
1. Construction	V(000)	V(111)	IV(2HH)	III(200)	III(211)	II(000)	II(111)	II(222) or I(ANY)	0	0	0	0
2. Hazardous Areas	Within Residential Housing Area			Outside Residential Housing Area			No Deficiencies		0	0	0	0
	Double Deficiency	Single Deficiency	Double Deficiency	Single Deficiency \$ 7772								
3. Fire Alarm	No Alarm		No FD Notification		With F.D. Notification							
					No Manual Alarm	Manual Alarm \$ 3698		1	2	0	2	
4. Smoke Detection	None		Residential Housing Area			Total Building \$ 4519		2	4	0	4	
			Large Sleeping Rooms	All Sleeping Rooms	Full Coverage							
5. Automatic Sprinklers	None		Residential Housing Areas \$ 84636			Entire Building \$ 86491		0	0	0	0	
6. Interior Finish (Corns/Egress)	Class C		Class B			Class A \$ 13869		0	-1	0	-1	
7. Interior Finish (Other Areas)	Class C		Class B \$ 15256			Class A \$ 15256		-1	0	0	-2	
8. Cell/Sleeping Room Enclosure	Cells face on Corridor		Intervening Common Space in Resid. Housing Area									
			Open	Smoke Resistant <1 hour \$ 16645	Fire Resistant >1 hour		0	0	0	0		
9. Separation of Residential	Incomplete		Smoke Resistant <1 hour			>1 Hour Fire Resistance \$ 16645		4	2	4	4	
10. Exit System	<2 Routes		Multiple Routes									
			Deficient	No Deficiencies		Direct Room Exits \$ 15214		0	0	0	0	
11. Exit Access	Dead Ends		No Dead Ends >50ft and Travel is:				<= 150 ft		0	0	0	0
	>100 ft	>50 ft	>200 ft	<=200 ft	>150 ft	<=150 ft \$ 1019						
12. Vertical Openings	Open or Incomplete Enclosures			Enclosed								
	Thru 4>= Floors	2-3 Floors	1 Floor	Smoke Resistant	Fire Resistant \$ 26142		1	2	2	2		
13. Smoke Control	No Control		Smoke Compartments			Heat + Smoke Vent System \$		0	2	2	2	
			Passive	Mechanically Assisted \$								
								Points Earned:	7	11	8	11
								Points Needed:	7	10	8	11
								Surplus:	0	1	0	0

The Least-Cost Compliance Plan

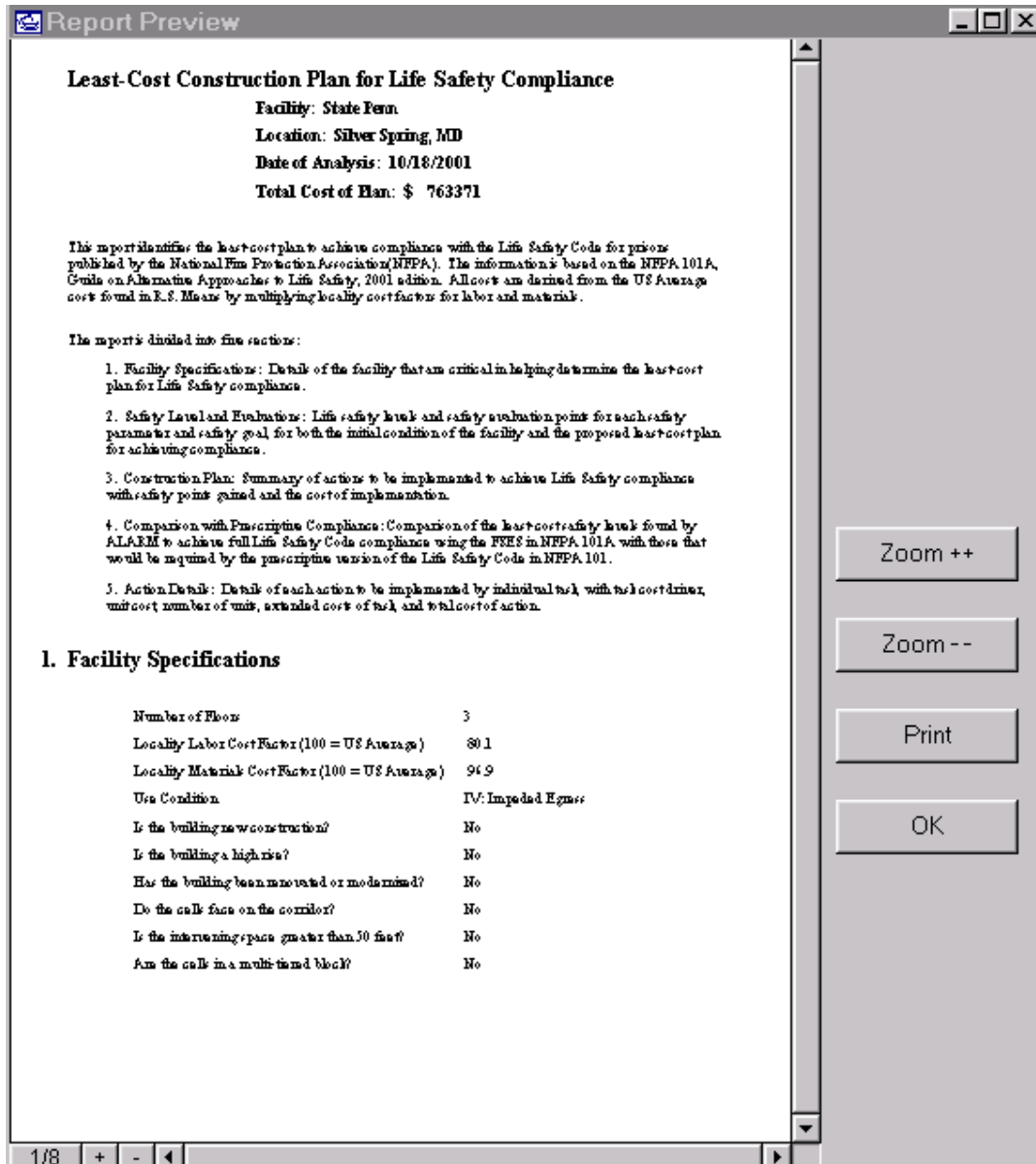
The yellow and green safety levels have been recolored either dark gray or aqua. Aqua indicates a safety level improvement that is included in the least-cost construction plan to reach compliance. In the least-cost plan displayed here, five improvements are needed to satisfy the total points required for all four of the safety goals. In Parameter 2: Hazardous Areas you need to upgrade from a double deficiency outside housing areas to a single deficiency. The second improvement in Parameter 3: Fire Alarm requires moving from No Manual Alarm to a Manual Alarm with Fire Department Notification. The third improvement in Parameter 8 calls for moving from Open space to Smoke Resistant < 1 hour. In Parameter 9 you need to improve from Smoke Resistant < 1 hour separation to  $\geq$  1 hour Fire Resistance. Finally, in Parameter 12: Vertical Openings you must upgrade from Smoke Resistant Enclosure to Fire Resistant Enclosure.

Other information provided on this screen is the Total Optimum points, bottom right, and the Cost of Optimal Solution, top center banner. The former shows the total points earned by the least-cost compliance plan toward each safety goal. Note that now there is a positive or zero Surplus of Points Earned over Points Needed for all four of the mandatory safety goals of the *Life Safety Code*. The latter is the total cost of all improvements in the least-cost compliance plan.

Once the project has been optimized, no more data can be entered. To modify the data and redo the analysis, first save the project under a different file name, open that new file, edit the data or add new data, and then re-optimize.

## 6.2 The Report

Once optimization is complete **ALARM** takes the data that you have entered and compiles a comprehensive report on the Least Cost Construction Plan for the Facility. **ALARM** then asks if you would like to view the facility report. The report may also be viewed by selecting the Compute Menu and choosing Report so that the Report Preview Window appears.



**Report Preview Window**

The report is composed of five separate sections. A sample report showing the optimization of State Penn.fse is included as an appendix. The first page provides a basic overview of the report explaining all five sections. It also prints out the information about the facility entered in the initial Project Information windows. Click on the “+” symbol at the bottom left to display page 2 of the report.

The second page of the report provides the safety levels and safety evaluation points earned for each parameter and safety goal, both for the initial condition of the facility and for the proposed least-cost plan for achieving compliance.

The third page is a summary of the construction plan. The table illustrates the actions that must be implemented to achieve Life Safety compliance. The page shows the cost of implementation and the safety points gained for each improvement.

The fourth section provides a comparison of the least-cost safety levels found by *ALARM* to achieve full *Life Safety Code* compliance using the FSES in NFPA 101A to those that would be required by the prescriptive version of the *Life Safety Code* in NFPA 101.

The final pages describe in detail of the actions needed to achieve compliance. The descriptions document each task, the task cost drivers, unit cost, number of units, extended costs of the task, and the total cost of each action.



## 7.0 Technical Background: How *ALARM* Finds the Least Cost Plan

### 7.1 Linear Programming

Linear programming is a powerful mathematical method for solving the problem of allocating limited resources among multiple competing activities. This method has been used to allocate production resources, plan shipping routes, assist in agricultural planning, and even design radiation therapy techniques. Linear programming uses a mathematical model to describe the problem of interest. The model is constructed of a series of mathematical linear functions. The model is then systematically solved to find the optimal solution.

Linear programming is the ideal tool to be used in identifying the least-cost construction plan for achieving compliance with the *Life Safety Code* because the safety goal requirements are all based on a linear summation of points earned by each safety parameter. *ALARM* uses a linear programming model to cost-effectively allocate a limited construction budget among competing activities by searching through all possible combinations of safety improvements that will satisfy the compliance requirements of the *Life Safety Code*.

To address the *Life Safety Code* a special type of linear programming, called zero-one, is implemented in *ALARM*. The zero-one approach is used when each of the choice variables are either true or false. In this model the choice variables are all of the individual safety levels of all the 13 safety parameters. A level is either selected for inclusion in the compliance plan or it is not. Each safety parameter is represented by one equation in the model. Each equation consists of the sum of all the safety level variables in the parameter being set equal to one. For instance, the equation for Parameter 5 would look like this:

$$X_{5,1} + X_{5,2} + X_{5,3} = 1$$

Note that in this zero-one model, each of the X's can take on only the values zero or one. Thus setting the equation equal to one ensures that one and only one of the safety levels can be included in the compliance plan. This is true for all 13 safety parameters.

The four safety goals of Fire Control (S1), Egress (S2), Refuge (S3), General Fire Safety (S4) are modeled in a similar way using the special weighting factors from Worksheet 5.5.4: Individual Safety Evaluations of the *Life Safety Code*. In this case there are four equations, one for each safety goal. The left-hand side of each equation is the sum of the products for all safety level variables over all 13 safety parameters of the points for each level times the corresponding weighting factors (0, 1, or 0.5) in Worksheet 5.5.4. Each of these linear expressions is set equal to the required number of points for each safety goal found in Worksheet 5.5.5: Mandatory Safety Requirements.

The objective function to be minimized is the cost function defined by summing the products of all safety level variables times their construction costs across all 13 safety

parameters. In this way, only the costs of those safety variables included in the solution (i.e., with values equal to one rather than zero) would be included in the total cost computation.

## 7.2 Modeling the Interdependencies

The nine footnotes found at the bottom of Worksheet 5.5.3 presented a special challenge in the modeling of the *Life Safety Code* for prisons. These footnotes indicate circumstances that trigger alternative point values for many of the levels as shown in the parenthetical values in the body of the Worksheet. The conditions can be classified into two types, predetermined and interdependent, depending on whether or not the truth value of the condition can be changed within the model by changes in the values of the safety level variables. Predetermined conditions are those which it is assumed the building manager cannot alter when trying to improve the point score of any safety parameter. Examples of predetermined conditions are the number of floors, construction type, whether the building is new or existing construction, and if the cells are facing an access corridor. Interdependent conditions are those that are affected by the safety level of other parameters. For instance, any safety level whose points depend on the value of Parameter 5 is considered to be affected by an interdependent condition.

Each footnote lists one or more conditions that are used to determine the alternative parenthetical point value that should be awarded for that safety level. To evaluate an interdependency, an equation or series of equations is created using the primary safety level variable and a special parenthetical variable. Each equation is entered as an additional row in the large linear matrix. These additional equations determine the truth value of the conditions and activate the appropriate (either the primary or the alternative parenthetical) point value for the safety level. The point values of each of the primary and parenthetical variables are included in safety goal equations at the bottom of the matrix.

## 7.3 The Zero-One Integer Programming Method

Once the zero-one integer programming model for the *Life Safety Code* and its many footnotes was constructed, software code to efficiently solve the set of equations was sought. Public domain computer code written in the C programming language, called *lp\_solve*, was identified and evaluated for robustness and efficiency in solving zero-one problems. The original versions of the code up through version 1.5 were written by Michel Berkelaar of the Eindhoven University of Technology in the Netherlands. Revisions of the code up to the current version (2.3) used in **ALARM** were developed by Jeroen Dirks. The code has been successfully tested on many different models including very large ones involving 30,000 variables and 50,000 constraints. The code addresses zero-one integer problems using a version of the Branch and Bound algorithm widely cited in the operations research literature.

Before incorporating the *lp\_solve* code into the **ALARM** software, we tested it on over 200 projects involving the *Life Safety Code* for health care facilities that had already been solved using the previous version of **ALARM**. The previous solutions were based on a two-stage process involving the Revised Simplex Method to solve the non-integer

version of the problem and then applying heuristic techniques to estimate the true integer solutions. The solutions obtained using *lp\_solve* were either as low or lower in cost than the solutions previously found. Once the accuracy and efficiency of *lp\_solve* were confirmed by these tests, we adapted the code and compiled it as a Dynamic Link Library (DLL) file which is called directly from ***ALARM 2.0***. The DLL function receives as a parameter the large integer matrix of the model that is built from the data entered in the Project Window. The function returns an array of the (non-zero) safety level variables that are included in the least-cost solution. The solution array that defines the least-cost compliance plan is then shown in the Project Window by coding the improved safety levels in the aqua color.



## 8.0 Safety Improvements and Cost Data

While the safety levels of the FSES are defined as a part of the NFPA 101A for detention and correctional occupancies, the construction methods used to improve from one level to another are not explained in the NFPA code. A major feature of *ALARM* is the detailed description of the tasks and costs associated with making improvements in safety levels. To find accurate safety improvements, Hughes Associates Inc, a fire and safety engineering firm in Baltimore, MD, was contracted to assist in developing a complete list of safety improvements and to collect cost data needed for the improvements.

### 8.1 Safety Improvements

A comprehensive list and detailed specifications for all fire safety improvements that apply to each of the thirteen fire safety parameters included in NFPA 101A was compiled. The analysis was performed for each parameter to determine the various methods available for upgrading from an existing condition to each condition having a higher score. Where more than one method was available, each method was listed.

Unit terms (i.e., Cost Drivers) such as linear feet, square feet, or quantity were determined for and assigned to each element of the tasks associated with a candidate upgrade. Typical elements included doors and frames, smoke detectors, sprinklers, and interior finish. In cases where an upgrade required two or more separate elements, the term for each of these items was identified separately but marked as being linked to the specific upgrade. For example, in Parameter 13 the provision of a “Heat and Smoke Vent System” required both the actual smoke removal system and an automatic smoke detection system to initiate smoke control.

### 8.2 Cost Data

Most materials and labor cost data for safety improvements were collected by Hughes Associates from R.S. Means, *Means Facility Cost Data, 1999*, R. S. Means Company: Kingston, MA, a nationally recognized source of data for construction cost estimation. Minor refinements were made in some of the estimates based on feedback from inquiries to several organizations familiar with detention and correctional facility construction costs. This information was obtained by contacting several government as well as private correctional organizations, including the following: National Institute of Corrections, American Correctional Association, National Sheriffs’ Association, and Maryland Department of Corrections, Capital Construction Division.

For some safety improvement tasks the baseline data available from R. S. Means did not provide adequate detail. For such special cases as retrofitting a fire alarm system, automatic sprinklers or a smoke removal system, manufacturers and installers were contacted directly to obtain supplemental cost estimates.

The data were based on construction costs for the Washington DC/ Maryland suburban area. *ALARM* automatically adjusts all cost data to the locality of the facility. When the

zip code is entered at the creation of a new project, all costs are adapted for the geographic location of the facility. Some improvements require cost estimates that are very region specific, such as the creation of a water supply. In these rare cases the user is asked to obtain a specific cost estimate.

### 8.3 Cost Algorithms

The cost algorithm used to estimate the costs associated with a specific safety improvement are based on the unit cost of each driver and the element quantity needed. The basic form of the algorithm took the following form:

Total Upgrade Cost =  $\sum$  Unit Cost of Driver\* Element Quantity, summed over all tasks required to achieve the safety upgrade.

Unit Cost of Driver = The labor and materials costs for each dimensional unit or count of the element or task involved in the upgrade.

Element Quantity = The quantity of each element (number of dimensional units or count) required to be installed to achieve the design upgrade and qualify under NFPA 101A for the upgraded state and score being sought.

The total upgrade cost is the summation of the costs of all of the elements associated with a particular upgrade.

Some safety improvements, such as sprinkler or smoke detection installation, required more complex algorithms. These cases can be seen in *ALARM* where special calculators are necessary to determine the number of units of each cost driver needed. These algorithms were also designed by Hughes Associates.

## References

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Gass, Saul I., *Linear Programming: Methods and Applications*, 4<sup>th</sup> edition, McGraw-Hill Book Company: New York, 1975.

Hillier, Frederick S. and Lieberman, Gerald J., *Introduction to Operations Research*, 3<sup>rd</sup> edition, Holden-Day, Inc.: San Francisco, 1980.

National Fire Protection Association, "Fire Safety Evaluation System for Detention and Correctional Facilities," Chapter 5 of NFPA 101A, *Guide on Alternative Approaches to Life Safety*, 2001 edition, Quincy, MA, 2001.

National Fire Protection Association, *NFPA 101, Life Safety Code*, 2000 edition, Quincy, MA, 2000.

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R. S. Means, *Facilities Cost Data*, 1999, R. S. Means Company: Kingston, MA, 1999.

Weber, Stephen F. and Lippiatt, Barbara C., "Cost-Effective Compliance with Life Safety Codes," *Fire Technology* Vol. 32, Number 4 (Nov/Dec 1996).

Weber, Stephen F. and Lippiatt, Barbara C., *ALARM 1.0: Decision Support Software for Cost-Effective Compliance with Fire Safety Codes*, National Institute of Standards and Technology, NISTIR 5554, Gaithersburg MD 20899, December 1994.





## Appendix A

# Least-Cost Construction Plan for Life Safety Compliance

**Facility: State Penn**

**Location: Silver Spring, MD**

**Date of Analysis: 10/23/2001**

**Total Cost of Plan: \$ 72365**

This report identifies the least-cost plan to achieve compliance with the Life Safety Code for prisons published by the National Fire Protection Association(NFPA). The information is based on the NFPA 101A, Guide on Alternative Approaches to Life Safety, 2001 edition. All costs are derived from the US Average costs found in R.S. Means by multiplying locality cost factors for labor and materials.

The report is divided into five sections:

1. Facility Specifications: Details of the facility that are critical in helping determine the least-cost plan for Life Safety compliance.
2. Safety Level and Evaluations: Life safety levels and safety evaluation points for each safety parameter and safety goal, for both the initial condition of the facility and the proposed least-cost plan for achieving compliance.
3. Construction Plan: Summary of actions to be implemented to achieve Life Safety compliance with safety points gained and the cost of implementation.
4. Comparison with Prescriptive Compliance: Comparison of the least-cost safety levels found by ALARM to achieve full Life Safety Code compliance using the FSES in NFPA 101A with those that would be required by the prescriptive version of the Life Safety Code in NFPA 101.
5. Action Details: Details of each action to be implemented by individual task, with task cost driver, unit cost, number of units, extended costs of task, and total cost of action.

## 1. Facility Specifications

Number of Floors	3
Locality Labor Cost Factor (100 = US Average)	80.1
Locality Materials Cost Factor (100 = US Average)	96.9
Use Condition	IV: Impeded Egress
Is the building new construction?	No
Is the building a high rise?	No
Has the building been renovated or modernized?	No
Do the cells face on the corridor?	No
Is the intervening space greater than 50 feet?	No
Are the cells in a multi-tiered block?	No

## 2a. Safety Levels and Individual Safety Evaluations: Initial Condition

Safety Parameter	Safety Level	Individual Safety Evaluations			
		Fire Controls(S1)	Egress(S2)	Refuge(S3)	General(S4)
1. Construction	III(211)	0.0	0.0	0.0	0.0
2. Hazardous Areas	Double Deficiency	-4.0	-2.0	-4.0	-4.0
3. Fire Alarm	No Manual Alarm	0.5	1.0	0.0	1.0
4. Smoke Detection	Full Coverage	2.0	4.0	0.0	4.0
5. Automatic Sprinklers	None	0.0	0.0	0.0	0.0
6. Interior Finish (Corrs&Egress)	Class B	0.0	-1.0	0.0	-1.0
7. Interior Finish (Other Areas)	Class C	-1.0	0.0	0.0	-2.0
8. Cell/Sleeping Room Enclosure	Open	0.0	0.0	-3.0	-3.0
9. Separation of Residential Areas	Smoke Resistant<1 hour	2.0	1.0	2.0	2.0
10. Exit System	No Deficiencies	0.0	0.0	0.0	0.0
11. Exit Access	<=200 ft >150 ft	0.0	-2.0	0.0	-2.0
12. Vertical Openings	Smoke Resistant	0.0	0.0	0.0	0.0
13. Smoke Control	Passive	0.0	2.0	2.0	2.0
<b>Total Points Earned:</b>		<b>-0.5</b>	<b>3.0</b>	<b>-3.0</b>	<b>-3.0</b>
<b>Minimum Points Required</b>		<b>7.0</b>	<b>10.0</b>	<b>8.0</b>	<b>11.0</b>
<b>Deficit(-)/Surplus(+)</b>		<b>-7.5</b>	<b>-7.0</b>	<b>-11.0</b>	<b>-14.0</b>

## 2b. Safety Levels and Individual Safety Evaluations: Proposed Least-Cost Solution

Safety Parameter	Safety Level	Individual Safety Evaluations			
		Fire Controls(S1)	Egress(S2)	Refuge(S3)	General(S4)
1. Construction	III(211)	0.0	0.0	0.0	0.0
2. Hazardous Areas	Single Deficiency	0.0	0.0	0.0	0.0
3. Fire Alarm	Manual Alarm	1.0	2.0	0.0	2.0
4. Smoke Detection	Full Coverage	2.0	4.0	0.0	4.0
5. Automatic Sprinklers	None	0.0	0.0	0.0	0.0
6. Interior Finish (Corrs&Egress)	Class B	0.0	-1.0	0.0	-1.0
7. Interior Finish (Other Areas)	Class C	-1.0	0.0	0.0	-2.0
8. Cell/Sleeping Room Enclosure	Smoke Resistant <1 hour	0.0	0.0	0.0	0.0
9. Separation of Residential Areas	Smoke Resistant<1 hour	4.0	2.0	4.0	4.0
10. Exit System	No Deficiencies	0.0	0.0	0.0	0.0
11. Exit Access	<=200 ft >150 ft	0.0	0.0	0.0	0.0
12. Vertical Openings	Fire Resistant	1.0	2.0	2.0	2.0
13. Smoke Control	Passive	0.0	2.0	2.0	2.0
<b>Total Points Earned:</b>		<b>7.0</b>	<b>11.0</b>	<b>8.0</b>	<b>11.0</b>
<b>Minimum Points Required</b>		<b>7.0</b>	<b>10.0</b>	<b>8.0</b>	<b>11.0</b>
<b>Surplus</b>		<b>0.0</b>	<b>1.0</b>	<b>0.0</b>	<b>0.0</b>

### 3. Construction Plan: How to Achieve Least-Cost Compliance

Safety Parameter	Points Gained	Cost	Action to be implemented
1. Construction	No Change	\$ 0	No Improvement Needed
2. Hazardous Areas	4	\$ 7772	Provide fire resistive enclosure protection for all nonsprinklered hazardous areas
3. Fire Alarm	1	\$ 3698	Install fire alarm activation stations
4. Smoke Detection	No Change	\$ 0	No Improvement Needed
5. Automatic Sprinklers	No Change	\$ 0	No Improvement Needed
6. Interior Finish (Corrs&Egress)	No Change	\$ 0	No Improvement Needed
7. Interior Finish (Other Areas)	No Change	\$ 0	No Improvement Needed
8. Cell/Sleeping Room Enclosure	3	\$ 18108	Replace open separation with new smoke resistant walls and doors as needed
9. Separation of Residential Areas	2	\$ 16645	Upgrade separation walls and doors to 1-hr fire resistant ratings
10. Exit System	No Change	\$ 0	No Improvement Needed
11. Exit Access	2	\$ 0	No Improvement Needed: Alternative Point Value Earned
12. Vertical Openings	2	\$ 26142	Enclose all vertical openings with fire resistive enclosures
13. Smoke Control	No Change	\$ 0	No Improvement Needed
<b>Safety Points Gained: 14</b> <b>Total Cost: 72365</b>			

#### 4. Comparison with Prescriptive Compliance

The NFPA offers two versions of the Life Safety Code. The prescriptive version (NFPA 101) specifies in great detail exactly what must be done to achieve compliance. It offers only one solution, with no flexibility or substitutions permitted. The alternative version (NFPA 101A), on which the ALARM software is based, does not have fixed requirements. Rather, it allows facility managers to use any combination of safety levels for the 13 fire safety parameters, as long as the required point scores are earned for all four safety goals: fire control, egress, refuge, and general safety. This system of trade-offs among the safety parameters is called the Fire Safety Evaluation System (FSES) and provides facility managers with many alternative compliance solutions that are equivalent in life safety to prescriptive code compliance with NFPA 101. The flexibility provided by the FSES of the Alternative Approaches to Life Safety (NFPA 101A) allows for major cost savings in achieving compliance with the Life Safety Code. The table below compares the increases in safety levels that your facility would need for compliance with the prescriptive code with those it would need under the plan found by ALARM using the FSES.

Safety Parameter	Safety Levels		
	Initial	Least-Cost Plan	Prescriptive Requirement
1. Construction	III(211)	No Increase Needed	No Increase Needed
2. Hazardous Areas	Double Deficiency	Single Deficiency	No Deficiencies
3. Fire Alarm	No Manual Alarm	Manual Alarm	Manual Alarm
4. Smoke Detection	Full Coverage	No Increase Needed	No Increase Needed
5. Automatic Sprinklers	None	No Increase Needed	No Increase Needed
6. Interior Finish (Corrs&Egress)	Class B	No Increase Needed	No Increase Needed
7. Interior Finish (Other Areas)	Class C	No Increase Needed	No Increase Needed
8. Cell/Sleeping Room Enclosure	Open	Smoke Resistant <1 hour	Smoke Resistant <1 hour
9. Separation of Residential Areas	Smoke Resistant<1 hour	>1 Hour Fire Resistance	No Increase Needed
10. Exit System	No Deficiencies	No Increase Needed	No Increase Needed
11. Exit Access	<=200 ft >150 ft	No Increase Needed	No Increase Needed
12. Vertical Openings	Smoke Resistant	Fire Resistant	Fire Resistant
13. Smoke Control	Passive	No Increase Needed	No Increase Needed

**5. Action Details : Breakdown of costs by task**

Safety Parameter 2: Hazardous Areas

Provide fire resistive enclosure protection for all nonsprinklered hazardous areas in the building.

Tasks	Cost Driver	Unit Cost	Units	Total Cost
Enclose the walls and ceilings of all hazardous areas in fire resistive enclosures. 1-hr enclosure except for 2-hr enclosures for separation of areas not incidental to residential housing and new boiler or fuel fired heating rooms.	Area of wall and ceiling that is less than 1 hour fire resistant.	3.21	1800	5784.75
Install fire doors hazardous areas in fire resistive enclosures. 1-hr enclosure except for 2-hr enclosures for separation of areas not incidental to residential housing and new boiler or fuel fired heating rooms.	Each opening into or out of the hazardous area.	993.54	2	1987.08
<b>Total Cost:</b>				<b>7771.83</b>

**5. Action Details : Breakdown of costs by task**

Safety Parameter 3: Fire Alarm

Install fire alarm activation stations(fire alarm boxes).

Tasks	Cost Driver	Unit Cost	Units	Total Cost
Install fire alarm activation stations(fire alarm boxes).	Fire Alarm Box Stations(use calculator)	205.43	18	3697.65
<b>Total Cost:</b>				<b>3697.65</b>

**5. Action Details : Breakdown of costs by task**

Safety Parameter 8: Cell/Sleeping Room Enclosure

Replace open separation with new smoke resistant walls and doors as needed.

Tasks	Cost Driver	Unit Cost	Units	Total Cost
Replace all portions of cell faces that are not 1-hour fire resistance with slab to slab faces having at least 1-hour fire resistance ratings.	Area of separation wall that is less than 1 hour fire resistant.	3.21	5000	16068.75
Replace all cell door that have less than 1-hour fire resistance with doors having 20 min. or greater fire resistance.	Number of exits in separation wall.	339.80	6	2038.77
			Total Cost: 18107.52	

**5. Action Details : Breakdown of costs by task**

Safety Parameter 9: Separation of Residential Areas

Upgrade separation walls and doors to produce 1-hr fire resistant ratings and raise fire resistance of entire building to 1-hr fire resistance.

Tasks	Cost Driver	Unit Cost	Units	Total Cost
Replace all portions of cell faces that are not 1-hour fire resistance with slab to slab faces having at least 1-hour fire resistance ratings.	Area of separation wall that is less than 1 hour fire resistant.	3.21	4545	14606.49
Replace all cell door that have less than 1-hour fire resistance with doors having 20 min. or greater fire resistance.	Number of exits in separation wall.	339.80	6	2038.77
			Total Cost: 16645.26	

## 5. Action Details : Breakdown of costs by task

### Safety Parameter 12: Vertical Openings

Enclose all vertical openings with fire resistive enclosures.

Tasks	Cost Driver	Unit Cost	Units	Total Cost
2-hr protection for openings (shafts, etc.) connecting 4 or more floors in new construction.	Area of partition necessary to enclose vertical opening.	3.21	60	192.83
Install fire doors 2-hr protection for openings (shafts, etc.) connecting 4 or more floors in new construction.	Number of unprotected openings in shafts.	993.54	9	8941.86
1-hr protection for openings (shafts, etc.) connecting 3 or less floors in new construction.	Area of partition necessary to enclose vertical opening.	3.21	60	192.83
Install fire doors 1-hr protection for openings (shafts, etc.) connecting 3 or less floors in new construction.	Number of unprotected openings in shafts.	853.37	9	7680.29
1/2-hr protection for openings (shafts, etc.) in existing construction.	Area of partition necessary to enclose vertical opening.	3.21	60	192.83
Install fire doors 1/2-hr protection for openings (shafts, etc.) in existing construction.	Number of unprotected openings in shafts.	993.54	9	8941.86
				Total Cost: 26142.48