FRAMEWORK OF A FACILITY MANAGEMENT CODE BASED DECISION MODEL TO EVALUATE AND PREDICT PLACEMENT OF FIRE ALARM AUDIBLE AND VISUAL NOTIFICATION DEVICES

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FRAMEWORK OF A FACILITY MANAGEMENT CODE BASED DECISION MODEL TO EVALUATE AND PREDICT PLACEMENT OF FIRE ALARM AUDIBLE AND VISUAL NOTIFICATION DEVICES

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DEDICATION

This thesis is dedicated to my loving and supportive husband Gregory Armwood who labored and endured as much as I, to make this study a success. You are my source of confidence, strength , and comfort. I am honored to be your wife. I also dedicate this report to my son Gregory Armwood Jr. for reminding me of the importance of preparing for the future . I want to thank my dad Reverend Dr. John Edward Whitmyer for a life time of love and encouragement. I am grateful to my step mother Mrs. Hattie Jennings-Whitmyer for taking care me and my family while I worked on this project. Finally, I dedicate this work to my Aunt and Pastor Apostle Ann Savannah for your spiritual guidance, love, and support.

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LIST OF FORMULAS

Equation 1: $ST = S + 20\ LOG_{10}(10) + 11$

Equation 2: $AI = 20\ Log_{10} \sqrt{[L^2 + (0.5W)^2]} + 11$

Equation 3: $AT = AW + AR + AI$

Equation 4: $R = 10^{[AT - AR - 11)/20]}$

Equation 5: $R = 10^{(AT - AW) - AR - 11)/20}$

Equation 6: $D = (L \times W)/\Pi R^2$

Equation 7: $D = [(L-130)/100] + 2$

ST - Sound level at the device (dB)
S - Rated sound level of audible device at 10 ft (dBA)
AI - Sound lost at a specified distance from the device (dB)
AW - Sound attenuation through a wall (dB)
AR - Required sound level (dB)
AT - Total sound level needed (dB)
L - Length (ft)
W - Width (ft)
R - Distance from an audible device (ft)
D - Quantity of devices

GLOSSARY

Analytical Areas – The largest square or rectangular that can be drawn around a space to divide it into areas that can be analyzed under the decision model.

Combination Audible/Visual Devices – A single device that produces two distinct signals; one which can be seen and the other can be heard.

Corridor – A passageway used exclusively as a path for egress usually with rooms opening onto it.

Design Areas – subdivisions of the Analytical Areas as prescribed in the output data of the Decision Model, to use in the proper allocation of visual notification devices.

Fire Protection Engineer – engineers who study the physics and chemistry of fire and apply engineering principals to protect people and their environment from its' detrimental effects

Floor-to-Ceiling Walls: walls that extend from the floor to a reflected ceiling or continuing up to the floor slab of the next level or the roof.

Notification device – Devices that produce a visual and/or audible signal when activated to warn building occupants of an emergency

Open plan offices – offices divided by movable partitions that do not extend to the height of the reflected ceiling.

Room – an area enclosed by at least four adjacent floor-to-ceiling walls that is not used as a corridor or passageway.

Visual Device – a Device that produces a signal from a strobe light, that can be detected by the human eye.

SUMMARY

This thesis proposes to provide the framework for a code based decision model that facility manager's can use to make preliminary determinations about the quantity and placement of fire alarm system audible and visual notification devices needed for a particular space. The hypothesis of this research is that a decision model can be created that Facility Managers can use to estimate the fire alarm system notification devices needs for code compliance. The theory proposes that appropriate conclusions can be drawn given basic input data about notification devices, environmental space characteristics, and dimensional space measurements. The report cites one path of evaluative steps that can be followed to determine if the layout of fire alarm notification devices meet code. This process is mapped in a flow chart with detailed explanations for each step. The thesis report concludes that it is possible to create a code based decision model that facility managers can use to predict and evaluate the quantity and location of audible and visual fire alarm notification devices. The hypothesis is validated through application to two representative spaces for which code based conclusions are derived.

CHAPTER 1

INTRODUCTION

Facility Management is the practice of coordinating the physical work place with the people and work of an organization (1). Facility Managers are challenged with maintaining a safe and code compliant building as they continuously alter the physical work place to meet the goals and objectives of a dynamic work force. In accordance with the Facility Management Practices Research Report by the International Facility Management Association (IFMA), turnover, restructuring, and reorganization are catalysts for an average churn rate of 35% (2). This creates a work environment subject to perpetual change, including that of the physical space and configuration.

This thesis addresses the problem of fire alarm system notification deficiencies that are created when office space undergoes minor space alterations in which walls or tall partitions are built, modified, or relocated. This thesis research proposes to establish the framework of a facility management code based decision model to evaluate and predict placement of fire alarm audible and visual notification devices. The purpose of this research is to assist facility managers, who may not be well versed in the application of fire codes and standards, a resource for planning and estimating work associated with fire alarm notification devices for minor space alteration projects and correction of deficiencies in existing spaces. This capability is useful to the facility manager as the building owner's representative, and responsible party for maintaining the fire alarm system in a code complaint configuration (4). The hypothesis is 1) a code based decision model can be created that facility mangers can use to estimate the quantity and spacing of fire alarm system notification devices, and 2) appropriate conclusions can be drawn given basic facility related input data.

The thesis models the thought process used by a fire protection engineer to evaluate a project or an existing area for code compliance. The thought process is diagramed on a flow chart and tailored toward the facility manager as an end user. The decision model in no way diminishes nor replaces the technical expertise that a qualified Fire Protection Engineer provides for projects and space inspections. The decision model's output presents estimates subject to the limitations of the logic and calculation methods. Output data is not intended to replace the sound judgment and expertise of fire protection professionals. The model serves as a starting place for establishing requirements.

The Facility Management Decision Model is illustrated in a flow chart format, which maps the chronological steps and mathematical calculations necessary to generate conclusions given information about the measurements of a space and performance criteria for desired devices. Validation of the decision model developed in this document is the necessary first step toward the creation of an automated, user-friendly tool. The model provides the logic, equations, calculations, and output information that establish the foundation for programming.

CHAPTER 2

LITERATURE REVIEW

2.1 Background

Facility managers are exposed to safety, legal, and budgetary risk when the performance of fire alarm audible and visual signals are deficient. The construction or modification of walls and tall partitions can create barriers that absorb sound and render alarms inaudible or block the visibility of strobe lights. This problem can be isolated to a small area or multiple small projects and can have a collective effect.

Fire alarm notification is an inherent component of facility management planning for fire safety (3). The audible and visual alarms generated by horns, bells, speakers and strobe lights, provide the stimuli needed to start planned emergency procedures. Deficiencies adversely impact protection of occupants from fire by delaying or stifling the alert needed to initiate emergency action (4). Emergency notification deficiencies not only have safety implications, they can effect the facility management budget since they are often discovered long after the small projects are completed. For example, on January 21, 2004, a Computer Network Administrator was on the 24th floor of a government building in Atlanta Georgia, when a colleague phoned her from a computer room on a lower floor of the same building. The fire alarm system in the building had activated. The emergency message on the 24th floor indicated the area was not in danger and instructed occupants to remain at their location. The associate on the lower floor questioned the source of the background noise that could be heard through the phone. The alarms were inaudible in the computer room and the associate did not know that an alarm condition existed in the building. The computer room was constructed under a minor space renovation project 7 months prior to the incident (5).

Facility department budgets for alteration projects are usually separate from the funds allocated toward maintenance and repairs (1). Tenants sometimes provide the funding for small projects. The fire alarm notification problem should be addressed and funded with the alteration project. Problems discovered after the project is completed will have to be corrected with funds from another source.

Fire alarm notification deficiencies are a legal liability for facility managers because it is a code-required feature. Fire alarm notification requirements are adopted into the laws of federal, state, county, and local municipalities through reference within the text of building code requirements. Building codes cite the National Fire Alarm Code, produced by the National Fire Protection Association (NFPA), as the criteria that must be met to comply with fire alarm system requirements. A detailed discussion of National Building Codes and National Fire Codes is presented in the literature review section of this report.

Why are minor space alteration projects vulnerable to generating fire alarm notification deficiencies? The answer includes a variety of reasons beginning with the size of the project. Minor space alterations can easily fall through the cracks because they are small in scope, budget, and schedule. They do not involve the same level of planning and design required of larger projects with multiple and complex work items. Minor space alterations can be ordered by a scope of work without specifications or design drawings.

Full design and review services are usually not allocated for minor space alterations due to the limited scope and funding associated with these small projects. The absence of a design team, which includes the expertise of a fire protection engineer, can cause fire alarm notification to go unchecked during project development, construction, and closeout. Fire protection engineers (FPE), are professionals who apply engineering principals to protect people and their environment from fire. Fire protection engineers analyze fire hazards and mitigate fire damages through the use of a variety of safety measures including proper system design (6). Fire protection engineers are well-versed in fire and building code requirements. Engineers in fire protection work in design, construction, research and development, and they often serve as code compliance officials when they represent governmental agencies as Authorities Having Jurisdiction (AHJ).

The code community addresses alterations based on the specific work performed. It is clear that new work must meet code standards, and it is clear that a code compliant environment must be maintained. However, the code does not specify all the items that must be checked, outside the scope of the new work, to ensure the space changes do not negatively impact other code required building features. The scope of small projects does not routinely include fire alarm notification because the alarm devices that serve small spaces are usually installed outside the boundaries of the project area. Strobe lights are not required in individual offices, and the audible devices that serve individual offices are often located in corridor areas. The need to analyze audible notification after walls have been added is not obvious. The National Fire Alarm Code, requires analysis and tests when the notification devices on the fire alarm system are added or deleted (4). During minor space alterations devices are sometimes relocated, however, they are rarely added or deleted.

Facility managers recognize the need to address the issue of emergency notification and they use a variety of methods to identify where devices should be located. Three Facility Managers from governmental agencies identified different approaches. The first Facility Manager indicated he previously permitted the electrical contractor to lay out fire alarm devices. This practice was discontinued when deficiencies were routinely discovered. The new approach allowed fire alarm technicians to determine the placement of devices. While this provided better results, there were still deficiencies (7). The second facility manager indicated he had to guess where devices should be placed on one of his time sensitive minor space alteration projects (8). The third facility manger indicated he often had to relocate devices in association with minor space alterations. His method was to relocate alarm devices to the wall closest to the wall from which the devices were removed (9). All three facility mangers identified an interest and expressed a need for a tool that would help them make better preliminary, code based determinations about where fire alarm audible and visual devices should be provided.

2.2 Fire Alarm Notification Design Challenges

The National Fire Alarm Code requirement for the placement of fire alarm system audible and visual notification devices is not presented in a simplistic straightforward manner. Application of the code criteria requires knowledge of audible device performance the how that performance is impacted by environmental conditions. The status of existing audible fire alarm system devices is easy to measure through testing, however, the placement of devices to achieve required performance standards is not easy to determine during design. The quantity and placement of audible devices needed to fix existing deficiencies is also not a straightforward analogy. Audible devices can always be added to increase volume, but this approach does not facilitate optimum placement, minimum cost, or consideration for limiting the demands on the electrical resources of the fire alarm system. Audible fire alarm notification devices are pictured in Figure 1. The audible signals produced by horns, bells, and speakers have different sound characteristics, but they are all required to deliver the sound at a minimum level of loudness.

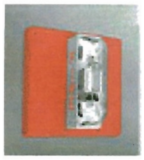
Horn Bell Speaker

(Source: Google Images)

Figure 1: Audible Fire Alarm Notification Devices

Code criteria for visual devices are just as challenging to decipher. It requires knowledge of how to read and apply tabulated data and cross-referenced code sections. Visual devices, in the form of strobe lights, are required for emergency notification for the hearing impaired. Strobe lights can be mounted on the wall or at the ceiling. The code criteria for placement of strobe lights are dependent upon the mounting orientation of the device. Wall and ceiling mounted strobe lights are pictured in Figure 2.

Ceiling Mounted Strobe



Wall Mounted Strobe

(Source: Author Photograph 2003)

Figure 2: Wall and Ceiling Mounted Strobe Lights

The design criteria for strobe lights require familiarity with a collection of cross referenced charts and strategic space delineations to determine what is needed for a particular space. Combination devices provide audible and visual signals. The design approach for these devices is to first meet visual notification requirements. Then audible performance is evaluated to determine if additional audible devices are needed. Combination devices are pictured in Figure 3.

Speaker/Strobe Device

Horn/Strobe Device

(Source: Google Images)

Figure 3: Combination Audible and Visual Devices

Facility managers must ensure consideration for the impact small projects may have on notification is properly addressed and budgeted in each alteration project. Facility mangers must also be prepared to quickly respond to reports of fire alarm notification deficiencies.

Facility Managers need a user-friendly tool that they can use to evaluate building spaces for the proper placement and performance of fire alarm system audible and visual notification. This is necessary for life safety, budget stability, and code compliance.

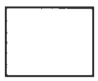
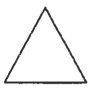
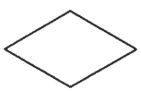
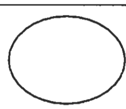
2.3 Flow Charts and Models

This was an applied research project, employing a quantitative approach to test the hypothesis that a code based decision model can be created to predict and evaluate the adequacy of fire alarm system notification devices. To achieve this objective, the researcher has chosen to simulate the thought process that a Fire Protection Engineer would use to draw conclusions about the need and adequacy of emergency notification signals. This process is a dynamic reality because it contains independent and interactive components acting together (10).

Deterministic models are used in the fire protection industry to evaluate fire dynamic processes and to solve fundamental equations of mass momentum and energy (11). The deterministic model is the appropriate choice for this thesis study. It is appropriate for modeling the dynamic reality of the fire protection engineer's thought process. The deterministic model is useful for this study of code based decisions that change slowly. Further, it is valid for the researcher's assumption, that the conclusions drawn by the fire protection engineer in the past will happen in the future without any random affect. The researcher uses mathematical modeling where precise and unambiguous results are needed, within the framework of the deterministic model for the thought process of the fire protection engineer (10).

The decisions and evaluations performed as a Fire Protection Engineer goes through an analogy, provides the basis for the decision model. The organization and relationships of the elements of this thought process are represented a network plan called a flow diagram (10). A flow diagram is a pictorial diagram describing a process. The flow diagram uses simple and easily recognizable symbols to describe a process (12). Symbols used in the design of the flow diagram for this report are defined in Table 1.

Table 1: Definition of Flow Chart Symbols

Symbol	Definition
	The square symbol represents input data about the space, or information about notification devices.
	The triangle represents numeric constants.
	The trapezoid represents status labels.
	The parallelogram identifies calculations.
	The diamond represents a decision.
	The circle is the final determination of the code based fire alarm notification needs of the space.

The fire protection engineer thought process is augmented with considerations that are necessary to achieve an applicable, simplistic, user-friendly, model that is considerate of the facility manger as an end user. Limitations and exclusions are established in consideration of constraints on time, resources, and the capability of a decision model.

A sample minor space alteration project is used to develop the decision model and assistance with evaluations and adjustments needed to complete the framework. After completion, the model is tested with input information from an actual project and evaluation of an existing area, to validate the model and conclusions.

CHAPTER 3

MODELING PROCEDURE

3.1 Scope

The methodology in establishing requirements for emergency notification begins by defining the scope and limitations of the decision model. The model is only valid when applied within the boundaries of the defined scope. The scope is defined in the following section, which specifies limitations for code basis, occupancy classification, units of measurement, area, devices, and interior space conditions.

3.1.1 Code Basis

There are a number of building and fire code standards that address requirements for fire alarm systems. The most universally applied and referenced criteria for the allocation of fire alarm audible and visual notification devices are those cited in the codes authored by the National Fire Protection Association (NFPA). Specifically the NFPA standard number 72 entitled, The National Fire Alarm Code, is the standard in which fire alarm notification criteria are defined. Building codes and the Federal Law, Americans with Disabilities Act (ADA), require compliance with NFPA 72 notification standards as a condition for meeting their fire alarm criteria. The wide acceptance of the NFPA 72 code, for fire alarm system notification standards, maximizes the applicability and usefulness of the decision model. Chapter seven of the 2002 edition of NFPA 72 addresses fire alarm system notification devices. It is necessary to extract from this section, the specific code references that will be used in the decision model. Appendix E provides a list of the NFPA 72 code sections upon which the conclusions of the decision model are based. The sections have been edited to tailor them toward the scope and applications of the decision model (4).

3.1.2 Occupancy Classification

Codes categorize spaces into use groups known as occupancy classifications. Spaces with similar activity tend to be associated with like hazards therefore protection needs are identical and they are identified by the same occupancy type. Building Codes and Fire Codes differ slightly in their segregation of occupancy types but most recognize the core group of occupancies which include business, assembly, mercantile, education, industrial, residential, and institutional.

The decision model evaluates spaces that can be categorized as business occupancies. These are considered office spaces used for the transaction of business. Assembly occupancies are those in which 50 people or more gather for meetings or other activity (4). Assembly and other occupancy classifications that are ancillary to the business occupancy can be analyzed in the decision model. These spaces include conference rooms; break areas, and storage rooms.

3.1.3 Units of Measurement and Area limitations

Units of measure for space, sound, and illumination have to be defined for parameters used in the model as input data, output data, and variables in the calculations. English units are used for spatial measurements. Length, width, and height are identified in units of feet.

The unit of measurement for sound levels is the decibel (dB). When dB is measured, it can be evaluated in different frequency ranges, which are associated with scales. The scales are identified as A-weighted, B-weighted, and C-weighted. Audio frequencies that are detectable by the human ear are measured in frequencies associated with the A-weighted scale. The shorthand for sound level measurements filtered in the A-weighted scale is dBA. When differences between sound levels in the same scale are cited, it is not necessary to specify the weighted scale. The differences are specified in dB units (13). The sound levels provided as input data should be in units of dBA. Sound level differences and those generated in the calculations are in dB units. The output audio levels are in dBA units.

When visual notification devices are activated, they flash on-and-off at a specified rate, with a specified effective light intensity. The effective light intensity is a measure of the equivalent brightness of a flashing light to that of a steady burning light. It is the light output that the human eye would see if the flashing light were constant. Visual notification devices are identified in units of their effective light intensity. These are measured in candela (cd) units. The model uses units of candela to analyzed and specify output criteria for visual notification devices.

The larger the area of evaluation, the more variables there are that have to be considered and analyzed. The margin of error increases with the addition of variables and square footage, therefore, it is necessary to limit the square footage. The limitation must be considerate of the usefulness of the model for its intended purpose. The applicability of the model declines linearly with increased limitations on square footage.

This parameter must be carefully selected. The steps for determining this variable were iterative, requiring preliminary definitions to be established and tested. The first value was set at 10,000 square feet with primary consideration for the applicability of the model. After the equations and logic were in place, it was determine that the area had to be reduced. The final area that the model calculations and logic can tolerate in a single evaluation is a total of 5,000 square feet. The 5,000 square feet can be divided into smaller areas for the decision model analysis, however the summation of all the divisions should not include a total area greater then 5,000 square feet.

3.1.4 Notification Devices

The model considers fire alarm system notification devices that produce visual and audible signals. Strobe lights are considered for visual alarms. Beacons, flashing exit lights, textual, tactile and any other types of notification devices other then that specified are outside the scope of the decision model. Strobe lights are the only visual appliance that the model considers. The lights can be either wall mounted or ceiling mounted. The strobes must have manufacturers specified effective intensity rating specified in candela units. Audible devices include electrically powered horns, bells, and speakers. Speaker intelligibility and the clarity with which messages are delivered are beyond the scope of this report. Combination audible/visual devices are recognized in the decision model as long as they employ the audible devices cited above with a strobe light for notification. Combination devices are popular due to the cost savings associated with purchasing and installing one device that provides both audible and visual notification.

3.1.5 Interior Space Criteria

The interior characteristics of a space affect the performance of notification devices. The calculations and variables selected for the decision model are based on spaces with smooth ceilings and walls made of a single layer of maximum 5/8 inch thick gypsum wall board with metal or wooden studs. Doors are wooden with a hollow core and occupy no more then 10% of a wall area. The sound attenuation factor (AW) used in the decision model is based on this type of construction. AW equals 20 in the decision model where an audible device is located on outside of a wall boundary. This means the sound level will be reduced 20 dBA on the side of the wall opposite the audible device.

The model cannot account for all of the architectural and aesthetic features that can be designed for a space. The model assumes standard areas and features found in office facilities. Extra high ceilings (greater then 30 feet), atriums, communicating spaces and mezzanines, are outside the scope of this decision model.

Average ambient sound levels are identified in the National Fire Alarm Code for design purposes. The values are estimates and may not accurately reflect the actual conditions of a particular space. Sound level measurements should be taken especially if the ambient conditions have unusual noise sources. The estimated sound level for business and assembly occupancies is identified as 55 dBA (4).

3.1.6 Minor Space Alteration Projects

A dollar value, level of effort required, or whether planning or design effort is required often defines the project (1). Minor space alterations are defined in this study as those projects less then $100,000.00 that require minimum design, and include the addition or relocation of walls and partitions.

3.2 Assumptions

The decision model analyzes existing spaces within existing facilities. It is assumed the spaces analyzed would be part of a facility that has an existing fire alarm system that was properly designed, installed, and maintained in accordance with the NFPA 72. It is assumed that the notification devices already exist in the space or devices have already been selected for consideration.

Notification devices are usually placed in common use areas and then added to subsequent areas as needed for proper coverage. It is assumed that audible and visual notification appliances would be placed within the boundaries of any walls that might enclose corridors and open areas.

Visual devices are not required in all rooms. They are required in rooms for general and common use such as rest rooms, meeting rooms, and lobbies. It is assumed that rooms selected for visual notification analysis require devices within the room. When more than one strobe light is required and they are located in the same line of view, they must be synchronized such that they blink at the same time and at the same rate. This criteria of NFPA 72 was instead as the result of studies showing that different flashing rates could induce epileptic seizures (4).

3.3 Determination of Input Data

The input data must include information that facility managers can collect, measure, and access. The depth of data must be adequate to deliver the information needed for the calculations and logic employed by the decision model. In the interest of balancing these two issues, a space division technique was created by the researcher.

A space to be analyzed by the decision model must be separated into spaces that are enclosed on all sides with walls or partitions. These enclosures, are identified as 1)rooms, 2)corridors, and 3)open areas. Rooms are defined as enclosures with ceiling height walls or partitions greater than 5 feet in height. Corridors are defined enclosures used exclusively for egress, with a path that is distinguished by ceiling high walls. Open areas are defined as enclosures within the boundaries of walls ceiling height or greater, usually housing multiple work spaces or reception and entrance space. The total space is separated into these enclosures because each pose unique challenges in the process of establishing notification requirements.

Imaginary lines are drawn around each enclosure to form a rectangle outline. The rectangle is drawn around each enclosure separately regardless of overlap. Rectangles shall be drawn to fully incorporate irregular shaped areas. Although this produces void spaces in the rectangle where square footage does not exist, it does not have a significant impact due the evaluation approach used in the decision model. The area of the rectangle is not a significant factor.

Each of the rectangles forms what is defined as an "analytical area." Each analytical area is addressed individually by the decision model. The analytical areas should be numbered and described in terms of length, width, and ceiling height. The model will evaluate each analytical area separately and deliver solutions about notification needs for each. The technique used to outline enclosures and draw analytical areas are illustrated in Appendix B. Blue lines represent enclosures. The red dotted lines define the analytical areas. If the analytical areas are too large, the output data for visual devices may require subdivision into smaller analytical areas.

The decision model requires the facility manager to provide basic information about the desired notification devices and the environmental conditions of the space. The rated decibel level for audible devices is needed. This information can be obtained from the back of a device or manufacturer's information. Maintenance personnel can usually identify the rating of fire alarm system components. An audible device can produce different sound levels depending upon the power setting. Care should taken to make sure the rated output is accurate for a particular device or space. The manufacturer's rated sound level for an audible device is determined from laboratory test measurements taken at a predetermined distance. The distance is usually 10ft away from the device (14).

Visual devices are distinguished by the orientation in which they will be installed. The facility manger must determine if visual devices will be mounted on a wall or the ceiling. Performance is achieved in both configurations but the parameters for spacing are derived differently. In existing facilities, mounting decisions are influenced by factors such as the ease with which wires are run in the interstitial ceiling space verses the pulling wires through walls.

Ambient sound levels experienced in a space under normal operating conditions must be established so that the required output sound level can be calculated. The National Fire Alarm Code identifies ambient sound levels expected in different occupancies for use as a design basis. The sound level for business and assembly occupancies is 55 decibels (4). Determination of the required sound level for audible devices is one of the goals of the model; therefore, the accuracy of this input parameter has a significant impact on the output of the model. While design ambient sound levels are presented as default values in the model, entry of values that reflect the specific conditions measured in a space are permitted.

3.4 Overview of Modeling Procedure

The decision model considers audible, visual, and combination audible/visual devices separately and delivers unique results for each type of device and each area considered. The output data describes minimum device ratings and maximum allocation distances that should exist for appropriate performance. When used within the specified scope, this model will provide the information needed to make sound preliminary judgments about what is needed to achieve minimum standards for emergency notification. The flow chart is illustrated in Appendix B. The evaluation of notification devices is divided into five categories cited on the flow chart under steps 1, 2, 3, 4 and 5. Step 1 represents a data input and decision paths specifying the type of area to be evaluated with its' associated dimensions. The type of notification device is selected in Step 2. Audible devices are analyzed in decision path of Step 3. Combination devices are analyzed in the decision path of Step 4 which requires the visual device requirements to be met by first going through the decision path for visual devices in Step 5. Once these outputs are determined, the combination device must be run through the decision path of Step 3 to make sure the audibility criteria is met. The number of combination devices required to meet the visual criteria can not be reduced, however more audible devices may need to be added if the audibility requirements are not met. Visual requirements are analyzed under decision path in Step 5.

The equations and variables are listed and defined in the List of Formulas. A detailed explanation of each step of the modeling procedure is provided in Appendix E.

3.5 Decision Model Validation

Two representative samples were tested under the hypothesis of the thesis, which proposes that a code based decision model for the allocation of fire alarm notification devices can be created for facility mangers. A minor space alteration project and an existing space are evaluated with the decision model.

The minor space alteration project includes the construction of three offices, along an exterior wall, on the 2^{nd} floor of a high-rise office building. Audible notification is evaluated in this example. Appendix C contains a line drawing of the project area. The second project is an analysis of an existing conference room to determine requirement for strobe devices. The conclusions of the model will be compared to the approach used on the projects by the facility manger.

Minor Alteration Project Details.

- The construction requirements are specified with a scope of work, which describes the office dimensions and location.
- There is no design team and no drawings.
- The job includes carpenters, plumbers, electricians, and painters.
- Dimensions of the offices are
    - Office 1: L = 22 feet   W = 22 feet
    - Office 2: L = 22 feet   W = 15 feet
    - Office 3: L = 22 feet   W = 15 feet
    - The reflected ceiling heights in all three offices are 8 feet. Walls extend up to the reflected ceiling.
    - Wall construction is single layer of ½ inch gypsum wallboard on metal studs. Doors are wooden with a hollow core and occupy no more then 10% of a wall area.
- The offices are lined in a row with the center office sharing a wall with the end offices.

The first step is to identify input data.

-Type of device in the area are speakers.

-Speakers are set to produce 78dBA

-The spaces are defined as rooms

-The space is divided into three analytical areas. For this analysis, the areas will referenced as R1, R2, and R3. These areas are outlined in Appendix C. R1 is taken through the model first.

Step 1

The space includes rooms

L = 22ft W = 22ft H = 8ft
AW = 20
(i_o)= 1

Step 2

Select audible device decision path

Step 3

Sub-Step 3A: Elect to use default ambient sound level of 55 dBA

Sub-Step 3A2: Calculate AR = 55+15 = 70

Sub-Step 3B: Identify the decibel rating of the speaker S= 78 dBA

Sub-Step 3C: Calculate ST = 78 +20 log(10)+11 = 109

Sub-Step 3D: Space calculation $AI = 20\log_{10} \sqrt{(L^2+(1/2W)^2} + 11$

$$AI = 20\log_{10} \sqrt{(22^2 + (1/2(22))^2} +11$$

$$AI = 39$$

Sub-Step 3E: Calculate AT = AW+AR+AI = 20+70+39 = 129

Value of ST=109 to AT=129

Sub-Step 3F: No - ST is not greater then nor equal to AT

Sub-Step 3G: Compares the value of ST=109 to AT-AW=109

Yes ST equals AT-AW

The decision model output that analytical area R1 needs one speaker within the room that is no further then 25 feet from any area within the room.

The same procedure is followed for analytical areas R2 and R3 using the dimensions of the areas. Since the dimensions of the two areas are the same the model output will be applicable to both areas. Care must be taken to ensure the length and width parameters for R2 and R3 are consistent with how the values represent the rectangular analytical area. The width for these area is 15ft the length is 22ft.

Steps and values in the decision model are the same as that for R1, therefore this effort is not duplicated. The decision model is picked up at Step 3C2 where the values of the parameters differ.

Sub-Step 3D: AI = Space calculation

$$AI = 20\log_{10}\sqrt{(L^2+(1/2W)^2} + 11$$

$$AI = 20\log_{10}\sqrt{(22^2 + (1/2(15))^2} + 11$$

$$AI = 38$$

Sub-Step 3E: Calculate AT = AW+AR+AI = 20+70+38 = 128

Value of ST=109 to AT=128

Sub-Step 3F: No - ST is not greater then nor equal to AT

Sub-Step 3G: Compares the value of ST=109 to AT-AW=108

No- ST does not equal AT-AW

Sub-Step 3H: Yes - ST is greater then AT-AW

Sub-Step 3H1: Calculate $R = 10^{(ST-AR-11)}/20$

$R = 10^{(109-70-11)/20}$

$R = 10^{1.4} = 25$

The decision model output that analytical areas R2 and R3 need one speaker within the rooms that are no further then 25 feet from any area within the rooms.

The second validation uses the decision model to evaluate an existing conference room to determine the visual notification needs. The first step is to identify input data.

-Preference is for ceiling mounted strobes based on the use of similar devices in the building.

-The space is defined an existing conference room.

-The dimensions of the rectangular analytical area that encloses the space are as flows:

Step 1

The analytical space is a room with the following dimensions

L = 16ft

W = 12ft

H = 10ft

AW = 20

(i_o)= 1

Step 2: Select visual notification device

Step 5: Visual Device logic path

Sub-Step 5A: No - the space is not a corridor

Sub-Step 5B: No I do not want to use wall mounted devices

Sub-Step 5C: Ceiling mounted devices

Sub-Step 5C1: Determine that BL = L since L is greater then W BL = 16

Step 5C2: yes - BL is less then 20

yes - The ceiling height (H) is equal to 10

$D=2^0 = 1$

The decision model concludes the space needs one strobe light rated for 15 candela.

CHAPTER 4

RESULTS

The decision model provided results for each of the validation projects. The minor alteration validation project in which three offices were constructed, the decision model output that a speaker was needed in each of the three offices to get a code based audibility level, with the existing devices that were identified. In the validation evaluation of an existing space for a ceiling mounted strobe, the decision model output the space needed one strobe light rated for minimum of 15 candela.

A fire protection engineer was asked to review the validation projects for compliance with National Fire Code notification requirements to test the appropriateness of the decision model output. The fire protection engineer's conclusions agreed with the decision model. He concluded one speaker was needed in each of the offices in the sample project. He also concluded one ceiling mounted strobe was required in the existing space example (16).

The results of the code based decision model are compared to the notification criteria specified for the project. Fire alarm speaker work is not in the scope of work for the minor alteration project. The facility manager's intention is to leave existing devices in their current locations. The location of the existing devices are illustrated on the drawing in Appendix C which shows all but one of the three offices has a speaker inside the room. The facility management assumption is that the existing speakers are loud enough to be heard in the new offices. The decision model predicts a speaker is needed in each room to provide the audible levels specified in the National Fire Alarm Code.

CHAPTER 5

CONCLUSION

The results of the validation projects prove the hypothesis that a code based decision model can be created, for facility mangers to predict the allocation of fire alarm notification devices using facility related data as input. The similarity of the conclusions drawn by the fire protection engineer to the output of the decision model demonstrates that the output is appropriate. The decision model can help the facility manager by providing a means to determine if the existing devices associated with the minor alteration project are adequate or if fire alarm notification devices modifications should be planned and budgeted.

CHAPTER 6

RECOMMENDATONS

Further development and broader application of the work in this thesis project is recommended. The code based decision model provides the framework for the creation of an automated tool to predict the allocation of notification devices. An effort can be made to translate the logic paths into a user friendly software package for practical application. This research sets the groundwork for expansion of the current model to more variables and space types. This model can be extended to become applicable to larger spaces, a wider variety of construction materials, more occupancy types, and different space configurations. The methodology used in this research defines the process that can be used to create a decision model for other facility systems such as HVAC or sprinklers, and different code criteria such as Life Safety Code or the National Electric Code. Further validation of the decision model is recommended by using it to analyze multiple projects using all the combinations of the logic paths incorporated in the flow chart.

APPENDIX A

Analytical Area Figures

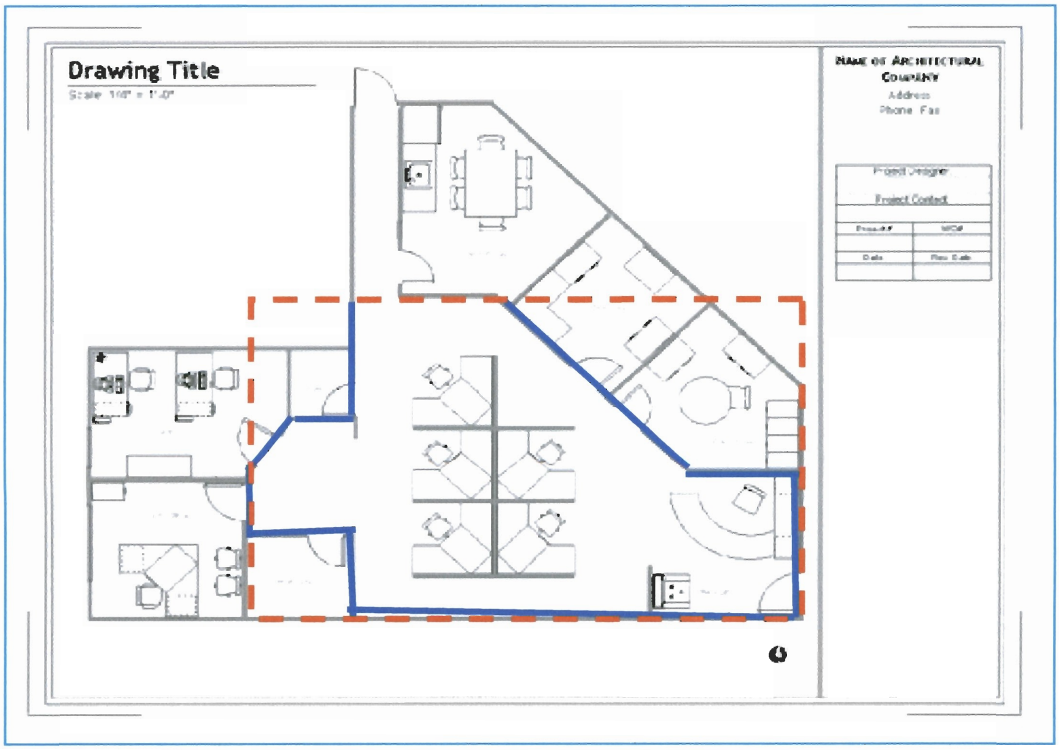


Figure 8: Analytical Area of an Open Area

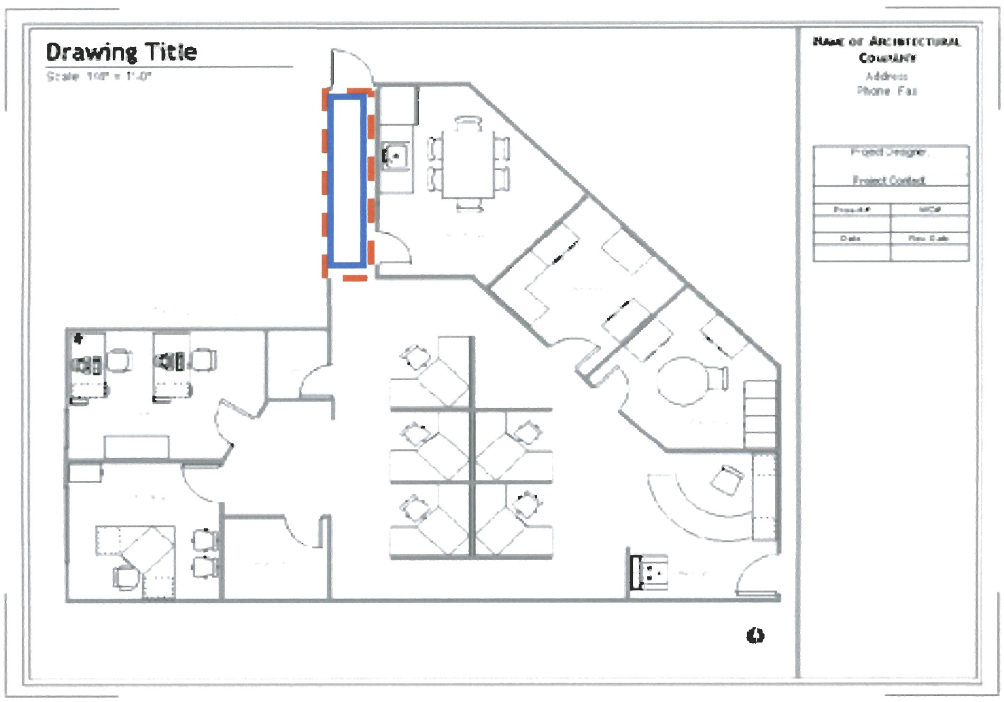


Figure 9: Analytical Area of a Corridor

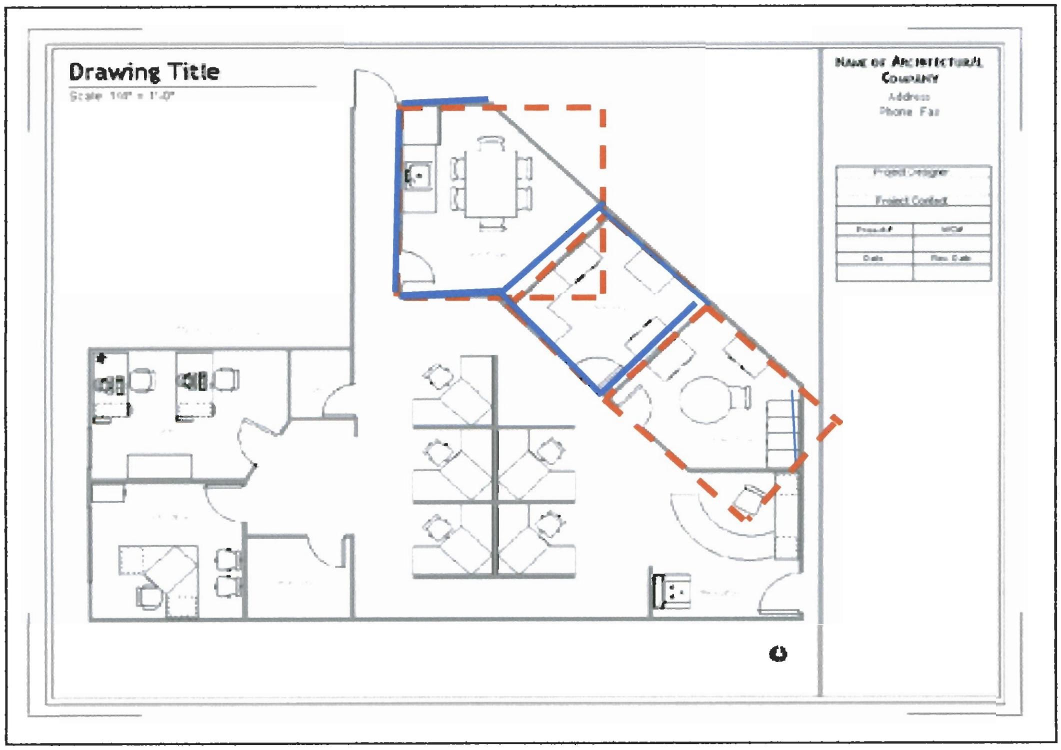
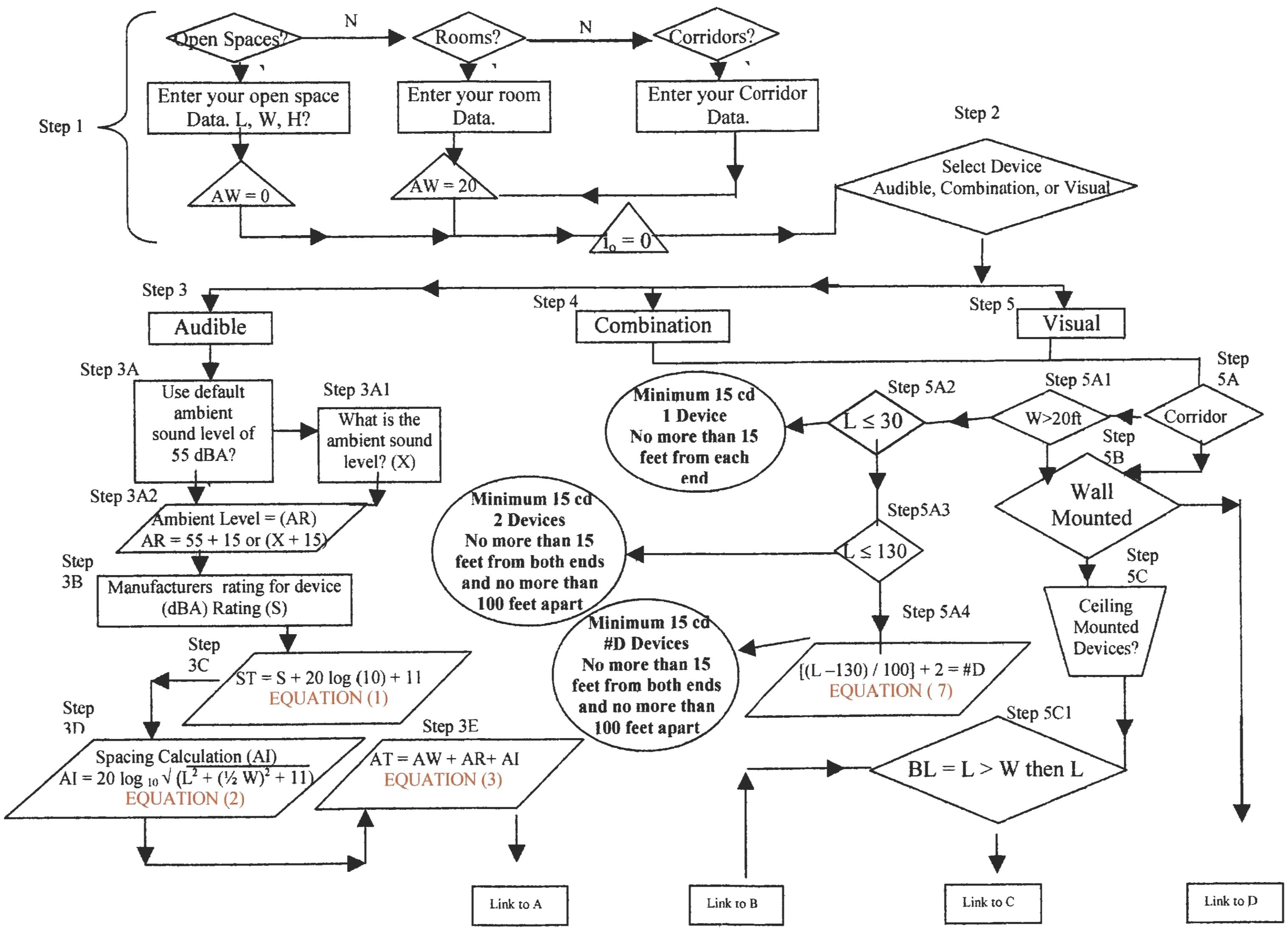


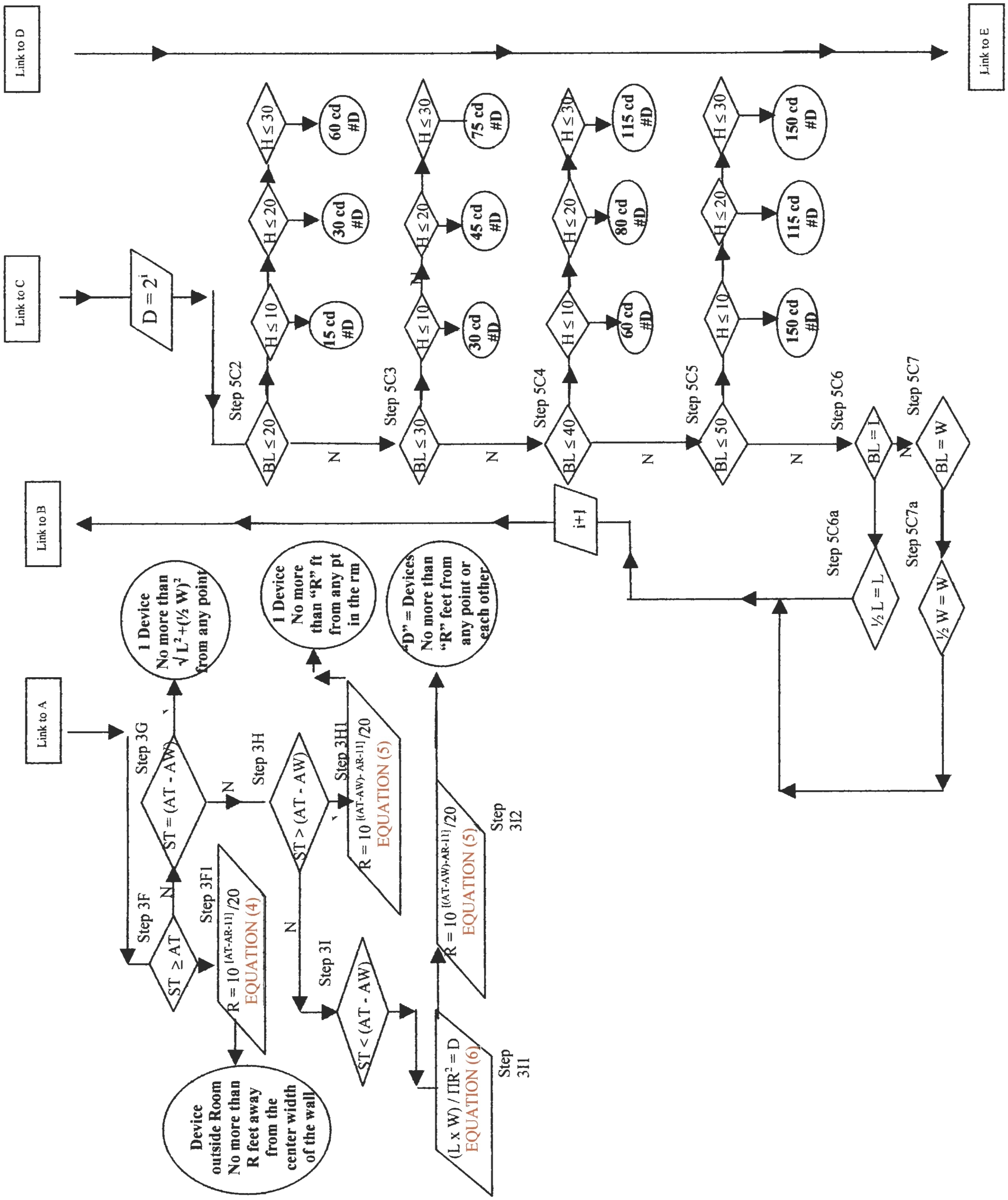
Figure 10 Analytical Area of a Room

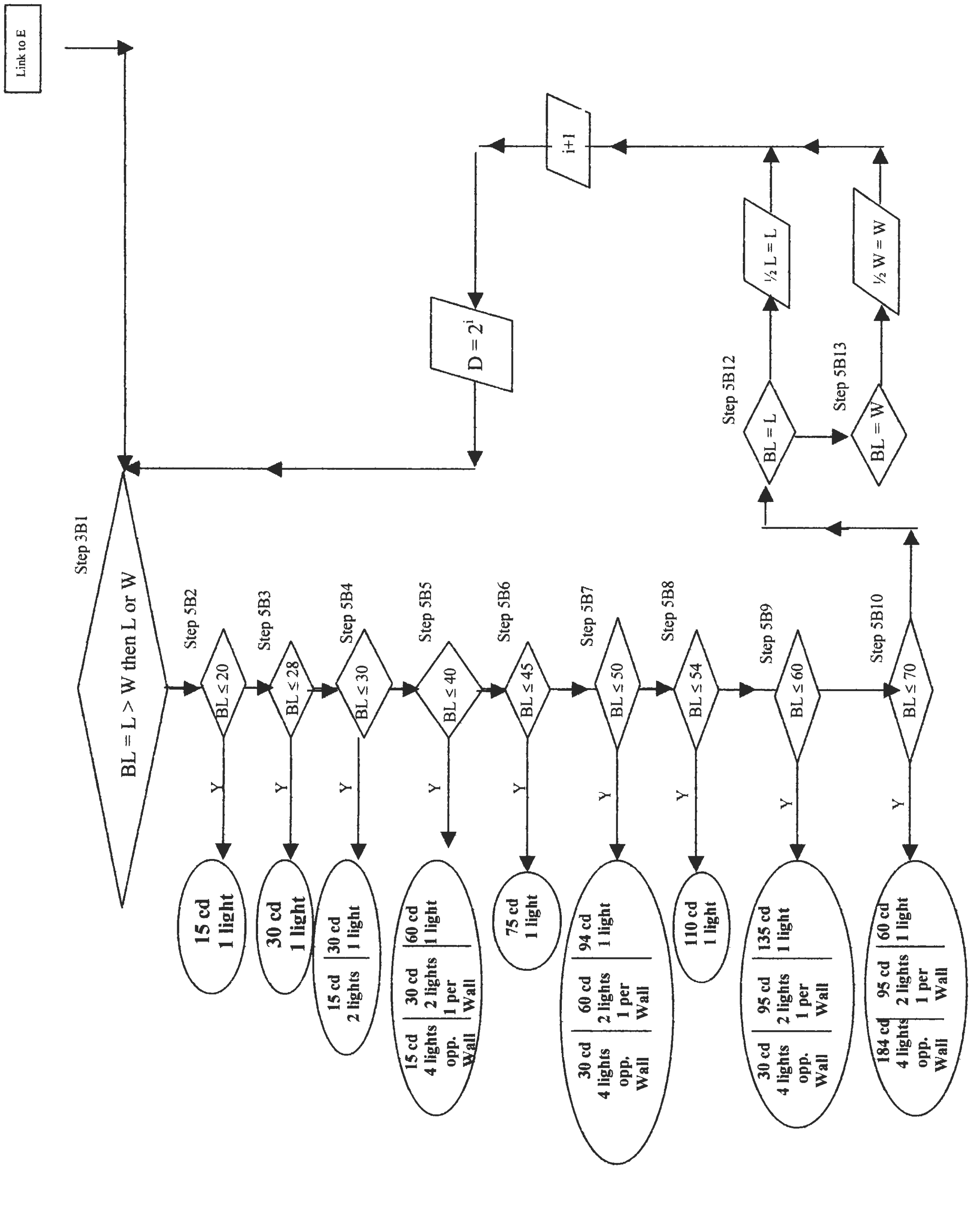
APPENDIX B

Decision Model Flow Chart

FACILITY MANAGEMENT CODE BASED DECISION MODEL FOR FIRE ALARM NOTIFICATION DEVICES

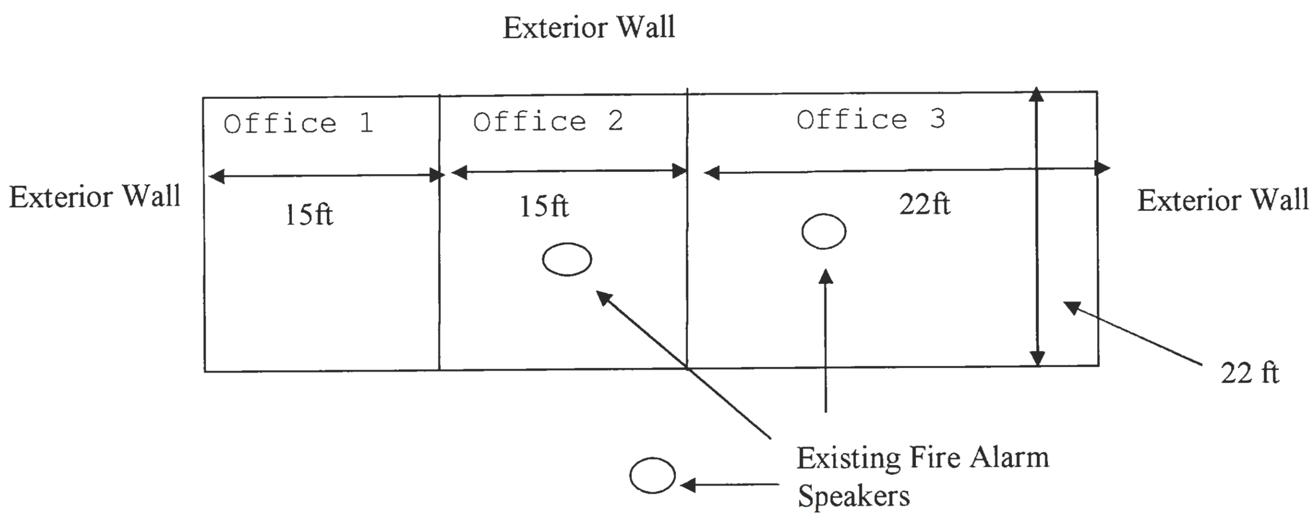



Link to A
Link to B
Link to C
Link to D
Link to E
Step 3F
ST ≥ AT
N
Step 3F1
R = 10 [AT-AR-11]/20
EQUATION (4)
Device outside Room No more than R feet away from the center width of the wall
Step 3G
ST = (AT - AW)
1 Device No more than √ L² +(½ W)² from any point
N
Step 3H
ST > (AT - AW)
Step 3H1
R = 10 [(AT-AW)- AR-11]/20
EQUATION (5)
1 Device No more than "R" ft from any pt in the rm
N
Step 3I
ST < (AT - AW)
Step 3I1
(L x W) / ΠR² = D
EQUATION (6)
Step 3I2
R = 10 [(AT-AW)-AR-11]/20
EQUATION (5)
"D" = Devices No more than "R" feet from any point or each other
D = 2^i
Step 5C2
BL ≤ 20
H ≤ 10
15 cd #D
H ≤ 20
30 cd #D
H ≤ 30
60 cd #D
N
Step 5C3
BL ≤ 30
H ≤ 10
30 cd #D
H ≤ 20
45 cd #D
H ≤ 30
75 cd #D
N
Step 5C4
BL ≤ 40
H ≤ 10
60 cd #D
H ≤ 20
80 cd #D
H ≤ 30
115 cd #D
N
Step 5C5
BL ≤ 50
H ≤ 10
150 cd #D
H ≤ 20
115 cd #D
H ≤ 30
150 cd #D
N
Step 5C6
BL = L
N
Step 5C6a
½ L = L
Step 5C7
BL = W
Step 5C7a
½ W = W
i+1


Link to E
Step 3B1
BL = L > W then L or W
D = 2^i
i+1
Step 5B2
BL ≤ 20
Step 5B3
BL ≤ 28
Step 5B4
BL ≤ 30
Step 5B5
BL ≤ 40
Step 5B6
BL ≤ 45
Step 5B7
BL ≤ 50
Step 5B8
BL ≤ 54
Step 5B9
BL ≤ 60
Step 5B10
BL ≤ 70
Step 5B12
BL = L
½ L = L
Step 5B13
BL = W
½ W = W
Y
15 cd 1 light
30 cd 1 light
15 cd 2 lights | 30 cd 1 light
15 cd 4 lights opp. Wall | 30 cd 2 lights 1 per Wall | 60 cd 1 light
75 cd 1 light
30 cd 4 lights opp. Wall | 60 cd 2 lights 1 per Wall | 94 cd 1 light
110 cd 1 light
30 cd 4 lights opp. Wall | 95 cd 2 lights 1 per Wall | 135 cd 1 light
184 cd 4 lights opp. Wall | 95 cd 2 lights 1 per Wall | 60 cd 1 light

APPENDIX C

Minor Space Alteration Validation Project Drawing



Minor Space Alteration Validation Project Drawing

Appendix D

Explanation of Steps in the Modeling Procedure

Modeling Procedure

The profile of each analytical area is evaluated through the logic and calculations of the decision model. The decision model includes five primary steps, some of which include sub steps. Each step in the process is described below. The steps are presented in the flow diagram in Appendix C.

Step 1

Step one starts the decision path based on whether the analytical area is categorized as a room, open area, or corridor. The length (L) and width (W), and ceiling height (H), of the analytical areas must be identified. If the space is an open area or corridor then the parameter for wall attenuation (AW), is assigned a value of zero since the audible device is assumed to be located within the space. If the analytical area is a room or corridor, then the audible device is assumed to be located outside the room. The sound reduction through the wall assembly and door composition within the scope of the decision model is 20dB (15). The sound attenuation for the wall and door (AW) is assigned a value of 20dB. Iterations may be required in later steps of the decision model. If necessary, the number of iterations is tracked with the variable (i_0). In step 1, the variable i_0 is assigned a value of zero and will increase by one for each iteration.

Step 2

The type of device to be evaluated for the analytical space is identified in step 2. Device selection is based on the physical device type and not the device function. If an analytical area needs to be evaluated for visual and audible notification, it would be inappropriate to select a combination device. Since only one device type can be selected at a time. The area should go through the evaluation twice, once for an audible device, then once for a visual device. Once the notification device is selected, the path for that device type is followed under step 3 for an audible device, or, steps 4 for combination audible and visual device, or step 5 for a visual device.

Step 3

The audible device path in step 3 begins with input parameters to assess the environmental sound levels and identify the sound level rating of existing audible devices.

Sub Step 3A, 3A1, and 3A2

In this step there is a choice of using the default ambient sound level of 55dbA in sub-step 3A, or identifying the actual environmental sound level (X) in sub-step 3A1. The selected value is used to calculate the sound level (AR) in sub-step 3A2. Sound level for the space is provided in dBA units. The calculations are based on the sound level chosen, plus the 15dB that the code requires audible devices to be above ambient sound levels (4).

Sub-Step 3B

The manufacturers sound level rating for the existing audible device or one being considered for installation is provided in step 3B. The rating of the audible device (S), is given in dBA units.

Sub-Step 3C

Step 3C represents a set of mathematical models of the evaluations that a fire protection would have to conduct to make determinations about the location of audible devices. The sound level produced at the audible device (ST), is calculated, based on device manufacturers audible rating as measured 10ft from the device (14). Step 3C calculates ST for the given device rating S. The logarithm is of the base 10 and the source of the log is the distance at which the manufacturer rating is provided, which is 10ft in this case.

Sub-Step 3D

Step 3D calculates the sound dissipation over the diagonal distance measured from a point in the corner on one side of the analytical area, to the center width on the opposite side. Since the analytical area is a rectangle, this distance is equal to the square root of the length (L), squared plus one half the width (W) squared. Figure 3.3.1 illustrates how this area is used in the evaluation of the analytical space.

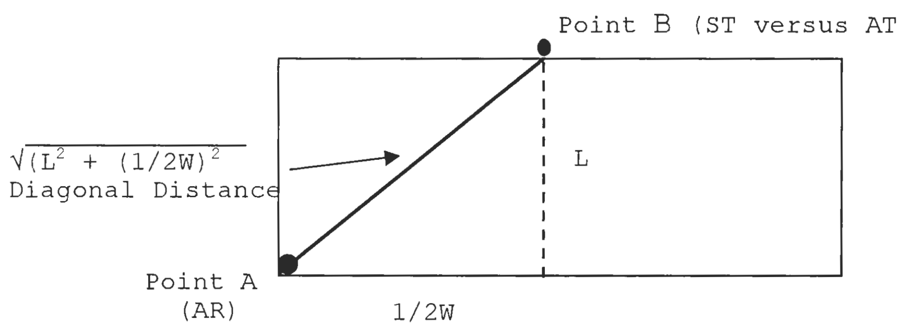


Figure 4: Measurement for sound dissipation

Sub-Step 3E

In sub-step 3E, the total sound level (AT), required for an audible device located the diagonal distance measured from the furthest corner of the rectangular shaped analytical area (Point A), to the center width of the opposite side (Point B), is calculated. Figure 3.3.1 identifies points labeled as point A and point B. The equation includes the parameter AW, which was assigned a value in step 1. The input data and calculated variables go through the logic necessary to decide the number and placement of audible devices. References are made throughout these sub-steps to points in Figure 4, to help the reader visualize the application and concept.

Sub-Step 3F

The logic question at step 3F determines if the sound level ST produced by the existing audible device, located at point B, is less then the sound level AT, that the device must produce in order to deliver the required audible level AR, to point A. If ST is greater then AT then it is loud enough to be located outside of a room or at a distance greater then the diagonal distance from point A inside the analytical area for an open space or corridor.

Sub-Step 3F1

Equation 4 calculates distance R, which represents the furthest distance a device, can be located away from any corner point of the analytical area for open areas and corridors. The variable R represents the maximum distance a device can be located outside of the analytical area considering a room. It is the conclusion of the decision model that one device located at the distance R out side of the analytical area, measured in a straight line from the center width of the wall (point B), to the device provides the audible level needed.

Sub-Step 3G

If ST is less then or equal to AT, then the sound needed to go through a wall of a room is no longer possible. The device is not loud enough and would have to be placed inside the room. At this point the wall parameter AW is subtracted from the total sound level AT. The analysis is valid for corridor and open spaces since the value of AW for those spaces is zero. If the space is a room, then AW equals 20dB therefore AT minus AW represents the total sound level required at the diagonal distance inside the room. If ST equals AT minus AW, then the model concludes that one device located a maximum distance equivalent to the diagonal distance, will provide adequate sound levels inside a room, corridor, or open space.

Sub-Step 3H, 3H1

If ST is greater then AT minus AW, then an audible device must be located inside a room, corridor, or open space, but it can be further from an inside wall then the diagonal distance. The maximum distance R, from a wall, is calculated in equation 5. The model concludes that one device at a maximum distance R should provide the required sound level.

Sub-Step 3I

If ST is less then AT minus AW then a device must be located within the room, corridor, or open area at a distance less then the diagonal distance. The number of devices will have to be calculated to provide proper radial coverage.

Sub-Step 3I1

Equation 6 calculates the maximum distance a device can be located from point A. This distance represents the radius of the circular area that the sound level will cover. The circular area in equation 6 is rounded up to the nearest whole number to identify the number devices D divide the analytical area. The model concludes that a quantity of D devices is needed within the analytical area.

Sub-Step 3I2

The devices should be located no more then a distance R from Point A and from each other, to deliver the desired audibility level. Equation 5 calculates the maximum distance.

Step 4

Step 4 is the path taken when combination devices are used. The National Fire Alarm Code requires combination device allocation follow the criteria for strobe light (4). The decision model follows this approach with the recommendation that the adequacy of combination device placement for audible notification is verified by re-entering the space for an audible device evaluation. Step 4 goes directly to step 5 where visual devices are analyzed.

Step 5

The placement of strobe lights is analyzed in step 5. Unlike audible devices there is no preliminary data required for the visual appliances. Visual device analysis is more dependent upon the physical attributes of the analytical space. The conclusions identify the candela rating, mounting orientation, and the spacing needed to provide the desired visual notification arrangement. Sub-Step 5A begins with an evaluation of the corridor areas. Wall and ceiling mounted devices for rooms and open areas are analyzed in Step 5B and 5C. The facility manger must choose between the mounting orientations. The ceiling height is limited to 30 feet for ceiling mounted strobe lights. The model does not evaluate ceiling mounted strobe lights installed at a height greater then 30 feet. Wall mounted devices should be used under those circumstances. The evaluations in steps 5B and 5C require the subdivision of the analytical area into "design areas," for the purpose of allocating strobes. The dimensions of design areas are based on the analysis of the space. They are specified in the output data.

Sub-Step 5A, 5A1

Step 5A determines if the analytical space is defined as a corridor. If the space is a corridor space, step 5A1 evaluates the dimensions to determine if the width of the corridor is greater then 20 feet. The National Fire Alarm Code requires the corridors with widths greater then 20 feet to be evaluated in accordance with room spacing criteria (4). If the width is less then 20 feet, then design standards for corridors may be applied. The corridor design standards are applied in steps 5A2, 5A3 and 5A4. They are based on basic spacing requirements to provide one visual device within 15 feet of the end of a corridor and no ore then 100 feet apart.

Step 5A2

Step 5A2 analyzes the length of the corridor. If the length is less then or equal to 30 feet, then the model concludes that one strobe light is need in the corridor. The strobe light needs to be 15cd or more, and located no more than 15 feet from either end of the corridor.

Step 5A3

Step 5A3 analyzes the length of corridors that are greater then 30 feet but less then or equal to 130 feet. Under these conditions the model concludes at least 2 strobe lights are needed. They should be rated no less then 15cd with one device within 15 feet of each end of the corridor and no more then 100 feet apart.

Step 5A4

The condition under which the corridor length exceeds 130 feet is analyzed in sub-step 5A4. The minimum number of visual devices is calculated in Equation 7. The model concludes that a minimum number of devices (D) are needed. They should be rated no less then 15cd with one device within 15 feet of each end of the corridor. The other devices should be no more then 100 feet apart.

Sub-Step 5B

When wall mounted visual devices are selected the model follows the path in step 5B. The evaluation is an application of National Fire Alarm Code requirements for the spacing of wall mounted visual devices. Before the criteria can be applied, the largest analytical area must be determined. Given the 5,000 ft^2 area limitation of the decision model, the largest design area presented in the logic is a 70 X 70 foot square. The square sizes that can enclose by the analytical area are evaluated in sub-steps 5B1 through 5B10. A base length variable (BL) is defined to break down large areas into that which can be managed by the decision model.

Step 5B1

The base length (BL), is the largest side of the analytical area as determined by the assignment of the value of BL to equal the length L, of the analytical area of L is greater then the width W. If L is less then W then BL is assigned the value of W. Since the analytical area is rectangular shaped, it should not be difficult to determine the design area. Care should be taken to ensure the entire space of the analytical area is enclosed. Figure 5 shows how to properly identify design areas within analytical areas.

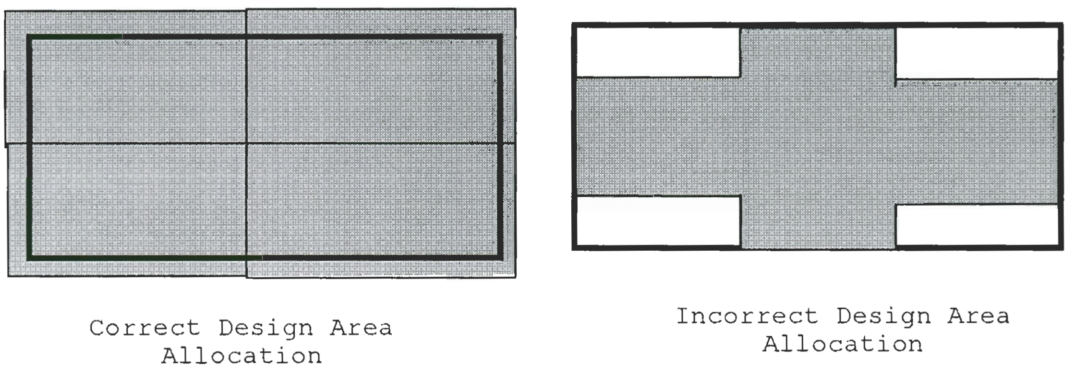
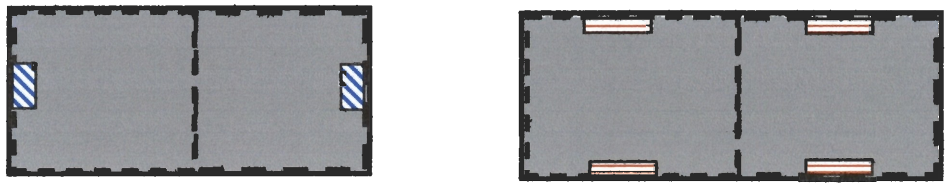


Figure 5: Visual Device Design Areas

If the BL is greater then 70 feet, then iteration begins in step 5B11 through 5B14 to divide the analytical area into smaller design areas.

Steps 5B11 through 5B14

The length or width dimensional parameter assigned to equal BL, is divided in half. The variable D, equals the number 2 raised to the power equivalent to the variable (i), for each iteration. The initial value of i_0 specified in step 1 is equal to 0. The value of D represents the number of iterations which equals the subdivided analytical areas. Since each area specifies the location for one visual device, D equals the number of visual appliances that will be needed. The value of i_0 increases by one for reach iteration. Therefore a second iteration would produce 2^2 design areas or 4 visual devices. Once a design area is determined, the model provides the options for the candela rating and quantity of visual devices that can be allocated for each design area to meet visual notification goals. Devices are always placed in the center of one side of the design area. If two devices are allocated for the design area they must be placed on in the center of opposite walls of the design area. If four devices are selected, they must be located in the center of each side of the design area. When the analytical area is divided into sections for design areas, all the sides that make up the design area will not fall on actual walls of analytical area that has been divided. When this happens the design should be chosen that represents the number of walls available. Figure 6 identifies how to allocate visual devices when an analytical area has been broken in two design areas. Since the center side of the design area is does not correspond with a wall, a four light configuration can not be chosen for design areas 1 and 2.



One strobe light per design area

Two strobe lights per design area

Figure 6: Illustration of Two Design Approaches for Wall Mounted Strobes

Sub-Step 5C

Ceiling mounted visual devices are analyzed in the path starting with step 5C. The evaluation is an application of National Fire Alarm Code requirements for the spacing of ceiling mounted visual devices. Before the code criteria can be applied, the base length and the design area must be determined using the same method employed in step 5B1. The largest design area for ceiling mounted strobes is 50ft X 50ft and the output data includes consideration for ceiling height (4).

Sub-Step 5C1

Details of step 5C1 are provided in the explanation for step 5B1

Sub-Step 5C2 through 5C8

Once the design area is determined, the appropriate range for the existing ceiling height is chosen from the selection of options under steps 5C2 through 5C5. The model identifies the size and quantity of design areas that the analytical space should be divided into for placement of visual devices. Ceiling mounted devices are placed at the center of the design area. One visual device of the specified candela rating is needed to meet the visual notification goals. Figure 7 provides an example of where ceiling mounted strobes should be located.

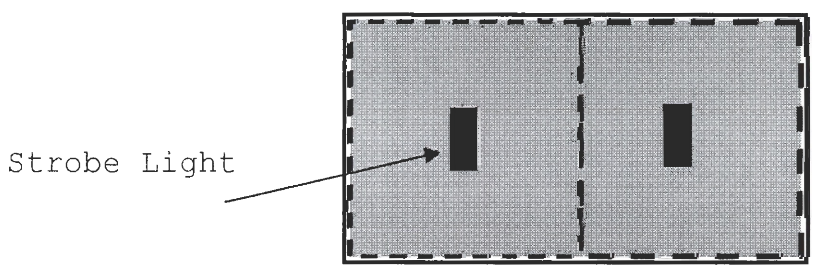


Figure 7: Allocation of Ceiling Mounted Strobe Lights

Appendix E

National Fire Alarm Code References

NFPA 72 Code References

NFPA 72 Section	Summation of Requirements	Reference
7.4.1.1	An average ambient sound level greater than 105 dBA shall require the use of a visual notification appliance(s).	Step 3A2
7.4.2.1	To ensure that audible public mode signals are clearly heard, they shall have a sound level at least 15dB above the average ambient sound level, measured 1.5 m (5ft) above the floor in the occupiable area using the A-weighted scale (dBA).	Step 3A2
7.4.6.3	If combination audible/visible appliances are installed, the location of the installed appliance shall be determined by the requirements of the spacing criteria for strobe lights	Step 4
7.5.4.1.2	Wall mounted visual notification appliances shall be installed in accordance with the guidelines of one of the following: 1. A single visual notification appliance 2. Two visible notification appliances located on opposite walls 3. More than two visible notification appliances in the same room or adjacent space within the field of view that flash in synchronization.	Figure 6
7.5.4.1.3	Room spacing shall be based	Figure 6

	on locating the visible notification appliance at the halfway distance of the wall	
7.5.4.1.4	In square rooms with appliances not centered or non-square rooms, the effective intensity from one visible wall-mounted notification appliance shall be determined by maximum room size dimensions obtained either by measuring the distance to the farthest wall or by doubling the distance to the farthest adjacent wall, whichever is greater.	Figure 6
7.5.4.1.5	If a room configuration is not square, the square room size that allows the entire room to be encompassed or allows the room to be subdivided into multiple squares shall be used.	Figure 5
7.5.4.1.6	If ceiling heights exceed 30 ft, ceiling mounted visual notification appliances shall be suspended at or below 30 ft or wall-mounted visible notification appliances shall be installed.	Step 5A
7.5.4.1.7	Ceiling mounted visible notification appliance should be at the center of the room	Figure 7
7.5.4.2.2	Corridor strobes shall not be less than 15 candela	Outcome for Steps 5A2, 5A3 and 5A4
7.5.4.2.3	The spacing of visual devices in corridors greater than 20 ft wide shall comply with the spacing requirements for rooms.	Step 5A1
7.5.4.2.4	Visible devices shall comply	Step 5A1

	with the criteria for corridor spacing when the corridor width is less then or equal to 20 ft.	
7.5.4.2.5	Visual devices shall not be more than 15 ft from the end of the corridor with a separation not greater than 100 ft between appliances.	Outcome of Steps 5A2, 5A2, and 5A4
7.5.4.2.7	In corridors where more tan two visible notification appliances are in any field of view, they shall flash in synchronization.	Assumptions Section 3.1
Table 7.5.4.1.1(a)	Room Spacing for Wall Mounted Visible Appliances	Outcome Parameters for Step 5B
Table 7.5.4.1.1(b)	Room Spacing for Ceiling Mounted Visible Appliances	Outcome Parameters for Step 5C
Figure 7.5.4.1.1	Room Spacing for Wall-Mounted Visible Appliances	Figure 6

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