Risk Management Series

Incremental Seismic Rehabilitation of School Buildings (K-12)

Providing Protection to People and Buildings

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Incremental Seismic Rehabilitation of School Buildings (K-12)

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by:

World Institute for Disaster Risk Management,
Virginia Polytechnic Institute and State University, Alexandria, Virginia

Building Technology Incorporated, Silver Spring, Maryland

Melvyn Green & Associates Inc., Torrance, California

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Principal Authors:

Frederick Krimgold, DRM/VT
David Hattis, BTI
Melvyn Green, MGA

Contributors:

John Harrald, GWU
Charles Scawthorn, ABS Consulting
Medhi Setareh, VT
Rene Van Dorp, GWU
William Whiddon, BTI

Project Advisory Panel:

Daniel Abrams, University of Illinois
Daniel Butler, National Retail Federation
John Coil, John Coil Associates
Joseph Donovan, Carr America
James Harris, National Multi Housing Council
Randal Haslam, Jordan School District, Utah
James Malley, Degenkolb Engineers
Mike Mehrain, URS Dames & Moore
Anthony Moddesette, UC Davis Medical Center
Lawrence Reaveley, University of Utah

Technical Review:

Chris Poland, Degenkolb Engineers
Daniel Shapiro, SOHA Engineers

Production:

Lee-Ann Lyons and Amy Siegel, URS Group, Inc.

The development of these manuals was inspired and guided by the leadership of Ugo Morelli, FEMA Project Officer

Contents

Executive Summary

Earthquakes are a serious threat to school safety and pose a significant potential liability to school officials and to school districts. School buildings in 39 states are vulnerable to earthquake damage. Unsafe existing buildings expose school administrators to the following risks:

- *Death and injury of students, teachers, and staff*
- *Damage to or collapse of buildings*
- *Damage and loss of furnishings, equipment, and building contents*
- *Disruption of educational programs and school operations*

The greatest earthquake risk is associated with existing school buildings that were designed and constructed before the use of modern building codes. For many parts of the United States, this includes buildings built as recently as the early 1990s.

Although vulnerable school buildings need to be replaced with safe new construction or rehabilitated to correct deficiencies, for many school districts new construction is limited, at times severely, by budgetary constraints, and seismic rehabilitation is expensive and disruptive. However, an innovative approach that phases a series of discrete rehabilitation actions implemented over a period of several years, **incremental seismic rehabilitation,** is an effective, affordable, and non-disruptive strategy for responsible mitigation action. It can be integrated efficiently into ongoing facility maintenance and capital improvement operations to minimize cost and disruption. The strategy of incremental seismic rehabilitation makes it possible to get started now on improving earthquake safety in your school district.

This manual provides school administrators with the information necessary to assess the seismic vulnerability of their buildings, and to implement a program of incremental seismic rehabilitation for those buildings. The manual consists of three parts:

Part A, Critical Decisions for Earthquake Safety in Schools, is for superintendents, board members, business managers, principals, and other policy makers who will decide on allocating resources for earthquake mitigation.

Part B, Managing the Process for Earthquake Risk Reduction in Existing School Buildings, is for school district facility managers, risk managers, and financial managers who will initiate and manage seismic mitigation measures.

Part C, Tools for Implementing Incremental Seismic Rehabilitation in School Buildings, is for school district facility managers, or those otherwise responsible for facility management, who will implement incremental seismic rehabilitation programs.

To get the most out of this manual:

- Communicate the importance of assessing your district's risks and pass this manual on to the staff members responsible for facility management, risk management, and financial planning. Specify that they develop an analysis of the current seismic risk of your buildings and a strategy for risk reduction.
- Promptly initiate a program of earthquake risk reduction in the district's buildings located in an earthquake-prone zone that were not designed and constructed to meet modern building codes.
- Consider incremental seismic rehabilitation as a cost-effective means to protect the buildings and, most importantly, the safety of students, teachers, and staff, because it is a technically and financially manageable strategy that minimizes disruption of school activities.

Foreword

The concept of seismically rehabilitating buildings in discrete segments, as resources become available or as part of a structural renovation program, was pioneered by FEMA and a Virginia Polytechnic Institute/Building Technology Inc. team that, in the early 1990s, published *Existing School Buildings – Incremental Seismic Retrofit Opportunities*, FEMA 318. Lack of resources at the time, however, restricted application of this promising concept to a few states in the Pacific Northwest and to a single occupancy or use category: schools. FEMA is therefore now pleased to make available an updated version of the manual on schools (K-12). Further, the team is also preparing a series of manuals that will address seven additional building uses: hospitals, retail establishments, multi-family dwellings, office buildings, emergency management facilities, warehousing/distribution centers, and hotels/motels. A separate manual will serve the needs of design professionals and building officials and will be applicable across all occupancy categories.

FEMA gratefully acknowledges the dedicated efforts of all members of the team: the Virginia Polytechnic Institute and State University (the prime contractor), the Project Advisory Panel, Project Consultants, Building Technology Inc, EQE Inc., Melvyn Green & Associates Inc., the Institute for Crisis Disaster and Risk Management of the George Washington University, and URS Group, Inc. The FEMA Project Officer adds his sincerest appreciation for the excellent support of this multi-disciplinary team.

The Federal Emergency Management Agency

Preface

This manual is intended to assist school administration personnel responsible for the funding and operation of existing school facilities across the United States. This guide and its companion documents are the products of a Federal Emergency Management Agency (FEMA) project to develop the concept of incremental seismic rehabilitation—that is, building modifications that reduce seismic risk by improving seismic performance and that are implemented over an extended period, often in conjunction with other repair, maintenance, or capital improvement activities.

The manual was developed after analyzing the management practices of school districts of varying sizes located in various seismic zones in different parts of the United States. It focuses on the identified concerns and decision-making practices of K-12 public and private school managers and administrators.

This manual is part of a set of manuals intended for building owners, managers, and their staff:

- *Incremental Seismic Rehabilitation of School Buildings (K-12)*, FEMA 395
- *Incremental Seismic Rehabilitation of Hospital Buildings*, FEMA 396
- *Incremental Seismic Rehabilitation of Office Buildings*, FEMA 397
- *Incremental Seismic Rehabilitation of Multifamily Apartment Buildings*, FEMA 398
- *Incremental Seismic Rehabilitation of Retail Buildings*, FEMA 399
- *Incremental Seismic Rehabilitation of Hotel and Motel Buildings*, FEMA 400
- *Incremental Seismic Rehabilitation of Storage Buildings*, FEMA 401
- *Incremental Seismic Rehabilitation of Emergency Buildings*, FEMA 402

Each manual in this set addresses the specific needs and practices of a particular category of buildings and owners, and guides owners and managers through a process that will reduce earthquake risk in their building inventory.

The manuals answer the question, as specifically as possible, “what is the most affordable, least disruptive, and most effective way to reduce seismic risk in existing buildings?” By using the process outlined in these manuals, building owners and managers will become knowledgeable clients for implementing incremental seismic rehabilitation specifically geared to their building use category.

In addition to this set of manuals, there is a companion manual, *Engineering Guideline for Incremental Seismic Rehabilitation,* FEMA 420. It is intended to assist architects and engineers who provide services to building owners and contains the information necessary for providing consulting services to owners for implementing incremental seismic rehabilitation. Architects and engineers using that handbook will be effective consultants serving a knowledgeable owner. Together they will be in a position to implement an effective incremental seismic rehabilitation program.

You may be liable for earthquake deaths and injuries in your older school buildings.

The 1933 Long Beach, California Earthquake destroyed at least 70 schools and damaged 420 more, 120 of them seriously. As a direct response, California enacted the Field Act, which established strict design and construction standards for new schools in California. But what about all the existing schools that were vulnerable to earthquakes? It took over 30 years to solve this problem, but more than just the passage of time was required.

In 1966 the Attorney General of California issued an opinion indicating that school boards were responsible for ensuring non-Field Act buildings were examined, and if schools were found to be unsafe and the board did not make the necessary corrections to make them safe, the individual school board members were personally liable. The opinion received widespread media attention. School boards, then realizing the gravity of the situation, became quite concerned about the structural condition of their pre-Field Act public school buildings. Legislative action soon followed. The Governor signed the Greene Act in 1967, which relieved the individual school board members of personal liability *only once the board initiated the process of examining existing buildings and established an intent to carry through to completion all the steps necessary for their replacement or repair.*

You too may be liable for earthquake deaths and injuries in your older school buildings, but can you wait 30 years to act? This manual provides you with the tools to assess your vulnerability and to find cost-effective ways to reduce your liability today.

Introduction

Schools, Risk, and Liability

School administrators face a wide array of risks. These risks range from playground accidents to armed attack. Risk management for schools is typically driven by experience and individual and group perceptions of danger; we recognize the need for seatbelts on school buses and sanitary precautions in the cafeteria, but the risk of catastrophic loss due to a damaging earthquake is more difficult to understand or to anticipate. Earthquakes are low-probability high-consequence events. Though they may occur only once in the life of a building they can have devastating, irreversible consequences.

Moderate earthquakes occur more frequently than major earthquakes. Nonetheless, moderate earthquakes can cause serious damage to building contents and non-structural building systems, serious injury to students and staff, and disruption of building operations. Major earthquakes can cause catastrophic damage including structural collapse and massive loss of life. Those responsible for school safety must understand and manage these risks, particularly those risks that threaten the lives of students, teachers, and staff.

Earthquake risk is the product of hazard exposure and building vulnerability, as shown in the following equation:

RISK = HAZARD x VULNERABILITY

To manage earthquake risk in existing school buildings one must understand the earthquake hazard and reduce school building vulnerability.

This manual is designed to give decision makers the framework and information for making informed decisions about investing in earthquake risk management measures. It is structured to follow the decision making process of existing planning and management practices and will help you evaluate financial, safety, and educational priorities.

School districts vary greatly in size, resources, and technical capability. Some have comprehensive long-term facility management, maintenance, and development plans. Some have none. The successful implementation of improved earthquake safety should be part of a comprehensive approach to building safety and multi-hazard mitigation.

Failure to address earthquake risk leaves the school district exposed to potential losses, disruption, and liability for deaths and injuries. While purchasing insurance may protect the school district from financial losses and liability, it still leaves the district susceptible to disruption as well as deaths and injuries. Only building rehabilitation can reduce losses, deaths and injuries, and control liability and disruption. However, single-stage seismic rehabilitation can be expensive and disruptive. Incremental seismic rehabilitation can reduce that cost and disruption.

Considering Incremental Seismic Rehabilitation

The incremental rehabilitation approach to seismic risk mitigation focuses on improvements that will decrease the vulnerability of school buildings to earthquakes at the most appropriate and convenient times in the life cycle of those buildings. The approach clarifies, as specifically as possible, what is the most affordable, least disruptive, and most effective way to reduce seismic risk in your buildings.

Prior to initiating a program of incremental seismic rehabilitation, a school district must first address the following three questions:

- Are your buildings located in a seismic zone?
- Are your school buildings vulnerable to earthquakes?
- What can you do to reduce earthquake risk in existing vulnerable school buildings?

This manual will help you find the right answers.

How to Use This Manual

Critical Decisions: School superintendents, business managers, board members, principals, and similar policy makers should read Part A. Section A.1 provides a general understanding of the earthquake hazard with which a school district is faced. Section A.2 provides an overview of how the seismic vulnerability of school buildings and resultant losses can be estimated. Section A.3 provides an overview of the actions a school district can take to reduce earthquake risk, including incremental seismic rehabilitation. Section A.4 details how to implement the concept of incremental seismic rehabilitation, including the additional benefits of integrating incremental seismic rehabilitation with other maintenance and capital improvement projects. By understanding these four sections, the school district's top management can establish a policy of seismic risk reduction and initiate a more specific, objective, and cost-effective program of incremental seismic rehabilitation by its technical staff.

Program Development: Those responsible for district facility, risk, and financial management should read Parts A and B, paying particular attention to Part B. Sections B.1 through B.3 provide detailed guidance on how the initiation of a program of incremental seismic rehabilitation can fit into the ongoing facility management process used by the school district, and indicates specific activities you can undertake. A separate Appendix, "Additional Information on School Facility Management," is provided at the end of this manual for those seeking more information on school facility management. It contains a discussion of the specific phases of the facility management process and the activities for school administrators seeking further detail.

Project Implementation: District facility managers, in addition to Parts A and B, should read Part C. Section C.1 discusses specific opportunities for combining increments of seismic rehabilitation with other maintenance and capital improvement projects. Section C.2 provides guidance on using the consulting services of architects and engineers in implementing a program of incremental seismic rehabilitation. A companion manual for design professionals has been developed to provide technical guidance for the detailed design of specific rehabilitation projects.

For Superintendents, Business Managers, Board Members & Principals

Part

A Critical Decisions for Earthquake Safety in Schools

A.1 *Is There an Earthquake Hazard for Your Schools?*

Earthquakes are one of the most serious natural hazards to which school districts may be exposed. Although school administrators face a variety of risks to occupant safety and operations that may appear more immediate, the consequences of earthquakes can be catastrophic. Therefore, in spite of their rare occurrence, earthquake safety should be given full consideration in design and investment for risk management and safety.

The first step to understanding earthquake risk:

RISK = HAZARD x VULNERABILITY

is to learn the **likelihood and severity** of an earthquake affecting your buildings.

The Earthquake Hazard: Where, When, and How Big

The surface of the earth consists of solid masses, called tectonic plates, which float on a liquid core. The areas where separate plates meet each other are called faults. Most earthquakes result from the movement of tectonic plates, and seismic hazard is strongly correlated to known faults. A map of zones of seismic hazard for the United States, based on maps provided by

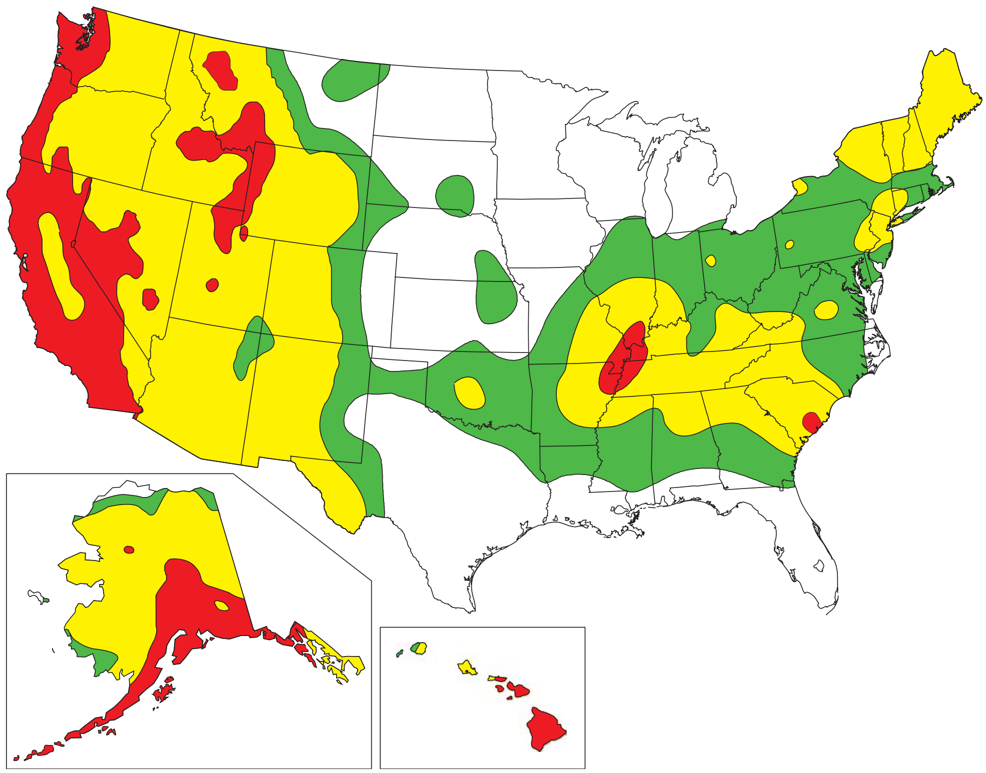
In Brief

- **Geographic location is the most significant factor of seismic hazard.**
- **Soil conditions at a particular site also influence the seismic hazard.**

the U.S. Geological Survey (USGS), shows three zones from the lowest, green, to the highest, red. The white areas have negligible seismic hazard.

The USGS earthquake hazard map is based on a complex assessment of expected seismic activity associated with recognized faults. The scientific understanding of earthquakes continues to improve and has resulted in increased estimates of seismic hazard in various parts of the country over the last decade.

Seismic Hazard Map



School administrators responsible for the safety of students, teachers, and staff need to know whether to be concerned about earthquakes. Some guidelines for determining earthquake risk in your location are:

If your school district is located in a red zone on the map

Earthquakes are one of the most significant risks facing your facilities.

- Take immediate action to undertake comprehensive vulnerability assessment. Professional structural engineers should perform this assessment.
- Identify and either replace or rehabilitate vulnerable existing buildings as soon as possible.

If your school district is located in a yellow zone

The probability of severe earthquake occurrence is sufficiently high to demand systematic investigation of your school buildings.

- Assign responsibility for investigation to the risk managers and facility managers within the district. If they are not available, seek professional engineering assistance from outside.
- Identify vulnerable buildings and schedule them for replacement, rehabilitation, or change of use.

- Also consider mitigation of non-structural hazards, such as securing bookshelves and suspended lighting that could injure building occupants in an earthquake.

If your school district is located in a green zone

While earthquake occurrence is less likely, low-cost mitigation strategies that protect building occupants and the community investment in facilities and systems should be considered.

- Pay particular attention to school buildings designated as emergency shelters.

Beyond this broad seismic zone designation, expected earthquake ground motion at a particular location is further influenced by local geology and soil conditions. Geotechnical engineering studies should be done to understand fully the earthquake hazard at a particular site in red and yellow zones.

A.2 Are Your School Buildings Safe?

The second step to understanding earthquake risk:

RISK = HAZARD x VULNERABILITY

is to learn the **expected damage and losses** that could result from an earthquake.

What Happens to School Buildings in Earthquakes

Earthquake fault rupture causes ground motion over a wide area. This ground motion acts as a powerful force on buildings. Buildings are principally designed to resist the force of gravity, but resistance to earthquake forces requires specialized earthquake engineering. Horizontal earthquake forces cause the rapid movement of the foundation and displacement of upper levels of the structure. When not designed to adequately resist or accom-

Fault rupture under or near the building, often occurring in buildings located close to faults.

Reduction of the soil bearing capacity under or near the building.

Earthquake-induced landslides near the building.

Earthquake-induced waves in bodies of water near the building (tsunami, on the ocean and seismic seiche[1] on lakes).

1 A wave on the surface of a lake or landlocked bay caused by atmospheric or seismic disturbances.

In Brief

- **Seismic vulnerability depends on structural type, age, condition, contents, and use of school buildings.**
- **Hazard exposure and building vulnerability may result in substantial death, injury, building and content damage, and serious disruption of educational programs.**

modate these earthquake forces, structures fail, leading to serious structural damage and, in the worst case, total building collapse.

In addition to ground motion, buildings may suffer earthquake damage from the following effects:

Building Age and Earthquake Vulnerability

The first earthquake design legislation for schools (the Field Act) was enacted in California in 1933. Since that time, awareness of earthquake risk has expanded across the country, and building codes have been improved because of research and experience. Since the early 1990s, most new schools in the United States have been constructed in accordance with modern codes and meet societal standards for safety. However, older school buildings should be reexamined in light of current knowledge. Some seismically active parts of the country have only recently adopted appropriate seismic design standards (the Midwest), and in other parts of the country, estimates of seismic risk have been revised upward (the Northwest). The serious problem resides in existing vulnerable school buildings constructed without seismic requirements or designed to obsolete standards. The building code is not retroactive so there is no automatic requirement to bring existing buildings up to current standards. Safety in existing buildings is the responsibility of the owner/operator. That means you!

Estimating Building Vulnerability

It is possible to estimate roughly the vulnerability of a school district's portfolio of buildings and to identify problem buildings with a technique called "rapid visual screening." School districts can produce generalized estimates of expected damage in the initial seismic risk assessment of its buildings.

Engineers have defined levels of the damage that can be expected in particular types of buildings due to varying intensities of earthquake motion. These levels of damage range from minor damage, such as cracks in walls, to total building collapse. In addition to building type, expected damage is also a function of building age and the state of maintenance. Schools suffering from deferred maintenance will experience greater damage than well-maintained schools. For example, failure to maintain masonry parapets significantly increases the possibility of life threatening failure in even a moderate earthquake.

After initial rapid screening, specific seismic risk assessment for individual school buildings requires detailed engineering analysis.

Other Earthquake Losses

While a serious concern in its own right, building failure is the direct cause of even more important earthquake losses:

- Death and injury of students, teachers, and staff
- Destruction of school contents and equipment
- Disruption of the delivery of all school services, including the capability to provide shelter, which is frequently assigned to schools in a disaster

The expected extent of these losses can also be estimated based on hazard and vulnerability assessments.

A.3 What Can Be Done to Reduce Earthquake Risk in Existing Vulnerable School Buildings?

Failure to address earthquake risk leaves the school district exposed to potential losses, disruption, and liability for deaths and injuries.

While purchasing insurance may protect the school district from financial losses and liability, it still leaves the district exposed to disruption as well as deaths and injuries. Only building rehabilitation can reduce losses, deaths, and injuries and control liability and disruption.

The implementation of seismic risk reduction through building rehabilitation will primarily involve the facility manager. However, to be effective it will require coordination among the facility managers, risk managers, and financial managers. This is further discussed in Part B (for Facility Managers, Risk Managers, and Financial Managers). In addition, it is the responsibility of the district's top administrators to make sure that hazards are assessed and risk reduction measures implemented.

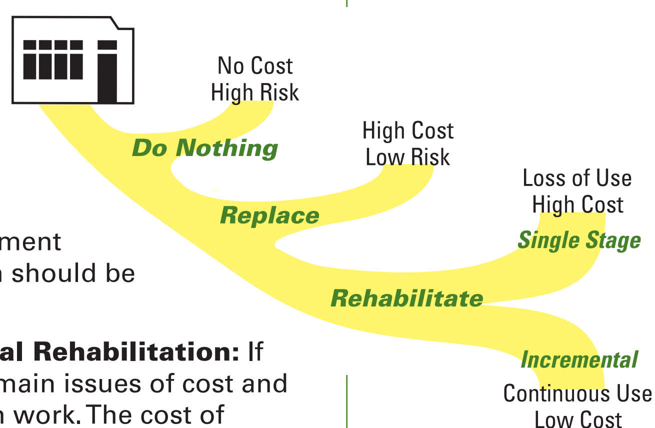
In Brief

- **Seismic rehabilitation of existing vulnerable school buildings can reduce future earthquake damage.**
- **Incremental seismic rehabilitation is a strategy to reduce the cost of rehabilitation and related disruption of educational programs.**

Options for Seismic Risk Reduction

The most important consideration for earthquake safety in school buildings is to reduce the risk of catastrophic structural collapse. Most likely in existing vulnerable buildings, structural collapse poses the greatest threat to life in a major earthquake. Choosing the method of protection from structural collapse in a deficient building requires two critical decisions:

Replace or Rehabilitate: If you decide to replace a building, new construction is carried out according to modern codes and can be assumed to meet current safety standards. However, financial constraints, historic preservation concerns, and other community interests may make the replacement option infeasible. In that, case rehabilitation should be considered.



Single-Stage Rehabilitation[2] or Incremental Rehabilitation: If the rehabilitation option is chosen, there remain issues of cost and disruption associated with the rehabilitation work. The cost of single-stage seismic rehabilitation has proved to be a serious impediment to its implementation in many school districts. Incremental seismic rehabilitation is specifically designed to address and reduce the problems of cost and disruption.

Estimating the Costs and Benefits of Seismic Rehabilitation of Existing School Buildings

The direct and indirect costs of seismic rehabilitation of a building are:

- Engineering and design services
- Construction
- Disruption of building operations during construction

[2] Single-stage rehabilitation refers to completing the rehabilitation in a single continuous project.

The benefits of seismic rehabilitation of a building are:

- Reduced risk of death and injury of students, teachers, and staff
- Reduced building damage
- Reduced damage of school contents and equipment
- Reduced disruption of the delivery of school services

Engineers have developed estimates of the reduction of earthquake damage that can be achieved with seismic rehabilitation following the Federal Emergency Management Agency's (FEMA's) current rehabilitation standards. This type of estimate, however, may significantly undervalue the benefit of seismic rehabilitation. In considering the return on seismic rehabilitation investments, it is appropriate to consider the value of damages avoided as well as the difficult-to-quantify values of deaths, injuries, and disruption of school functions avoided.

The primary obstacles to single-stage rehabilitation of vulnerable existing school buildings are the cost of rehabilitation construction work and related disruption of school functions. Incremental seismic rehabilitation offers opportunities to better manage the costs of rehabilitation and reduce its disruption. The following section introduces and explains incremental seismic rehabilitation in more detail.

A.4 Incremental Seismic Rehabilitation of Existing Schools

In Brief

- **Whereas single-stage seismic rehabilitation of an existing school building represents a significant cost, rehabilitation actions can be divided into increments and integrated into normal maintenance and capital improvement projects.**
- **The implementation of incremental seismic rehabilitation requires assessing the buildings, establishing rehabilitation priorities, and planning integration with other projects.**

Approach

Incremental rehabilitation phases seismic rehabilitation into an ordered series of discrete actions implemented over a period of several years, and whenever feasible, these actions are timed to coincide with regularly scheduled repairs, maintenance, or capital improvements. Such an approach, if carefully planned, engineered, and implemented, will ultimately achieve the full damage reduction benefits of a more costly and disruptive single-stage rehabilitation. In fact, for schools, a key distinction between the incremental and single-stage rehabilitation approach is that the incremental approach can effectively eliminate or drastically reduce disruption costs if activities are organized so that all rehabilitation occurs during the traditional 10-week summer breaks. Incremental seismic rehabilitation can be initiated in the near-term as a component of planned maintenance and capital improvement with only marginal added cost. Getting started as soon as possible on a program of earthquake safety demonstrates recognition of responsibility for school safety and can provide protection from liability.

Assessment of Deficiencies

A necessary activity that must precede a seismic rehabilitation program, be it single-stage or incremental, is an assessment of the seismic vulnerability of the school district's building inventory. Facility managers can implement such an assessment using district staff or outside engineering consultants as appropriate. The assessment should rank the building inventory in terms of seismic vulnerability and identify specific deficiencies. FEMA publishes a number of documents that can guide you through the assessment process. Portions of the assessment activities can be integrated with other ongoing facility management activities such as periodic building inspections. Facility assessments and the FEMA publications available to help you conduct them are discussed in more detail in Part B.

Rehabilitation Strategy

The incremental seismic rehabilitation program will correct the deficiencies identified by the assessment. The order in which seismic rehabilitation increments are undertaken can be important to their ultimate effectiveness. There are three aspects to prioritizing seismic rehabilitation increments:

Structural Priority: An initial prioritization of seismic rehabilitation increments should be established primarily in terms of their respective impact on the overall earthquake resistance of the structure. Facility managers will begin with these priorities when determining the order of seismic rehabilitation increments to be undertaken. However, the final order of increments may deviate from this priority order depending on other planning parameters. Additional engineering analysis may be required for certain building types when deviating from the structural priority order. This subject is discussed in more detail in Part B, Section B.2, and Part C.

Use Priority: School districts should consider planning alternative future uses of their existing buildings. Some vulnerable schools may be scheduled for demolition or changed to non-educational uses (for example, storage). Others may be scheduled for expansion and intensification of use. These considerations, among others, will influence the prioritization of seismic rehabilitation increments.

Integration: A major advantage of the incremental seismic rehabilitation approach is that specific work items can be integrated with other building maintenance or capital improvement projects undertaken routinely, as depicted in the illustrations on this page. Such integration will reduce the cost of the seismic rehabilitation action by sharing engineering costs, design cost, and some aspects of construction costs. Integration opportunities are a key consideration in adapting the sequence of actions suggested by the foregoing discussions of rehabilitation priorities. Integration opportunities are discussed in more detail in Part C, Section C.2.

Incremental Seismic Rehabilitation Plan

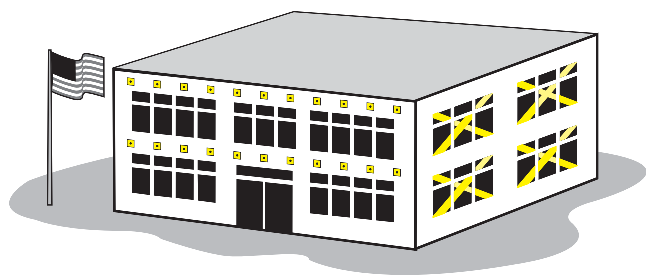
An essential feature of implementing incremental seismic rehabilitation in specific school buildings is the development and documentation of a seismic rehabilitation plan. The seismic rehabilitation plan will include all the anticipated rehabilitation increments and their prioritization as previously discussed. The documentation will guide the implementation of the incremental seismic rehabilitation program and should ensure that the school district does not lose sight of overall rehabilitation goals during implementation of individual increments.

Recommended Actions

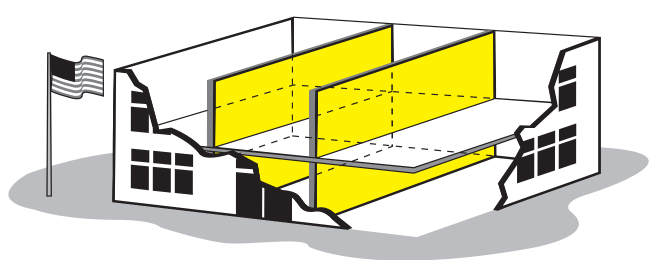
1. Communicate the importance of assessing your district's risks and pass this manual on to the staff members responsible for facility

SCHEMATIC INTEGRATION OPPORTUNITIES

Roof Work



Exterior Wall Work



Interior Work

management, risk management, and financial planning. Specify that they develop an analysis of the current seismic risk of your buildings and a strategy for risk reduction.

2. Promptly initiate a program of earthquake risk reduction in the district's buildings located in an earthquake-prone zone that were not designed and constructed to meet modern building codes.

3. Consider incremental seismic rehabilitation as a cost-effective means to protect the buildings and, most importantly, the safety of students, teachers, and staff, because it is a technically and financially manageable strategy that minimizes disruption of school activities.

For Facility Managers,
Risk Managers, &
Financial Managers

Part

Planning and Managing the Process for Earthquake Risk Reduction in Existing School Buildings

Introduction

Part B of this manual is written specifically for school facility managers, risk managers, and financial managers concerned with the seismic safety of their schools. As manager, you may have initiated a seismic safety program, or district senior management may have requested you to make a recommendation on addressing seismic safety in schools or may have already made the decision to address it. Part B describes when and how specific activities that will accomplish the goal of seismic risk reduction can be introduced into an ongoing school facility management process, regardless of how simple or sophisticated that process is. Part B also provides the framework and outline that can be used by the facility managers, risk managers, and financial managers in developing and communicating their recommendations to senior management.

An incremental seismic rehabilitation program is one of several seismic risk reduction strategies you can implement in schools. It can be implemented separately or in combination with other seismic risk reduction actions. If you determine that such a program is appropriate for your school district, the planning and implementation of incremental seismic rehabilitation should be

In Brief

- **Planning for earthquake risk reduction in schools requires a coordinated and integrated effort by facility managers, risk managers, and financial managers.**
- **Eight specific activities can be added to the current facility management process to implement an incremental seismic rehabilitation program.**
- **Nine additional activities can be added to the facility management process to further reduce seismic risk.**
- **There are three ways to start reducing seismic risk.**

integrated into the facility management processes and integrated with other seismic risk reduction actions that will complement it or support it.

B.1 Integrating the Efforts of Facility Management, Risk Management, and Financial Management

Preparing an analysis of school district earthquake risk reduction needs, and planning and managing such a process, benefits from an integrated effort by the school district's facility managers, risk managers, and financial managers, or the administrators charged with those respective responsibilities. Such an integrated effort may be a departure from current practices, but such collaboration is the key to improving safety cost effectively and with a minimum of disruption.

Facility managers currently carry out their planning activities by considering the parameters of educational program development, area demographics, and the physical condition and projected useful life of the existing school facilities. Often they consider pressing social issues such as vandalism, physical security, and equity as well. Some of these issues become federal or local government mandates, such as asbestos and lead abatement or energy conservation. Rarely do facility managers consider the risks to school buildings from natural disasters such as earthquakes or windstorms.

Risk managers, relatively recent additions to most school administrations, carry out their planning activities by considering three aspects: risk identification, risk reduction, and risk transfer. The latter generally involves the purchase of insurance or the contribution to a risk pool. Currently, the identified risks in schools are divided into risks to students, such as school bus accidents, sport activity or playground accidents, and food service hazards, and risks to staff, such as work-related disability and general health. Rarely do risk managers consider the risks to school facilities in general, and the risks to facilities and their occupants from natural disasters in particular. Rather, they tend to assume that facility risks are addressed by building codes and similar regulations.

Financial managers currently deal with facilities by controlling and managing maintenance budgets, capital improvement budgets, and insurance budgets. The demands on these budgets are presented to them by the facility managers and risk managers, but rarely do they consider the potential tradeoffs among them. The costs and benefits of various options of facility risk management are rarely explicitly addressed.

Addressing the problem of earthquake risk reduction requires the establishment of active communication among the three management functions and the coordination of activities into an integrated planning and management effort. Facility and risk managers will have to consider facility risk, and financial managers will have to consider the cost and benefits of various options for managing facility risk. Specific recommendations on implementing such an effort are provided in this Part B.

B.2 Integrating Incremental Seismic Rehabilitation into the Facility Management Process

B.2.1 A Model of the Facility Management Process for Existing School Buildings

The typical facility management process for existing school buildings consists of five phases of activities: Current Building Use, Planning, Maintenance & Rehabilitation Budgeting, Maintenance & Rehabilitation Funding, and Maintenance & Rehabilitation Implementation. Each phase consists of a distinct set of activities as follows:

Current Use: facility occupancy, facility operation, facility maintenance, and facility assessment

Planning: educational planning and facility planning

Budgeting: capital budgeting, maintenance budgeting, and insurance budgeting

Funding: financing of capital, maintenance, and insurance budgets

Implementation: capital improvement and maintenance

This process is sequential, progressing from current use through implementation of rehabilitation in any given building. A school district that has a large inventory of buildings is likely to have ongoing activities in all of these phases in different buildings. The process is illustrated in the following diagram. The Appendix to this manual, Additional Information on School Facility Management, contains a discussion of the specific phases and the activities therein for school administrators seeking further detail on the facility management process. This is a generalized model subject to local variation.

B.2.2 Elements of an Incremental Seismic Rehabilitation Program

The following activities are considered essential elements of an incremental seismic rehabilitation program for schools:

1. Seismic Screening
2. Seismic Evaluation
3. Developing a Risk Reduction Policy
4. Seismic Rehabilitation Planning for Specific Buildings
5. Staging Seismic Rehabilitation Increments
6. Budget Packaging
7. Bond Packaging
8. Seismic Rehabilitation Project Management

B.2.2.1 Seismic Screening

Incremental Seismic Rehabilitation

Element 1 ***Seismic Screening***

Seismic screening of the school district's building inventory is the first step of the incremental seismic rehabilitation process. Seismic screening procedures can be incorporated into other facility assessment activities. Begin with a determination of the status of the archival records. If building plans are available, a document review for the determination of building structure types is the first step in seismic screening. The following chart can be used to obtain an overall view of seismic concerns based on the seismic hazard map in Part A.

Level of Seismic Concern by Typical Building Type	Level of Seismic Concern by Building Location[1]		
	"Green"	"Yellow"	"Red"
Wood Frame		Low	High
Steel Frame		Low	High
Concrete Frame	Very Low	Medium	Very High
Un-reinforced Masonry	Low	High	Very High

Patterned after recommendations developed by Dr. Charles Scawthorn for the California Seismic Safety Commission's *Earthquake Risk Management: A Toolkit for Decision Makers.*

[1] Locations refer to the seismic hazard map in Part A, Section A.1.

The Federal Emergency Management Agency (FEMA) has developed FEMA 154, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook, Second Edition* as guidance for seismic screening of an inventory of buildings. It describes a technique for identifying the relatively more vulnerable buildings in a large inventory, so that they can be addressed in more detail.

The FEMA 154 publication addresses all building types and may be simplified for use in school buildings because of their similar characteristics. For example, most school districts need not consider mid-rise and high-rise buildings. In some cases, the screening will suggest specific seismic rehabilitation opportunities that do not require additional engineering and risk analyses.

The incorporation of seismic screening into ongoing facility assessment activities requires the assignment of the screening to the appropriate inspectors. If inspections are periodically carried out in the school district for other purposes such as life safety, occupational health and safety, or hazardous materials identification, it may be possible to assign the seismic screening to the same inspectors with some additional training. Alternatively, the seismic screening can be assigned to a consulting architect or engineer.

B.2.2.2 Seismic Evaluation

Seismic evaluation is an engineering analysis of individual school buildings. It usually follows the seismic screening, when the buildings identified as relatively more vulnerable are subjected to a more detailed analysis. In some cases however, for example when the district's building inventory is small, seismic evaluation of individual buildings may be the first step of the incremental seismic rehabilitation process.

Guidance for seismic evaluation of buildings is contained in standard ASCE 31[1], *Seismic Evaluation of Existing Buildings*, which is based on FEMA 310, *Handbook for the Seismic Evaluation of Existing Buildings—A Prestandard*. The standard provides engineering guidance on how to evaluate categories of buildings in order to identify deficiencies and determine effective rehabilitation measures.

Seismic evaluation can be done by district professional staff or by a consulting engineer.

[1] ASCE 31 can be obtained from the American Society of Civil Engineers at 800-548-2723.

B.2.2.3 Developing a Risk Reduction Policy

Convince the Board to adopt a clear policy statement supporting seismic risk reduction. Such a policy should, at a minimum, establish seismic performance objectives for the district's buildings. Seismic performance objectives define the target performance of a building following an earthquake of a specified intensity. The policy and objectives should be developed and documented as part of the seismic rehabilitation planning process.

Incremental Seismic Rehabilitation

Element 3
Developing a Risk Reduction Policy

B.2.2.4 Seismic Rehabilitation Planning for Specific Buildings

FEMA has developed engineering guidance to plan seismic rehabilitation for specific buildings, including FEMA 356, *Prestandard and Commentary for the Seismic Rehabilitation of Buildings*, which includes specific techniques for analyzing and designing effective seismic rehabilitation. The planning task entails four specific facility planning **subtasks:**

Incremental Seismic Rehabilitation

Element 4
Seismic Rehabilitation Planning for Specific Buildings

1. **Establish seismic target performance levels.** Establish, in cooperation with school district leadership, the performance level desired in each district building following an earthquake. Performance levels used in FEMA 356 are, in declining level of protection:
   - Operational
   - Immediate Occupancy
   - Life Safety
   - Collapse Prevention

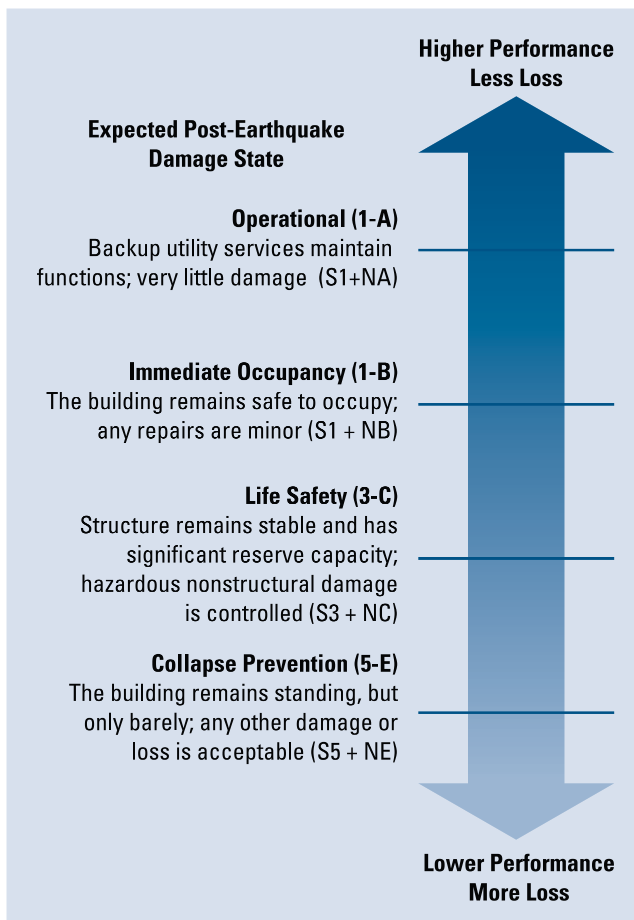
   This is an expansion of the two performance levels included in ASCE 31, *Seismic Evaluation of Existing Buildings*: Immediate Occupancy and Life Safety.

   The figures adapted from FEMA 356 on this and the following page demonstrate the use of these performance levels. Reasonable objectives and expectations should be considered for moderate, severe, and rare great earthquakes.

2. **Prioritize rehabilitation opportunities.** Carry out additional engineering and risk analysis in order to prioritize the seismic rehabilitation opportunities identified in the seismic evaluation in terms of risk reduction. ASCE 31, *Seismic Evaluation of Existing Buildings*, and FEMA 356, *Prestandard and Commentary for the Seismic Rehabilitation of Buildings*, include lists of seismic rehabilitation measures as a function of model building types. Priorities for these measures are established in terms of respective contribution to the overall earthquake resistance of the structure.

   Apply a "worst first" approach. Attend to heavily used sections of the most vulnerable buildings housing the greatest number of occupants. For example, higher priorities may be given to rehabilitation of classroom wings,

Target Building Performance Levels and Ranges



Adapted from FEMA 356, Figure C1-2

Damage Control and Building Performance Levels

	Target Building Performance Levels			
	Collapse Pervention Level (5-E)	Life Safety Level (3-C)	Immediate Occupancy Level (1-B)	Operational Level (1-A)
Overall Damage	**Severe**	**Moderate**	**Light**	**Very Light**
General	Little residual stiffness and strength, but load-bearing columns and walls function. Large permanent drifts. Some exits blocked. Infills and unbraced parapets failed or at incipient failure. Building is near collapse.	Some residual strength and stiffness left in all stories. Gravity-load-bearing elements function. No out-of-plane failure of walls or tipping of parapets. Some permanent drift. Damage to partitions. Building may be beyond economical repair	No permanent drift. Structure substantially retains original strength and stiffness. Minor cracking of facades, partitions, and ceilings as well as structural elements. Elevators can be restarted. Fire protection operable.	No permanent drift. Structure substantially retains original strength and stiffness. Minor cracking of facades, partitions, and ceilings as well as structural elements. All systems important to normal operations are functional.
Nonstructural Components	Extensive damage.	Falling hazards mitigated but many architectural, mechanical, and electrical systems are damaged	Equipment and contents are generally secure, but may not be operable due to mechanical failure or lack of utilities.	Negligible damage occurs. Power and other utilities are available, possibly from standby sources.
Comparison with performance intended for buildings designed under the *NEHRP Provisions* for the Design Earthquake	Significantly more damage and greater risk.	Somewhat more damage and slightly higher risk.	Less damage and lower risk.	Much less damage and lower risk.

Adapted from FEMA 356, Table C1-2

where pupils spend most of their time, and to corridors, stairs, and exits, which will facilitate the evacuation of the building in an earthquake.

3. **Define increments.** Break down the specific seismic rehabilitation opportunities into discrete incremental rehabilitation measures that make sense in engineering and construction terms. When establishing increments, consider scheduling to minimize the disruption to normal school operations, such as defining increments that can be accomplished over the summer vacation.

4. **Integrate with other rehabilitation work.** Link each incremental rehabilitation measure with other related facility maintenance or capital improvement work. The related work classifications may differ from district to district, but will fall into the following generic categories:
   - Building envelope improvements
   - Interior space reconfiguration
   - Life safety and accessibility improvements
   - Refinishing and hazardous materials removal
   - Building systems additions, replacements, and repairs
   - Additions to existing buildings

   Opportunities for project integration are listed in Part C, Section 2 of this manual. Some examples of the opportunities you can use to link projects are: when accessing concealed areas, when removing finishes and exposing structural elements, when performing work in a common location, sharing scaffolding and construction equipment, and sharing contractors and work force.

The four subtasks described above form an iterative process. The definition and related cost estimation of increments, as well as the integration with other maintenance and capital improvement projects, (subtasks 3 and 4), may lead to a revision of target performance levels (subtask 1), or to specific analysis carried out as part of subtask 2.

B.2.2.5 Staging Seismic Rehabilitation Increments

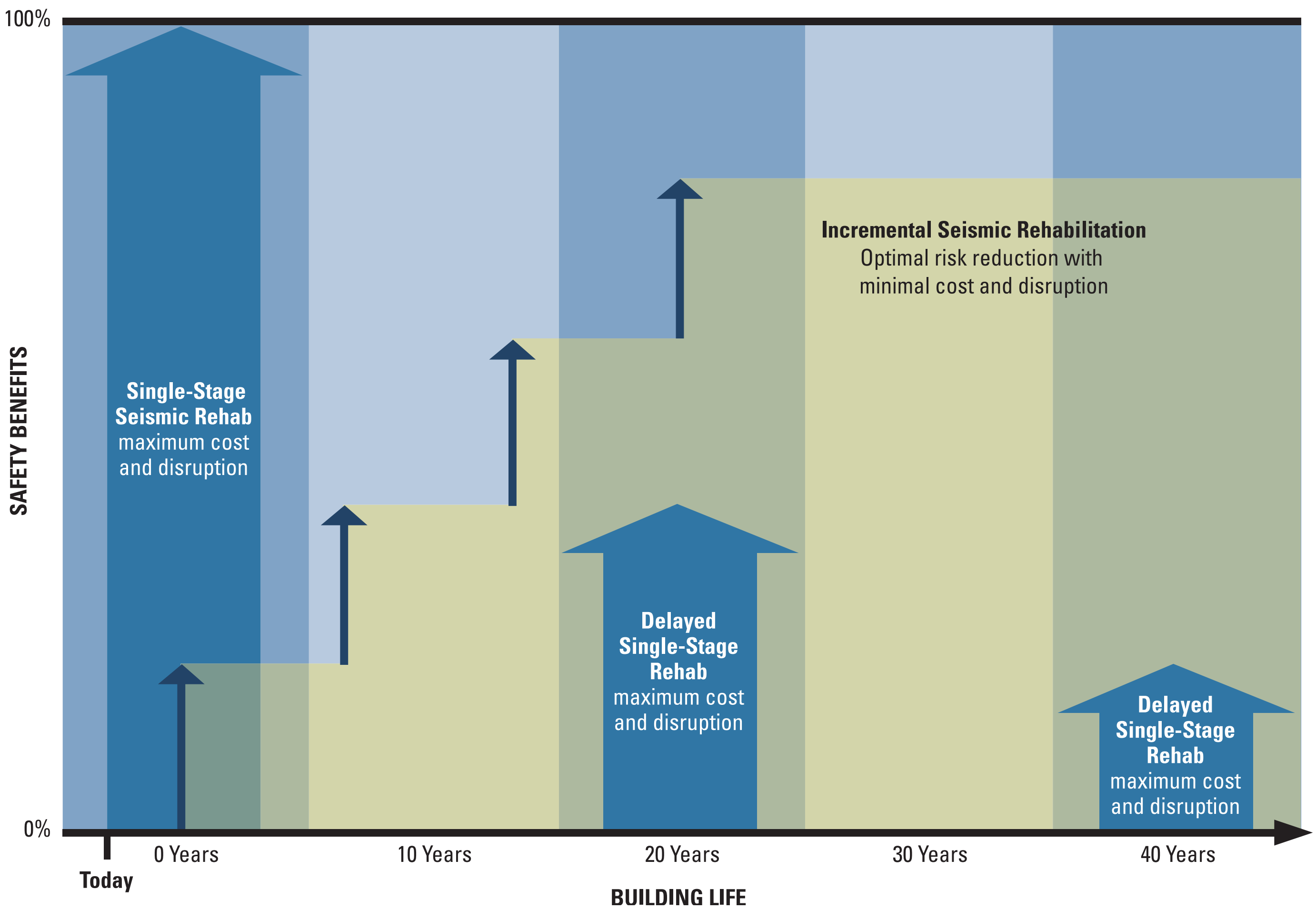
Incremental Seismic Rehabilitation

Element 5
Staging Seismic Rehabilitation Increments

Determine the number and scope of incremental stages that will be undertaken and the length of time over which the entire rehabilitation strategy will be implemented.

Estimates of seismic damage can be quantified in terms of percentage of building value damaged. Annual seismic damage is calculated as the probable damage that can result in any year from all possible earthquakes. The benefits of seismic rehabilitation are quantified as the reduction in annual seismic damage resulting from specific rehabilitation actions (also quantified in terms of percentage of building value). A generalized life-cycle benefit analysis shows that incremental approaches can return a substantial portion of the expected benefits of single-stage seismic rehabilitation carried out now.

The schematic diagram below illustrates such a life-cycle benefit analysis. The three wide arrows represent the benefits of single-stage rehabilitation occurring at three points in time: now, in 20 years, and in 40 years. Clearly,



the largest benefit derives from a single-stage rehabilitation done now, and it is designated as 100%. The benefits of single-stage rehabilitation done in the future must be discounted and expressed as some percentage lower than 100%, as represented by the decreased arrows. The stepped portion of the diagram represents incremental rehabilitation starting soon, and completed in four increments over 20 years. The benefits of the future increments must also be discounted, and the benefit of the completed incremental rehabilitation is therefore expressed as a percentage lower than 100%, but higher than the single-stage rehabilitation in year 20. Reducing the overall duration of the incremental rehabilitation will increase its benefit, and extending the duration will decrease it.

Incremental seismic rehabilitation affords great flexibility in the sequence and timing of actions when the following precautions are kept in mind:

- It is important to get started as soon as possible. Any early reduction of risk will provide benefit over the remaining life of the building. Delaying action extends risk exposure. The incremental approach can be more effective than a delayed, single-stage rehabilitation, as long as one gets started soon.
- Even if the completion of the incremental program takes 10 or 20 years, most of the risk reduction benefit is realized.
- There is a wide margin of error. For example, you may unintentionally increase the probability of damage in the first few years due to an initial rehabilitation increment that inadvertently makes the building more vulnerable to damage, and still realize the benefit of risk reduction if you complete the incremental rehabilitation over a reasonable period.

Incremental Seismic Rehabilitation

Element 6
Budget Packaging

B.2.2.6 Budget Packaging

The district business manager and facility manager, or the individual(s) performing these functions, should carefully plan how to present the incremental seismic rehabilitation budgets, given the political and financial realities of the district.

The facility capital improvements and maintenance budget proposals are results of the facility planning process. The budget, however, is also a vehicle for establishing funding priorities, through a board decision, a bond issue, or other process. It is unlikely for school districts in most parts of the United States to be able to raise funds for a comprehensive seismic rehabilitation program of all their school facilities. While the incremental rehabilitation approach appears to be a viable alternative, in some districts it may be necessary to "package" incremental seismic rehabilitation with other work in order to get it funded.

In regions of moderate seismicity and low seismic awareness (parts of New York and New England, for example), it may be useful to concentrate on rehabilitation measures that also reduce the risk of loss due to other natural or man-made forces, such as high winds. Such a multi-hazard approach will help justify mitigation investments.

For those parts of the country where the understanding of earthquake risk is limited, it may be necessary and appropriate to combine seismic rehabilitation costs with normal maintenance budgets.

Incremental Seismic Rehabilitation

Element 7
Bond Packaging

B.2.2.7 Bond Packaging

Since a bond issue is the most likely financing mechanism for seismic rehabilitation, the district business manager should select the appropriate type of bond instrument to fund the incremental seismic rehabilitation program under applicable laws and regulations.

There have been a few incremental seismic rehabilitation programs implemented by school districts in this country, the most extensive of which is the Seattle Public Schools program. Seattle Public Schools used two types of bonds to fund its program. Capital Levy Bonds were used to fund projects with smaller seismic rehabilitation increments categorized as repair and major maintenance. Capital Improvement Bonds were used to fund major projects categorized as modernization of hazardous buildings. This distinction was necessary because of Washington state law. Similar distinctions may be required in other parts of the country.

B.2.2.8 Seismic Rehabilitation Project Management

Incremental Seismic Rehabilitation

Element 8 ***Seismic Rehabilitation Project Management***

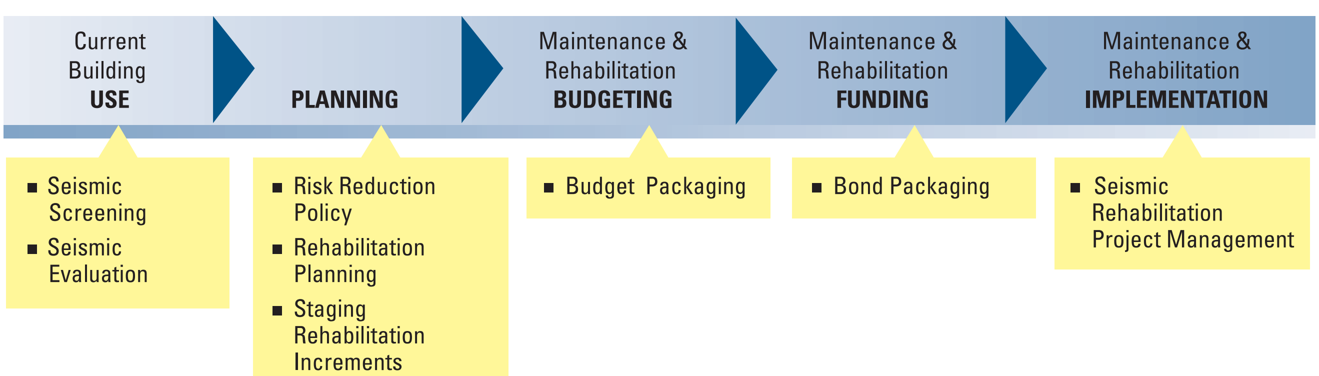
The implementation of the selected incremental seismic rehabilitation measures in combination with other building work may require added attention to project design and bid packaging.

- Fully brief or train in-house district architects/engineers or outside consultants preparing the bid documents on the rationale behind the rehabilitation measures, in order to assure that the seismic risk reduction objectives are achieved.
- Assure the continuity of building documentation from the analysis and design through construction and as-built drawings.
- Conduct a pre-bid conference to fully explain the seismic risk reduction objectives and the rationale for their selection to all prospective bidders.

Federal and state mandates and programs represent opportunities for seismic rehabilitation. Externally, federal and state programs may establish requirements affecting the implementation phase that have implications for school facilities (e.g., Americans with Disabilities Act [ADA] and Occupational Safety and Health Administration [OSHA] requirements). Additionally, governmental funding programs may mandate facility requirements in participating school districts (e.g., energy conservation). However, there are currently no seismic rehabilitation mandates or implications in any federal or state programs related to schools outside of California.

B.2.3 Integration into the Schools Facility Management Process

The following diagram illustrates the integration of the eight elements discussed in the preceding sections (B.2.2.1 through B.2.2.8) into the school facility management process. The elements are shown in the phase of the management process in which they are most likely to be implemented.



B.3 Opportunities for Seismic Risk Reduction in Support of Integrating Incremental Seismic Rehabilitation into the Facility Management Process

The following nine opportunities for seismic risk reduction will support the integration of an incremental seismic rehabilitation program:

1. Responding to Occupant Concerns
2. Emergency Management/Response Planning
3. Emergency Management/Mitigation Planning
4. Developing a Risk Reduction Policy
5. Incorporating Federal and State Mandates and Programs
6. Coordinating with Risk and Insurance Managers
7. Becoming Familiar with Applicable Codes
8. Establishing and Maintaining a Roster of Design Professionals
9. Negotiating Code Enforcement

These opportunities are created by internal and external factors that typically influence the school facility management process. Internal factors are generated within the school district and its administration. External factors are imposed on school districts by outside pressures, such as the government, insurance regulations and practices, or financial climate. The following factors may influence each respective phase:

Current Use: federal and state programs, emergency management, and occupant concerns

Planning: board policies and government mandates

Budgeting: budgetary constraints and risk management

Funding: economic conditions, federal and state programs, and bond financing regulations

Implementation: federal and state mandates and programs, codes and code enforcement

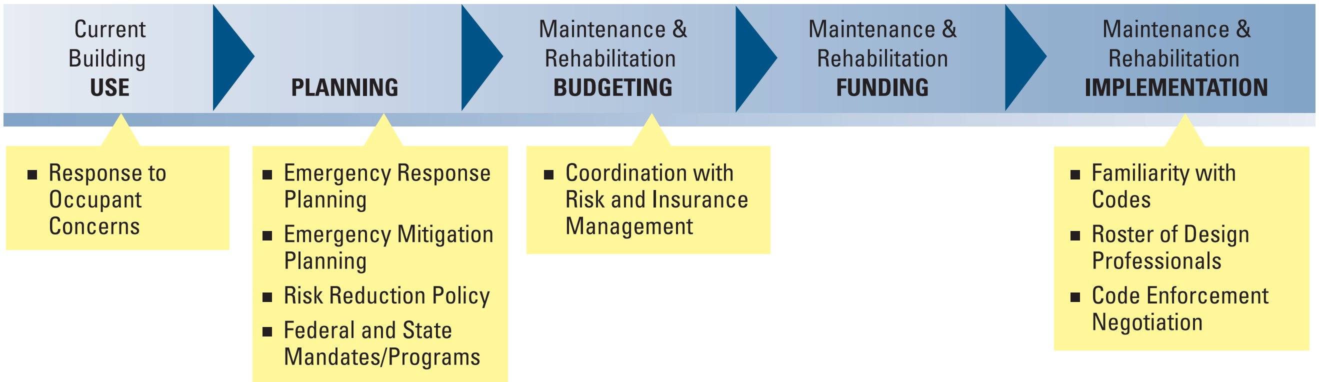
The Appendix to this manual, Additional Information on School Facility Management, contains a discussion of the specific phases and the related internal and external influences for those seeking more information on the facility management process.

The following diagram illustrates the integration of these opportunities into the school facility management process. The opportunities are shown in the phase of the management process in which they are most likely to be implemented. Each opportunity is discussed in detail in the following sections (B.3.1 through B.3.9).

B.3.1 Responding to Occupant Concerns

Track all staff, student, and parent concerns that relate to earthquake vulnerability, and make sure they are understood and considered in the **planning** phase.

Occupant concerns are a potentially significant pressure on the facility management process. In some school districts, they are often the only motivators to action. In other districts, those engaged in proactive strategic facility planning activities, occupant concerns may become the vehicle for channeling internal pressures of all kinds, including policies adopted by the Board, into capital improvements and maintenance actions.



B.3.2 Emergency Management/Response Planning

Establish a liaison with emergency management agencies and volunteer agencies (e.g., the Red Cross).

State or local emergency management agencies may assign specific roles that school buildings must perform in case of natural disasters, including earthquakes. This may affect the occupancy activities by requiring periodic exercises involving building occupants. Emergency management plans related to the role of school facilities in a disaster may be general and broad, or detailed and specific. In some cases, specific schools are assigned a particular function to perform after a disaster (e.g., temporary shelter).

Become familiar with the role of district schools in the local emergency response plans, and if it is a significant role, become active in the emergency planning process. Get the role defined in as specific and detailed a way as possible, assigning specific functions to specific facilities. The role of specific school buildings in the local emergency response plans should affect seismic performance objectives and the priority of specific seismic rehabilitation measures. Therefore, there should be full coordination between a district's emergency planning and facility planning functions.

B.3.3 Emergency Management/Mitigation Planning

Establish a liaison with emergency management mitigation planners at the state and local levels.

Endeavor to incorporate school district earthquake mitigation into the state's mitigation plan, and to recognize the district's incremental seismic rehabilitation measures as elements of the mitigation plan.

Federal resources and funds are available to states for the support of disaster mitigation planning activities. Federal matching funds may be available for the implementation of mitigation following a presidentially declared disaster. These resources are available through the Robert T. Stafford Disaster Relief and Emergency Assistance Act (P. L. 100-707). School districts should make every effort to obtain these resources.

B.3.4 Developing a Risk Reduction Policy

Convince the Board to adopt a clear policy statement supporting seismic risk reduction. Such a policy should, at a minimum, establish seismic performance objectives for the district's buildings. Seismic performance objectives define the target performance objective of a building following an earthquake of a specified intensity. The policies and objectives should be developed and documented as part of the seismic rehabilitation planning process.

B.3.5 Incorporating Federal and State Mandates and Programs

Become familiar with the seismic rehabilitation requirements imposed on the school district by federal and state programs, currently or under discussion for the future, and take them into account in planning activities.

B.3.6 Coordinating with Risk and Insurance Managers

Establish coordination between the facility management and risk management functions in the school district.

State and/or local school district risk and insurance management may have a direct or indirect role in the budgeting phase of the facility management process with regard to decisions related to insurance.

In areas of seismic risk, the risk of building loss or damage, the risk of occupant death or injury, and the risk of school district liability must all be assessed. The decision of whether to seek earthquake property and casualty insurance coverage and general liability coverage must be made. Insurance companies that offer such coverage do not usually offer incentives to customers to undertake loss reduction measures in the form of seismic rehabilitation. However, this situation might change, and the question may be subject to negotiation with some companies.

The school district risk manager should be fully informed on the district's approach to seismic risk reduction and should participate in the planning process. The manager will know if seismic risk is covered by the district's insurance carrier or by an insurance pool, and may know if it is possible to negotiate a rate reduction, deductible reduction, or increased maximum benefit based on attained levels of seismic risk reduction. On the other hand, the insurer may require some seismic rehabilitation as a condition of coverage.

If the school district participates in a regional or statewide risk and insurance pool, the pool may become an active participant in the district's facility assessment and planning processes for risk reduction.

B.3.7 Becoming Familiar with Applicable Codes

Become familiar with the seismic rehabilitation requirements imposed in your jurisdiction by building codes or other codes and ordinances, currently or under discussion for the future such as rehabilitation codes, and take them into account in planning activities.

You may become familiar with codes through services provided by Regional Educational Service Agencies, state agencies, or building-related trade associations.

B.3.8 Establishing and Maintaining a Roster of Design Professionals

Develop and maintain a roster of architects, engineers, and other consultants with expertise in the fields of seismic assessment of buildings, seismic design, and risk analysis to quickly make use of their specialized expertise when needed. Such qualified professionals can be identified with the assistance of professional societies such as the American Society of Civil Engineers, the American Institute of Architects, or the Earthquake Engineering Research Institute.

B.3.9 Negotiating Code Enforcement

Discuss the district's planned incremental seismic rehabilitation actions with the applicable code enforcement authorities.

Building codes impose requirements on the implementation phase in cases of repair, alteration, or addition to existing buildings. These requirements may be enforced by a state or local agency, or there may be a requirement that school district staff be responsible for the enforcement (for example, in the state of Utah). Such requirements can add costs to a project and jeopardize feasibility if not taken into account.

Although additions must comply with building code seismic requirements, few codes mandate seismic rehabilitation in repair and alteration projects. Incremental seismic rehabilitation is consistent with most building code requirements applicable to existing buildings.

If applicable, negotiate an optimization of life safety and risk reduction when undertaking seismic rehabilitation. Some code enforcement agencies negotiate required life safety and other improvements with owners of existing buildings who undertake voluntary building rehabilitation. Such negotiations attempt to strike a compromise between safety, feasibility, and affordability.

B.4 Preparing a Plan for the Superintendent and the Board

This section provides guidance to school facility managers, risk managers, and financial managers when preparing a proposal for a seismic safety program in response to top management's request.

B.4.1 Getting Started

The facility, risk, and financial managers of the school district should prepare a proposal for a seismic risk reduction program. This proposal should be based on an analysis of each of the elements of an incremental seismic rehabilitation program (B.2.2) and opportunities for seismic risk reduction (B.3) as discussed above, and additional components (B.5) discussed below. The proposal should include the following elements:

- A discussion of each recommendation in Part B from the perspective of the district's current facility management, risk management, and financial management practices. This may take the form of a comprehensive rewriting of Part B.
- A specific plan and recommendation for initiating the first two steps, **Seismic Screening** and **Seismic Evaluation**. The plan should include a budget and schedule of activities.
- A request for the budget for these first steps.

B.4.2 Getting Started Plus

If the necessary resources are available to the facility manager, perform a rapid visual screening, as outlined in B.2.2.1, prior to preparing the program proposal. Then, expand the proposal based on the known inventory of potentially vulnerable buildings as determined in the screening process.

B.4.3 Getting Started with a Jump Start

If the district has a current 5-year capital improvement plan or its equivalent, add the following details to the proposal discussed above:

- Identify existing buildings currently included for rehabilitation in the current 5-year plan.

- Perform a preliminary review of their seismic vulnerabilities, as outlined in B.2.2.1.
- Using Part C of this manual, identify potential seismic rehabilitation increments that could be integrated with the rehabilitation program.
- Add a FEMA 356, *Prestandard and Commentary for the Seismic Rehabilitation of Buildings*, seismic rehabilitation design task to the rehabilitation projects.

B.5 Additional Components of a Comprehensive Earthquake Safety Program

In addition to integrating an incremental seismic rehabilitation program into the school facility management process and integrating opportunities to support and implement such a program, there are additional activities that can become part of a comprehensive earthquake safety program for schools. These activities can be implemented at any time.

B.5.1 Building Contents Mitigation

Initiate housekeeping or maintenance measures to reduce or eliminate risks from earthquake damage to equipment, furnishings, and unsecured objects in buildings. Work may include such tasks as:

- Fastening desktop equipment
- Anchoring bookcases, storage shelves, etc.
- Restraining objects on shelves
- Securing the storage of hazardous materials such as chemicals

FEMA has developed materials that contain information on contents mitigation. These include FEMA 74, *Reducing the Risk of Nonstructural Earthquake Damage: A Practical Guide*, and FEMA 241, *Identification and Reduction of Nonstructural Earthquake Hazards in Schools*. Some state superintendents of public education may have developed similar materials.

B.5.2 Earthquake Curriculum

Introduce balanced awareness of seismic risk within the school population (students, teachers, parents) by introducing the subject into the curriculum. The curriculum should include timely and appropriate information such as the experience of school facility performance in recent earthquakes in your region or regions of similar seismicity (e.g., the Nisqually Earthquake of 2001 in Washington state or the northwest Oregon earthquake of March 25, 1993.) FEMA has developed materials for a school earthquake curriculum, including FEMA 159, *Earthquakes: A Teacher's Package for K-6 Grades*.

B.5.3 Earthquake Drills

Introduce earthquake drills and appropriate earthquake preparedness materials into the regular school program. Knowing what to do and where to go in an emergency can be critical to life safety in earthquakes. FEMA has developed materials for this purpose, including FEMA 88, *Guidebook for Developing a School Earthquake Safety Program*, and FEMA 88a, *Earthquake Safety Activities for Children*.

For Facility Managers

Part C

Tools for Implementing Incremental Seismic Rehabilitation in Existing School Buildings

Introduction

A school district facility manager charged with the responsibility of implementing a program of incremental seismic rehabilitation may be entering unfamiliar territory. Part C of this manual is intended to provide the facility manager with information and tools regarding building systems, maintenance, repair, and rehabilitation that should help implement such a program.

A program of incremental seismic rehabilitation is likely to be more affordable and less disruptive if specific increments of seismic rehabilitation are integrated with other maintenance and capital improvement projects that would be undertaken regardless of whether or not seismic issues were being addressed.

Guide to Sections C.1 and C.2

Section C.1, How to Use Engineering Services, provides the facility manager with practical information on the special services offered by seismic rehabilitation professionals. There are several essential activities that must be carried out by the facility manager to implement a program of incremental seismic rehabilitation successfully. (These activities are identified and discussed in Part B of this manual.) Some of these activities may require professional architectural and engineering services that differ from or exceed the traditional services usually retained by school districts.

Section C.2, Discovering Integration Opportunities for Incremental Seismic Rehabilitation, provides the facility manager with a set of tools to link specific increments of seismic rehabilitation with specific maintenance and capital improvement projects. These tools will assist the facility manager in defining appropriate scopes of work for projects that will include incremental seismic rehabilitation actions.

A companion document, *Engineering Guideline for Incremental Seismic Rehabilitation*, FEMA 420, provides design professionals with additional technical guidance for the detailed design of specific rehabilitation projects.

In Brief

- **Engineering services should be retained for three specific phases: seismic screening and evaluation, incremental seismic rehabilitation planning and design, and construction period support.**
- **Continuity of building documentation is of special importance.**

C.1 How To Use Engineering Services

To successfully implement integrated incremental seismic rehabilitation, a school district should retain engineering services for three specific phases:

- Seismic screening and evaluation
- Incremental seismic rehabilitation planning and design
- Construction period support

Seismic Screening and Evaluation

Seismic screening and evaluation of the district's building inventory begins with a review of archival drawings and specifications to determine the types of construction used. This determination is essential for all subsequent phases.

Following this review, building inventories should be screened in a process based on FEMA 154, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook*, Second Edition. The goal of the screening is to identify vulnerabilities in the inventory. Buildings that have little or no vulnerability are separated out.

For the buildings identified as vulnerable, the next category of service is a detailed seismic evaluation using ASCE 31, *Seismic Evaluation of Existing Buildings*, which is based on FEMA 310, *Handbook for the Seismic Evaluation of Existing Buildings: A Prestandard*. Smaller districts with few buildings may begin with this evaluation, which addresses individual buildings, and identifies both structural and nonstructural deficiencies that require rehabilitation. The output of each building evaluation is a list, possibly prioritized, of needed specific rehabilitation actions.

A school district may retain the services of a single engineering firm to perform both the screening and evaluation, or it can retain a firm for screening, and one or more firms for building evaluation.

Incremental Seismic Rehabilitation Planning and Design

A complete seismic rehabilitation plan covering all the deficiencies identified in the evaluation should be prepared for each building that has been evaluated. This can be done using ASCE 31 and FEMA 356, *Seismic Rehabilitation of Buildings*. However, in incremental seismic rehabilitation the correction of all the deficiencies is not implemented at once, but rather in discrete increments over a period of time. In order to accomplish this, it is necessary to carry out four specific steps:

- Establish target seismic performance levels
- Prioritize seismic rehabilitation opportunities
- Define increments
- Integrate seismic rehabilitation into maintenance and capital improvement programs

Each of these steps is amplified in the discussion of the school facility planning phase in Section B.2.

The potential for unintentional weakening of the building as the result of a particular increment should be analyzed carefully and must be avoided. This subject is discussed in more detail in the companion document, *Engineering Guideline for Incremental Seismic Rehabilitation*, FEMA 420.

Seismic rehabilitation planning and design may be carried out by the same engineering firm that performed the evaluation, or by a separate firm. Close coordination with the school risk management functions is a prerequisite for the successful implementation of performance objectives and prioritization steps. The definition of increments and integration of activities will also require close coordination with financial managers so as to be consistent with budgeting and funding processes, as discussed in Part B. The contractual agreement covering this work should reflect the fact that some of the work is implemented immediately and some of the work is left to the future.

Construction Period Support

Construction period support for incremental seismic rehabilitation is much the same as for any other construction project. The plans and specifications should be implemented correctly, and all specified quality control measures should be followed. All substitutions or changes should be carefully analyzed by the design professionals in terms of their seismic implications. Particular attention should be paid to the proper bracing and anchorage of nonstructural elements undergoing rehabilitation.

Continuity of Building Documentation

Assuring the continuity of building documentation is of particular importance for incremental seismic rehabilitation. The rehabilitation of each individual building may be staged over a period of several years or decades as discussed in Section B.2. The screening, evaluation, planning, and design may be split among several engineering firms. Institutional memory may disappear as district personnel, and even building ownership, may change. It is therefore essential that the school facility manager document all aspects and requirements of seismic rehabilitation from the earliest building screening, through evaluation, seismic rehabilitation planning, and completion of each increment of seismic rehabilitation, paying special attention to the scheduling of follow-up requirements and actions over time.

Fees for Professional Services

The professional services required to implement incremental seismic rehabilitation, as discussed above, clearly exceed the scope of traditional architectural/engineering design services. An appropriate fee structure for these new services will need to be developed and integrated into the budgeting process.

In Brief

- Opportunities to add seismic rehabilitation increments exist within most major maintenance and capital improvement activities.
- This section identifies these opportunities.

C.2 Discovering Integration Opportunities for Incremental Seismic Rehabilitation

Introduction

In order to benefit from opportunities to integrate incremental seismic rehabilitation with other maintenance and capital improvement activities, it is useful to discuss these activities as they are typically undertaken in schools and school districts. Most school districts are familiar with their particular building inventories and the related patterns of maintenance and capital improvement. Aggregate national data are of no particular relevance to a given district, but may be of general interest and is summarized in the sidebar opposite.

Categories of Maintenance and Capital Improvement Projects

School districts often categorize maintenance and capital improvement projects in the following eight categories:

1. Roofing maintenance and repair/re-roofing
2. Exterior wall and window maintenance
3. Fire and life safety improvements
4. Modernization/remodeling/new technology accommodation
5. Underfloor and basement maintenance and repair
6. Energy conservation/weatherization/air-conditioning
7. Hazardous materials abatement
8. Accessibility improvements

These categories reflect groupings of building elements, administrative and funding categories, or other parameters. Some school districts may use other categorizations of maintenance and capital improvement work. The purpose of this discussion is not to impose any particular categorization of work, but simply to demonstrate that planned work items may be particularly suitable opportunities to integrate particular incremental seismic rehabilitation measures. These pairings, of seismic rehabilitation measures with other maintenance tasks or categories, are referred to in this section as "integration opportunities." Facility managers using this manual are encouraged to modify the work categories to suit their own practices.

Work Descriptions and Matrices of Seismic Performance Improvement Opportunities

The eight sections, C.2.1 through C.2.8, provide the facility manager with information used to identify incremental seismic rehabilitation opportunities that can be combined. The information becomes a tool, a technical framework or basis for action, that can be communicated to the architect or engineer selected to work on any project resulting from an integration opportunity.

These sections present the expanded descriptions of each of the work categories defined above in a consistent format. Each category is described in terms of:

- General description
- Physical description
- Associated incremental rehabilitation work
- Performance of the work
- Special equipment
- Impact on building use

Matrices of possible specific seismic performance improvements, one matrix for each work category (Tables C-1 through C-5), accompany the descriptions of the first five categories of maintenance and capital improvement projects. These include:

- Roofing maintenance and repair/re-roofing
- Exterior wall and window maintenance
- Fire and life safety improvements
- Modernization/remodeling/new technology accommodation
- Underfloor and basement maintenance and repair

The integration opportunities for the last three categories of work are defined by reference to one or more of the five matrices.

The seismic performance improvements shown in the matrices fall into three categories:

■ Indicates improvements that can be implemented when the integration opportunity arises, with little or no engineering. These types of improvements address deficiencies that may be identified in an ASCE 31, *Seismic Evaluation of Existing Buildings*, Tier 1 analysis.

□ Indicates improvements that can be implemented when the integration opportunity arises but require substantial engineering design. These types of improvements address deficiencies that may be identified in an ASCE 31 Tier 1 or Tier 2 analysis.

☒ Indicates improvements that require engineering analysis to determine if they should be implemented when the integration opportunity arises because of the possibility of unintentionally increasing the seismic vulnerability by redistributing loads to weaker elements of the structural system (sequencing requirements).

Incremental seismic rehabilitation integration opportunities are a function of three levels of seismicity: low, moderate, and high. The definitions of these levels are those used in ASCE 31, *Seismic Evaluation of Existing Buildings*, and FEMA 356, *Seismic Rehabilitation of Buildings*. They include both seismic zonation and soil conditions. The soil conditions at the site may affect the level of seismicity and must be taken into account. For example, soft soil may amplify seismic forces on some buildings. The method for determining the level of seismicity is given in Section 2.5 of ASCE 31. The seismic improvements recommended for low levels of seismicity are significantly fewer than for the higher levels, because seismic vulnerability is lower. The seismic improvements recommended for moderate and high levels of seismicity are the same in number, but differ in the details of the improvements to reflect the different magnitudes of seismic loads encountered in the two levels.

Incremental seismic rehabilitation integration opportunities for each category of work are a function of building structure type. This manual uses five broad structural types, selected to be meaningful to school facility managers. The materials used for the building's vertical load-resisting system can be used to categorize the following structural types:

- Wood
- Unreinforced masonry
- Reinforced masonry
- Concrete
- Steel

The latter two structural types, concrete and steel, are broken down further into those with wood floors (flexible diaphragms) and concrete floors (rigid diaphragms). This breakdown covers an important parameter of seismic performance of the structures.

Generalized Maintenance and Capital Improvement Data

Whitestone Research (a private market research organization) indicates that expenditures for maintenance and repairs over a building's life exceed replacement costs for most building types and configurations, including schools.

The predominant categories of maintenance and repair activities for schools are, first, interior finishes, followed by electrical, mechanical, and plumbing systems. The only other significant cost repair category is roofing. All these activities offer opportunities for integration with incremental seismic rehabilitation work.

The timing of the work is also highly predictable. About 60% of building replacement costs are typically spent in years 20, 25, 30, 40, 45 and 50. These are the highest expense years, in roughly increasing order, with year 50 incurring about 12% of replacement costs for outsourced repair and renovation expenses.

These patterns suggest significant opportunity (and tendency) to implement strategies like incremental rehabilitation at specific points over the service life of a school building. They also imply specific target periods when the strategies could most likely be considered and implemented. Building age is an important characteristic for incremental seismic rehabilitation.

The facility manager using this section to identify incremental seismic rehabilitation integration opportunities in a particular building should use Sections C.2.1 through C.2.8 and the matrices therein as follows:

- Determine the category of maintenance or capital improvement under consideration, and go to the section that corresponds most closely to that category.
- Determine the level of seismicity applicable to the building by considering the seismic map and the soil conditions, and identify the applicable rows of the matrix.
- Determine which of the seven structural categories most closely fits the building, and identify the applicable column of the matrix.
- List all the nonstructural and structural seismic improvements identified in the matrix column and rows.
- Note the category of each improvement (■, □, or ☒).

The facility manager should present to the architect or engineer the annotated list of all the nonstructural and structural seismic improvements identified for consideration and inclusion in the respective scope of design work. The architect or engineer should design the project using the companion document, *Engineering Guideline for Incremental Seismic Rehabilitation*, FEMA 420, which includes more detailed guidance on incremental seismic design. The architect or engineer designing the incremental seismic rehabilitation program will most likely break down the seven structural type categories into further subcategories, as used in ASCE 31 or FEMA 356. These categories and subcategories are discussed in detail in FEMA 420.

Note that 'school building additions' are a category of typical capital improvement that is not included among the eight categories listed at the beginning of this section. Additions have been constructed on many schools over the course of their useful lives. Current additions will be designed to meet the seismic requirements of the building code. Additions may also offer opportunities to strengthen an adjacent building or buildings. These opportunities require careful design and analysis, and they are not specifically identified in the integration opportunities matrices (Tables C-1 through C-5). Furthermore, inadequately designed additions, without proper joints or connections to the existing building, could actually cause damage in an earthquake, as different sections of the building pound against each other.

Definitions of Seismic Performance Improvements

The seismic performance improvements, both nonstructural and structural, that are included in the matrices of integration opportunities described in the preceding paragraphs and included in Sections C.2.1 through C.2.5 are all extracted from a generic list of seismic performance improvements. The generic list is presented in Section C.2.9, which includes brief related explanations for each item on the list. The user of this manual can identify specific seismic performance improvements in the respective project category matrices, and may then refer to these definitions for additional explanation of the involved activities.

The generic nonstructural improvements in C.2.9 are ranked and numbered from highest to lowest priority, in terms of engineering judgment of improvement of life safety in schools. The improvements selected from this list for inclusion in each of the matrices in C.2.1 through C.2.5 are presented in the same order of ranking and retain their respective number. This explains the occasional skipping of a number when a specific nonstructural improvement is omitted because it is not applicable in the particular matrix.

The generic structural improvements in C.2.9 are arranged in the order of structural subsystems and elements, and are not ranked in terms of impact on life safety. The improvements selected from this list for inclusion in each of the matrices in C.2.1 through C.2.5 are presented in the same order.

C.2.1 Roofing Maintenance and Repair/Re-Roofing

General Description of the Work: This category of work includes repair or replacement of any or all of the following elements:

- Roof drainage system
- Eaves and fascias
- Flashing and vents
- Roofing membrane
- Insulation
- Walking surface and ballast
- Parapets and caps
- Roof-mounted equipment
- Roof deck

Most roof maintenance and repair work is done either in response to a failure, or as scheduled periodic maintenance or preventive maintenance work. Most seismic rehabilitation integration opportunities for this work category will relate to either scheduled or preventive maintenance. Placement of roof-mounted equipment usually relates to other work categories such as modernization.

In some jurisdictions, an application for a re-roofing permit triggers a code requirement to implement specific seismic rehabilitation such as parapet bracing.

Physical Description of the Work: Work on the roof can be localized to specific areas, can extend to the entire perimeter of the roof, or may involve the complete roof surface or large portions of it. Work may be limited to the roofing membrane or may include work on the substrate, deck, and supporting system.

Associated Incremental Seismic Rehabilitation Work: Incremental seismic rehabilitation associated with roofing maintenance and repair may include strengthening diaphragms, diaphragm/wall connections, parapets, chimneys, equipment attachment and bracing.

Performance of the Work: Repair work on the roof is often performed by district maintenance staff. Outside contractors may be used for more extensive work.

An architecture/engineering (A/E) firm is typically used in connection with the installation of mechanical, electrical, telecommunication or similar equipment. Also, districts often use the services of an A/E for preparation of re-roofing specifications and bid documents.

Special Equipment: Scaffolding is sometimes used in connection with roof work. Cranes or hoists may be used to lift materials or equipment.

Impact of Work on Building Use: Work on the roof generally does not interrupt building use, except for complete re-roofing including the deck.

Table C-1: Roofing Maintenance and Repair/Re-Roofing

Rank*	Level of Seimicity			Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure						
							Wood	Masonry[1]		Concrete		Steel	
	L	M	H					Unreinforced Masonry	Reinforced Masonry	Wood Diaphragm	Concrete Diaphragm	Wood Diaphragm	Concrete Diaphragm
Nonstructural													
1	✓	✓	✓	n/a	n/a	Bracing of Parapets, Gables, Ornamentation & Appendages		■		■	■	■	■
2	✓	✓	✓	n/a	n/a	Anchorage of Canopies at Exits	■	■	■	■	■	■	■
3		✓	✓	n/a	n/a	Bracing or Removal of Chimneys	■	■	■	■	■	■	■
10		✓	✓	n/a	n/a	Anchorage and Detailing of Rooftop Equipment	■	■	■	■	■	■	■
Structural													
n/a		✓	✓	All Elements		Load Path and Collectors	□	□	□	□	□	□	□
n/a		✓	✓	Horizontal Elements	Diaphragms	Attachment and Strengthening at Boundaries	■	■	■	■	□	■	□
n/a		✓	✓	Horizontal Elements	Diaphragms	Strength/Stiffness	■	■	■	■	□	■	□
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Openings	□	□	□	□		□	
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Re-entrant Corners	□	□	□	□	□	□	□
n/a		✓	✓	Horizontal Elements	Diaphragms	Topping Slab for Precast Concrete		□	□		□		□
n/a	✓	✓	✓	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection		■	■	■	☒	■	☒
n/a	✓	✓	✓	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall		■	■	■	□	■	□

* Nonstructural improvements are ranked on the basis of engineering judgment of their relative impact on improving life safety in schools. Structural improvements are not ranked, but rather, organized by structural element and sub-system.

■ Work that may be included in the building rehabilitation/maintenance/repair project using little or no engineering

□ Work requiring detailed engineering design to be included in the project

☒ Work requiring detailed engineering design and evaluation of sequencing requirements; The "x" designates work that could redistribute loads, overstressing some elements

Note 1: Masonry buildings with a concrete roof should use the concrete building, concrete diaphragm for integration opportunities.

C.2.2 Exterior Wall and Window Maintenance

General Description of the Work: Exterior wall and window maintenance may involve the following activities:

- Pointing
- Patching
- Painting
- Caulking

This category of work may also include major projects such as:

- Window repair and replacement
- Refinishing with new cladding or material

Most exterior wall maintenance and repair work is done in response to failure or as scheduled periodic maintenance or preventive maintenance work. Caulking and window repair and replacement are also often linked to energy conservation/weatherization work.

Federal or state mandates that require energy conservation improvements may lead to window repair or replacement.

Physical Description of the Work: Work is usually carried out throughout an entire school as a scheduled maintenance activity, although localized patching work is possible. Work may include repainting of brick exterior walls, window replacement, and energy conservation improvements.

Associated Incremental Seismic Rehabilitation Work: Strengthening of shear walls and diaphragm/wall connections.

Performance of the Work: Exterior wall and window work may be performed by skilled construction personnel on the district staff or by an outside contractor. In many cases, there may be an A/E involved to provide design, specifications, and bid process and construction administration services.

Special Equipment: Access to higher exterior areas may require scaffolding or swing stages. This access may provide economical opportunities for the integration of seismic rehabilitation measures.

Impact on Building Use: Since most of the work is being performed from the building exterior, it may be possible to accomplish it throughout the school year. However, some of the seismic rehabilitation measures may be noisy or require access from the interior, so this work may have to be done when the building is vacant.

Table C-2: Exterior Wall and Window Maintenance

Rank*	Level of Seimicity: L	Level of Seimicity: M	Level of Seimicity: H	Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure: Wood	Masonry[1]: Unreinforced Masonry	Masonry[1]: Reinforced Masonry	Concrete: Wood Diaphragm	Concrete: Concrete Diaphragm	Steel: Wood Diaphragm	Steel: Concrete Diaphragm
Nonstructural													
1	✓	✓	✓	n/a	n/a	Bracing of Parapets, Gables, Ornamentation & Appendages		■	■	■	■	■	■
2	✓	✓	✓	n/a	n/a	Anchorage of Canopies at Exits	■	■	■	■	■	■	■
12	✓	✓	✓	n/a	n/a	Cladding Anchorage		□	□	□	□	□	□
13		✓	✓	n/a	n/a	Anchorage of Masonry Veneer	■	■	■	■	■	■	■
14		✓	✓	n/a	n/a	Anchorage of Exterior Wythe in Cavity Walls		■	■	■	■	■	■
15	✓	✓	✓	n/a	n/a	Glazing Selection and Detailing	■	■	■	■	■	■	■
17		✓	✓	n/a	n/a	Anchorage of Steel Stud Backup		■	■	■	■	■	■
20		✓	✓	n/a	n/a	Shut-Off Valves	■	■	■	■	■	■	■
Structural													
n/a		✓	✓	All Elements		Collector and Drag Element Improvement	□	□	□	□	□	□	□
n/a		✓	✓	Foundation		Anchor Bolts	■						
n/a		✓	✓	Foundation		Anchorage	■						
n/a		✓	✓	Foundation		Cripple Stud Bracing	■						
n/a		✓	✓	Horizontal Elements	Diaphragms	Attachment and Strengthening at Boundaries	■	■	■	■	□	■	□
n/a	✓	✓	✓	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	■	■	■	■	☒	■	☒
n/a		✓	✓	Vertical Elements	Braced Frames	Capacity/Stiffness	□	□	□	□	☒	□	☒
n/a		✓	✓	Vertical Elements	Braced Frames	Continuity	□	□	□	□	□	□	□
n/a		✓	✓	Vertical Elements	Braced Frames	Connections	□	□	□	□	□	□	□
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Capacity/Stiffness	□	□	□	□	☒	□	☒
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Connection	□	□	□	□	□	□	□
n/a		✓	✓	Vertical Elements	Shear Walls	Capacity	■	□	□	□	☒	□	☒
n/a		✓	✓	Vertical Elements	Shear Walls	Continuity	■	□	□	□	□	□	□
n/a		✓	✓	Vertical Elements	Shear Walls	Lateral Stability		■	■	■	□	■	□
n/a	✓	✓	✓	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall	■	■	■	■	□	■	□

* Nonstructural improvements are ranked on the basis of engineering judgment of their relative impact on improving life safety in schools. Structural improvements are not ranked, but rather, organized by structural element and sub-system.

■ Work that may be included in the building rehabilitation/maintenance/repair project using little or no engineering

□ Work requiring detailed engineering design to be included in the project

☒ Work requiring detailed engineering design and evaluation of sequencing requirements; The "x" designates work that could redistribute loads, overstressing some elements

Note 1: Masonry buildings with a concrete roof or floors should use the concrete building, concrete diaphragm for integration opportunities.

C.2.3 Fire and Life Safety Improvements

General Description of the Work: Fire and life safety improvements may involve the following building elements:

- Corridors and doors
- Stairs
- Lobbies
- Exits
- Alarms
- Standpipes
- Automatic fire sprinkler systems

Districts will usually schedule this work as part of the normal planning process. Only if the work is in response to a disaster, such as a fire, will the work be unplanned. However, a building disaster that requires some construction may provide an opportunity to integrate seismic safety improvements.

This category of work is usually mandated rather than routine. It may be in response to a building or fire code requirement, or as part of the long-range safety improvement plan of the district. It may also be part of a general modernization program. Some codes may also require seismic rehabilitation when a building experiences a significant amount of damage in a disaster such as fire, flood, or earthquake.

Physical Description of the Work: Fire and life safety improvements usually involve the building's means of egress, which will affect specific internal spaces. Often the work is near the center of the building, such as in the corridors and stairwells. In some cases, it may affect spaces on the building perimeter, such as lobbies, entrances, and stairways. Items include:

- The removal and replacement of corridor wall finishes, doors, transoms and equipment (e.g., lockers and cabinets) will provide access to walls and ceilings;
- The installation of new walls or alteration to existing walls at fire separations and stairway enclosures;
- New stairways may be installed either within the building or on the exterior. If stairways are added, the work may require removal of part of a floor and the construction of new walls; and
- The installation of alarms, standpipes, or sprinklers will provide access to concealed spaces.

Associated Incremental Seismic Rehabilitation Work: Incremental seismic rehabilitation work associated with fire and life safety improvements may include shear walls, bracing, beam/column connections, diaphragm to wall anchors, and bracing of equipment.

Performance of the Work: Typically this work involves skilled construction personnel. These may be district personnel or contractors. In some cases an A/E is involved.

Special Equipment: No special equipment is required for this task except for scaffolding to provide access to the work areas.

Impact on Building Use: Typically this work will be performed when the building is vacant.

Table C-3: Fire and Life Safety Improvements

Rank*	Level of Seimicity: L	Level of Seimicity: M	Level of Seimicity: H	Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure: Wood	Masonry[1]: Unreinforced Masonry	Masonry[1]: Reinforced Masonry	Concrete: Wood Diaphragm	Concrete: Concrete Diaphragm	Steel: Wood Diaphragm	Steel: Concrete Diaphragm
Nonstructural													
4	✓	✓	✓	n/a	n/a	Bracing or Reinforcing Masonry Walls at Interior Stairs		■	■	■	■	■	■
5		✓	✓	n/a	n/a	Suspension and Bracing of Lights	■	■	■	■	■	■	■
6	✓	✓	✓	n/a	n/a	Anchorage and Bracing of Emergency Lighting	■	■	■	■	■	■	■
7		✓	✓	n/a	n/a	Fastening and Bracing of Ceilings	■	■	■	■	■	■	■
8		✓	✓	n/a	n/a	Restraint of Hazardous Materials Containers	■	■	■	■	■	■	■
9		✓	✓	n/a	n/a	Bracing and Detailing of Sprinkler and Piping	■	■	■	■	■	■	■
11		✓	✓	n/a	n/a	Fastening and Bracing of Equipment, Mechanical and Electrical	■	■	■	■	■	■	■
15	✓	✓	✓	n/a	n/a	Glazing Selection and Detailing	■	■	■	■	■	■	■
16		✓	✓	n/a	n/a	Bracing of Interior Partitions, Masonry & Wood	■	■	■	■	■	■	■
17		✓	✓	n/a	n/a	Anchorage of Steel Stud Backup		■	■	■	■	■	■
18		✓	✓	n/a	n/a	Attachment and Bracing of Cabinets and Furnishings	■	■	■	■	■	■	■
19		✓	✓	n/a	n/a	Attachment and Bracing of Large Ductwork	■	■	■	■	■	■	■
21		✓	✓	n/a	n/a	Support and Detailing of Elevators		■	■	■	■	■	■
Structural													
n/a		✓	✓	All Elements		Collector and Drag Element Improvement	□	□	□	□	□	□	□
n/a		✓	✓	Horizontal Elements	Diaphragms	Mezzanine Anchorage and Bracing		■	■	■	■	■	■
n/a	✓	✓	✓	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	■	■	■	■	☒	■	☒
n/a		✓	✓	Vertical Elements	Braced Frames	Capacity/Stiffness			□	□	☒	□	☒
n/a		✓	✓	Vertical Elements	Braced Frames	Continuity			□	□	□	□	□
n/a		✓	✓	Vertical Elements	Braced Frames	Connections			□	□	□	□	□
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Capacity/Stiffness			□	□	☒	□	☒
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Connection			□	□	□	□	□
n/a		✓	✓	Vertical Elements	Shear Walls	Capacity	■	□	□	□	☒	□	☒
n/a		✓	✓	Vertical Elements	Shear Walls	Continuity	■	□	□	□	□	□	□
n/a		✓	✓	Vertical Elements	Shear Walls	Extension of Wood Interior Walls to Roof	■	■	■				
n/a		✓	✓	Vertical Elements	Shear Walls	Lateral Stability		■	■	■	□	■	□
n/a	✓	✓	✓	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall		■	■	■	□	■	□

* Nonstructural improvements are ranked on the basis of engineering judgment of their relative impact on improving life safety in schools. Structural improvements are not ranked, but rather, organized by structural element and sub-system.

■ Work that may be included in the building rehabilitation/maintenance/repair project using little or no engineering

□ Work requiring detailed engineering design to be included in the project

☒ Work requiring detailed engineering design and evaluation of sequencing requirements; The "x" designates work that could redistribute loads, overstressing some elements

Note 1: Masonry buildings with a concrete roof or floors should use the concrete building, concrete diaphragm for integration opportunities.

C.2.4 Modernization/Remodeling/New Technology Accommodation

General Description of the Work: Facility modernization and remodeling work has the potential to involve any interior or exterior wall or element. This category may involve simple work on a single wall or the entire space reconfiguration of the building. The installation of conduits, cables, and wiring to accommodate new technology may involve the reconfiguration of concealed spaces under floors, above ceilings, and inside wall cavities and chases located throughout the building.

Interior remodeling and modernization are usually major activities and are included in the long-range educational plans of the district. Often this includes the conversion of open classroom plans (that were popular in the '60s and '70s) to more traditional classroom configuration. Thus, it is a common capital improvement activity.

Frequently this work is in response to changing educational requirements or major technological advances. It may also be triggered by federal or state mandates. Some codes may also require seismic rehabilitation when a building experiences a significant amount of damage in a disaster such as fire, flood, or earthquake.

Physical Description of the Work: This work may include reconfiguration of spaces and creation of new spaces, removal of walls and ceilings, construction of new partitions, installation of replacement finishes, and installation of communications networks for new technology. This access to spaces behind finishes and the new wall construction provide various opportunities for seismic rehabilitation work.

Associated Incremental Seismic Rehabilitation Work: Incremental seismic rehabilitation associated with this work may include shear walls, bracing, beam/column connections, diaphragm to wall anchors, and bracing of equipment.

Performance of the Work: This work will usually be performed by skilled construction personnel, either district staff or contractor personnel. Usually architectural/engineering design is used for major remodeling.

Special Equipment: Special equipment required for access to work areas for any seismic rehabilitation construction will typically be available during any remodeling work.

Impact on Building Use: Major remodeling will require the space to be vacated during the course of construction.

Table C-4: Modernization/Remodeling/New Technology

Rank*	Level of Seimicity: L	Level of Seimicity: M	Level of Seimicity: H	Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure: Wood	Masonry[1]: Unreinforced Masonry	Masonry[1]: Reinforced Masonry	Concrete: Wood Diaphragm	Concrete: Concrete Diaphragm	Steel: Wood Diaphragm	Steel: Concrete Diaphragm
Nonstructural													
4	✓	✓	✓	n/a	n/a	Bracing or Reinforcing Masonry Walls at Interior Stairs	■	■	■	■	■	■	■
5		✓	✓	n/a	n/a	Suspension and Bracing of Lights	■	■	■	■	■	■	■
6	✓	✓	✓	n/a	n/a	Anchorage and Bracing of Emergency Lighting	■	■	■	■	■	■	■
7		✓	✓	n/a	n/a	Fastening and Bracing of Ceilings	■	■	■	■	■	■	■
8		✓	✓	n/a	n/a	Restraint of Hazardous Materials Containers	■	■	■	■	■	■	■
9		✓	✓	n/a	n/a	Bracing and Detailing of Sprinkler and Piping	■	■	■	■	■	■	■
11		✓	✓	n/a	n/a	Fastening and Bracing of Equipment, Mechanical and Electrical	■	■	■	■	■	■	■
15	✓	✓	✓	n/a	n/a	Glazing Selection and Detailing	■	■	■	■	■	■	■
16		✓	✓	n/a	n/a	Bracing of Interior Partitions, Masonry & Wood	■	■	■	■	■	■	■
17		✓	✓	n/a	n/a	Anchorage of Steel Stud Backup		■	■	■	■	■	
18		✓	✓	n/a	n/a	Attachment and Bracing of Cabinets and Furnishings	■	■	■	■	■	■	■
19		✓	✓	n/a	n/a	Attachment and Bracing of Large Ductwork	■	■	■	■	■	■	■
21		✓	✓	n/a	n/a	Support and Detailing of Elevators		■	■	■	■	■	■
22		✓	✓	n/a	n/a	Underfloor Bracing of Computer Access Floor	■	■	■	■	■	■	■
Structural													
n/a		✓	✓	All Elements		Collector and Drag Element Improvement	□	□	□	□	□	□	□
n/a		✓	✓	Foundation		Anchor Bolts	■						
n/a		✓	✓	Foundation		Cripple Stud Bracing	■						
n/a		✓	✓	Foundation		New Foundations	■						
n/a		✓	✓	Horizontal Elements	Diaphragms	Mezzanine Anchorage and Bracing		■	■	■	■	■	■
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Openings	□	□	□	□		□	
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Re-entrant Corners	□	□	□	□	□	□	□
n/a	✓	✓	✓	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	■	■	■	■	☒	■	☒
n/a		✓	✓	Vertical Elements	Braced Frames	Capacity/Stiffness			□	□	☒	□	☒
n/a		✓	✓	Vertical Elements	Braced Frames	Continuity			□	□	□	□	□
n/a		✓	✓	Vertical Elements	Braced Frames	Connections			□	□	□	□	□
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Capacity/Stiffness			□	□	☒	□	☒
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Connection			□	□	□	□	□
n/a		✓	✓	Vertical Elements	Shear Walls	Capacity	■	□	□	□	☒	□	☒
n/a		✓	✓	Vertical Elements	Shear Walls	Continuity	■	□	□	□	□	□	□
n/a		✓	✓	Vertical Elements	Shear Walls	Extension of Wood Interior Walls to Roof	■						
n/a		✓	✓	Vertical Elements	Shear Walls	Lateral Stability		■	■	□	□	□	□
n/a	✓	✓	✓	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall		■	■	■	□	■	□

* Nonstructural improvements are ranked on the basis of engineering judgment of their relative impact on improving life safety in schools. Structural improvements are not ranked, but rather, organized by structural element and sub-system.

■ Work that may be included in the building rehabilitation/maintenance/repair project using little or no engineering

□ Work requiring detailed engineering design to be included in the project

☒ Work requiring detailed engineering design and evaluation of sequencing requirements; The "x" designates work that could redistribute loads, overstressing some elements

Note 1: Masonry buildings with a concrete roof or floors should use the concrete building, concrete diaphragm for integration opportunities.

C.2.5 Underfloor and Basement Maintenance and Repair

General Description of the Work: Underfloor and basement maintenance may involve the following activities:

- Repair of deterioration
- Termite repair
- Equipment replacement

Most underfloor repair activities will be in response to a problem. The solution may be immediate or assigned to the capital improvements budget. For example, settlement and resulting underpinning repair may be the result of a floor problem and require major immediate intervention.

Usually there are no mandates or code issues involved with underfloor repair work. Safety is the usual driving force.

Physical Description of the Work: Work includes replacement of deteriorated wood elements, repair of cracked or bowed walls, underpinning where buildings have settled, and replacement of basement equipment.

Associated Incremental Seismic Rehabilitation Work: Incremental seismic rehabilitation work associated with underfloor and basement work may include cripple stud bracing, foundation anchorage, new foundation, and floor to wall anchoring.

Performance of the Work: The work is often performed by school district staff or by outside contractors.

Special Equipment: Special equipment is usually not required for underfloor work. However access is usually all that is necessary. Major design work will often require A/E services.

Impact on Building Use: Except for equipment replacement, the work may be done at any time, independent of building use.

Table C-5: Underfloor and Basement Work

Rank*	Level of Seimicity: L	Level of Seimicity: M	Level of Seimicity: H	Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure: Wood	Masonry[1]: Unreinforced Masonry	Masonry[1]: Reinforced Masonry	Concrete: Wood Diaphragm	Concrete: Concrete Diaphragm	Steel: Wood Diaphragm	Steel: Concrete Diaphragm
Nonstructural													
8		✓	✓	n/a	n/a	Restraint of Hazardous Materials Containers	■	■	■	■	■	■	■
11		✓	✓	n/a	n/a	Fastening and Bracing of Equipment, Mechanical and Electrical	■	■	■	■	■	■	■
20		✓	✓	n/a	n/a	Shut-Off Valves	■	■	■	■	■	■	■
Structural													
n/a		✓	✓	All Elements		Collector and Drag Element Improvement	□	□	□	□	□	□	□
n/a		✓	✓	Foundation		Anchor Bolts	■						
n/a		✓	✓	Foundation		Anchorage	■	■	■	□	□	□	□
n/a		✓	✓	Foundation		Cripple Stud Bracing	■						
n/a		✓	✓	Foundation		New Foundations	■	□	□	□	□	□	□
n/a		✓	✓	Foundation		Pile Cap Lateral Load		■	■	□	□	□	□
n/a		✓	✓	Foundation		Uplift	■	■	■	□	□	□	□
n/a	✓	✓	✓	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	■	■	■	■	☒	■	☒
n/a		✓	✓	Vertical Elements	Braced Frames	Connections						□	□
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Connection						□	□
n/a		✓	✓	Vertical Elements	Shear Walls	Capacity	■	□	□	□	☒	□	☒
n/a		✓	✓	Vertical Elements	Shear Walls	Continuity	■	□	□	□	□	□	□
n/a	✓	✓	✓	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall		■	■	■	□	■	□

* Nonstructural improvements are ranked on the basis of engineering judgment of their relative impact on improving life safety in schools.
Structural improvements are not ranked, but rather, organized by structural element and sub-system.

■ Work that may be included in the building rehabilitation/maintenance/repair project using little or no engineering

□ Work requiring detailed engineering design to be included in the project

☒ Work requiring detailed engineering design and evaluation of sequencing requirements; The "x" designates work that could redistribute loads, overstressing some elements

Note 1: Masonry buildings with a concrete roof or floors should use the concrete building, concrete diaphragm for integration opportunities.

C.2.6 Energy Conservation/Weatherization/Air-Conditioning

General Description of the Work: Energy conservation/weatherization and air-conditioning projects may include the following items:

- Exterior envelope work
- Insulation
- Windows
- Electrical and HVAC equipment
- Ducts and piping

Building elements affected may include exterior walls, ceilings, attic spaces, roofs, and basements.

These improvements may be in response to a long-term school district policy, special state or federal funding, or as part of other routine equipment replacement. In all cases, the intent is not only to save energy but also to reduce operating costs and improve occupant comfort.

Federal or state mandates may be factors leading to energy conservation improvements. If special grants are available, they can be made part of the capital improvement program. Local building code requirements may also encourage energy conservation improvements.

Physical Description of the Work: The physical work involved in energy conservation improvements may be localized or involve the entire building. Items include:

- Window improvements or replacement
- New insulation in exterior walls
- New insulation in the attic, which may permit access to the ceiling space
- New insulation installed on the roof deck, which can be coordinated with other roof-top work
- HVAC equipment installation, which should meet the anchorage requirements for seismic forces and may provide access to areas for other work
- The addition of air-conditioning, which may include the installation of ducts or piping to spaces throughout the building

Associated Incremental Seismic Rehabilitation Work: This work may include the incremental seismic rehabilitation work associated with the following other project categories discussed earlier:

- C.2.1, Roofing Maintenance and Repair/Re-Roofing
- C.2.2, Exterior Wall and Window Maintenance
- C.2.4, Modernization/Remodeling/New Technology Accommodation

See Tables C-1, C-2, and C-4 for integration opportunities.

Performance of the Work: The work may be performed by school district personnel or by outside contractors depending on the project size or complexity. Whether the services of an A/E are required will depend on the nature of the work.

Special Equipment: Special equipment may be required to provide access to the work. This may include scaffolding or a crane or lift.

Impact on Building Use: Some of this work may be done at any time of year from the roof. Most window or interior work must be accomplished when school is not in session. Typically this work cannot be done around occupants and may require the building to be vacant.

C.2.7 Hazardous Materials Abatement

General Description of the Work: The presence of hazardous materials may involve abatement of:

- Asbestos
- Lead paint
- Radon

Most districts have had asbestos abatement programs for some time and radon programs more recently. Lead paint has also been recognized as a hazard for some time, but only recently has it been included in government programs for abatement.

Hazardous materials abatement programs may be triggered by federal requirements or mandates, state regulations or school district policies.

Physical Description of the Work: Hazardous materials abatement may include the removal of finishes such as plaster, ceiling materials, and flooring. It may include removal of the adhesives used. Asbestos abatement may include the removal or encapsulation of insulation on pipes and ducts. Lead paint abatement may include removal of the paint and finishes or encapsulation of the component containing the lead paint. Radon abatement may require installation of ventilation systems or other work in the basement.

Associated Incremental Seismic Rehabilitation Work: In some cases, the extent of the work may provide access to interior spaces that will provide a seismic rehabilitation opportunity. Seismic rehabilitation work could follow the hazard mitigation work before the finishes are reinstalled. This work may include the incremental seismic rehabilitation work associated with C.2.4, Modernization/Remodeling/New Technology Accommodation, discussed earlier.

See Table C-4 for integration opportunities.

Performance of the Work: The work is typically performed by specialty contractors or specially trained school district staff.

Special Equipment: Special equipment such as scaffolding would often be on the job as part of the abatement work. Other special equipment such as fans and enclosures are irrelevant to seismic work.

Impact on Building Use: Building use will be curtailed during any hazardous materials abatement work. The work cannot be done around occupants. It requires a vacant building.

C.2.8 Accessibility Improvements

General Description of the Work: Typically such work is done in response to a complaint, or a federal or state mandate. It is often included as part of the long-range plans of the district.

Physical Description of the Work: Most work involves revisions to walks and doors. Ramps are constructed, and in some cases elevators or lifts installed.

Toilet room improvements may require the removal of finishes and possibly construction of new walls.

Associated Incremental Seismic Rehabilitation Work: Accessibility improvements usually do not lead to seismic rehabilitation opportunities because of their relatively limited spatial applicability. Interior work relating to corridors and circulation routes may share some seismic rehabilitation opportunities with C.2.3, Fire and Life Safety Improvements.

See Table C-3 for integration opportunities.

Other interior work may lead to localized seismic rehabilitation opportunities but no major mitigation. Installation of an elevator may provide an opportunity to use the new shaft walls as shear walls, thereby adding shear capacity.

Performance of the Work: Accessibility improvements may be accomplished by school district staff or by outside contractors. Often the services of an A/E are utilized.

Special Equipment: No special equipment is used in this work that might be of assistance in seismic rehabilitation. However, any scaffolding used for interior finish work can provide access for seismic rehabilitation.

Impact on Building Use: Usually this work can be done around occupants of the building. It does not require a vacant building.

C.2.9 Definitions of Seismic Performance Improvements

The seismic performance improvements included in the matrices of integration opportunities in Sections C.2.1 through C.2.8 are all extracted from the generic list in the following tables. The table contains additional information (description and purpose) that should be useful to school facility managers using this section.

Note that the nonstructural improvements are ranked and numbered from highest to lowest priority, in terms of their impact on improving life safety in schools. The facility manager and risk manager may revise the ranking based on local considerations.

Nonstructural Seismic Performance Improvements

Rank *	Level of Seismicity			Definitions and Purpose		
	L	M	H	Seismic Performance Improvement	Description	Purpose
1	✓	✓	✓	Bracing of Parapets, Gables, Ornamentation & Appendages	Construct parapet bracing on the roof side of the parapet. Gables are braced in the attic space. Other elements are anchored in a positive manner.	Prevents parapets, gables and ornamentation from falling outward
2	✓	✓	✓	Anchorage of Canopies at Exits	Canopies or roofs over exits	Prevents collapse of canopies which would block exits and possibly injure persons
3		✓	✓	Bracing or Removal of Chimneys	Chimneys should be braced to the structure	Chimneys may topple onto yards or through roofs
4	✓	✓	✓	Bracing or Reinforcing Masonry Walls at Interior Stairs	Interior exit stairs may have unreinforced masonry enclosure walls that could collapse	Prevents collapse of walls blocking stairways
5		✓	✓	Suspension and Bracing of Lights	Lights may swing or otherwise fall in an earthquake	Falling lights could injure occupants. Lights should not be supported by a suspended ceiling in a high and moderate seismic zone. Pendent lights should have their sway limited.
6	✓	✓	✓	Anchorage and Bracing of Emergency Lighting	Positive attachment of emergency lights	Battery packs are heavy and could fall
7		✓	✓	Fastening and Bracing of Ceilings	Diagonal bracing of ceiling	Suspended ceilings should be braced against sidesway to reduce the chance of elements falling
8		✓	✓	Restraint of Hazardous Materials Containers	Chemical labs, shops, etc may have materials that could, when combined, create a fire or chemical hazard	Reduces danger of breakage and mixing of chemical
9		✓	✓	Bracing and Detailing of Sprinkler and Piping	Sprinkler pipes should be braced in each direction	Sprinkler lines could break and flood the building
10		✓	✓	Anchorage and Detailing of Rooftop Equipment	Equipment should be properly attached, and restrained if isolation-mounted	Equipment could slide or fall off platforms
11		✓	✓	Fastening and Bracing of Equipment – Mechanical and Electrical	Equipment above ceilings	Fans and other equipment could sway and fall on occupants
12	✓	✓	✓	Cladding Anchorage	Heavy cladding (concrete) must be connected to the structure	Prevents cladding from falling. Careful design is required so the cladding does not limit the structures type of lateral movement.
13		✓	✓	Anchorage of Masonry Veneer	Veneer over exterior wood or masonry walls or over other materials in steel or concrete structure. Materials may be brick, terra cotta, stone or similar materials	Inadequately anchored veneer could fall outward
14		✓	✓	Anchorage of Exterior Wythe in Cavity Walls	A masonry wall separated from the veneer by a hollow space	Veneer could fall outward. Existing anchorage should be checked for rust damage and loss of strength.
15	✓	✓	✓	Glazing Selection and Detailing	Glass above a walking surface	Prevents it from falling onto the walking surface and injuring persons
16		✓	✓	Bracing of Interior Partitions – Masonry & Wood	Bracing may be vertical or diagonal braces	Interior partitions must be braced to prevent falling/collapse
17		✓	✓	Anchorage of Steel Stud Backup	Steel studs behind veneer or other cladding	Steel studs are used as a backup to support veneer or other cladding and could become detached and fall
18		✓	✓	Attachment and Bracing of Cabinets and Furnishings	Anchorage to structural walls or other elements	Cabinets and other furnishings could topple. Cabinets have moved caused damage. Fallen file cabinets may block exit doors.
19		✓	✓	Attachment and Bracing of Large Ductwork	Large ducts	Ducts could fall on occupants
20		✓	✓	Shut-Off Valves	Installation of a shut-off device	Gas and water lines could break and should have a means of turning them off
21		✓	✓	Support and Detailing of Elevators	Elevator guides have become dislodged in earthquakes. Applies to cable lift elevators	Keeps elevators functioning
22		✓	✓	Underfloor Bracing of Computer Access Floor	Raised floors for cabling	Floors could collapse damaging equipment

* Rank in terms of 'life safety effectiveness'

Structural Seismic Performance Improvements

Level of Seismicity			Building Element	Structural Sub-System	Definitions and Purpose		
L	M	H			Seismic Performance Improvement	Description	Purpose
	✓	✓	Foundation		Anchor Bolts	Connection between the foundation and the building	Improve load path. Prevent building from sliding off foundation.
	✓	✓	Foundation		Anchorage	Connection between the foundation and the building for larger buildings	Improves load path. Provides adequate connection between the building and the foundation.
	✓	✓	Foundation		Cripple Stud Bracing	Short wood studs between the foundation and the first floor	Cripple studs are usually not braced. They may topple causing the building to fall off the foundation.
	✓	✓	Foundation		New Foundations	New foundations to convey loads	Additional foundations may be the preferred solution in some cases.
	✓	✓	Foundation		Pile Cap Lateral Load	Piles supporting buildings may try to move laterally from building loads during earthquakes	Brace piles at their top to eliminate the chance of lateral movement.
	✓	✓	Foundation		Uplift	Under overturning type loads foundations may be pulled upward	Reduces the uplift chance by improving foundation system.
Definition			Horizontal Elements			Floors, mezzanines and roofs	
Definition			Horizontal Elements	Diaphragms		Floors and roofs connecting walls and lateral force resisting elements	Diaphragms are the roof and floors of a building. They must be of adequate strength to transfer the earthquake loads to the walls and other elements. The connection from the diaphragm to the wall or other lateral force resisting element is part of the load path.
	✓	✓	Horizontal Elements	Diaphragms	Attachment and Strengthening at Boundaries	Improving the connection of the diaphragm to the edge/boundary elements with nails, bolts or welding	This is part of the load path and conveys the diaphragm forces into the walls or other lateral force resisting elements.
	✓	✓	Horizontal Elements	Diaphragms	Mezzanine Anchorage and Bracing	Anchor the mezzanine to the wall. Where there is an open side of the mezzanine bracing may be necessary	Make sure the mezzanine is attached to the building to provide for a load path for the mezzanine diaphragm and to reduce any pounding of the mezzanine against the building's walls or columns. A large mezzanine may require bracing on the open sides.
	✓	✓	Horizontal Elements	Diaphragms	Strength/Stiffness	Strengthen the diaphragm to limit its lateral deflection	Controls the movement of the diaphragm to reduce the damage due to drift and to control the out of plane loads on vertical elements.
	✓	✓	Horizontal Elements	Diaphragms	Strengthening at Openings	Strapping around diaphragm openings	Openings may create a weak point in the diaphragm. Straps will provide additional strength to wood diaphragms
	✓	✓	Horizontal Elements	Diaphragms	Strengthening at Re-Entrant Corners	"L" and "U" shaped buildings have stress concentrations at the interior corners	Reduces damage from cracking and failures caused by stress concentration
	✓	✓	Horizontal Elements	Diaphragms	Topping Slab for Precast Concrete	Concrete slab over precast concrete roof to create a continuous diaphragm. Connect to the vertical elements as part of a load path	Strengthens the roof to act as a lateral force element. Controls drift of the roof or floor.
Definition			Vertical Elements	Braced Frames		Steel or concrete beams and columns with diagonal bracing	Act as a lateral force resisting element and brace the structure
	✓	✓	Vertical Elements	Braced Frames	Capacity/Stiffness	Frame capacity improvements for adequate load resistance	Frames are often used as the lateral force resisting element on open sides of buildings. They must be connected to the horizontal elements.
	✓	✓	Vertical Elements	Braced Frames	Continuity	Braced frames should be continuous from the foundation to the roof	Discontinuities of lateral resisting elements create load transfer demands. Design standards may impose higher loads for this condition.
	✓	✓	Vertical Elements	Braced Frames	Connections	The details of the connections, bolts or welds, must be adequate. Improvements to strength will not result in unintentional increase in seismic vulnerability.	This assures the adequacy of the frame elements to resist loads. Improvements may be made by the addition of steel plates with bolting or welding.
✓	✓	✓	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	Connections between roof/floor and wall or other element	Permits earthquake loads to be conveyed to the foundation. Develops a load path.

Structural Seismic Performance Improvements (continued)

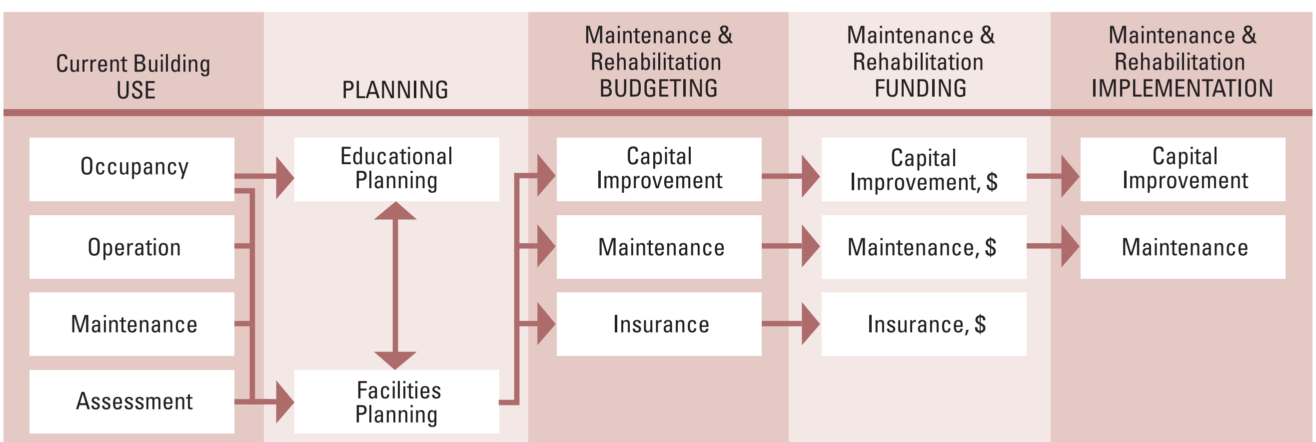
Level of Seismicity			Building Element	Structural Sub-System	Definitions and Purpose of Structural Performance Improvements		
L	M	H			Seismic Performance Improvement	Description	Purpose
Definition			Vertical Elements	Moment Frames		A steel or concrete system of beams and columns	Act as a lateral force resisting element and braces the structure
	✓	✓	Vertical Elements	Moment Frames	Beam Column Capacity/Stiffness	Frame capacity improvements for adequate load resistance	Frames are often used as the lateral force resisting element on open sides of buildings. They must be connected to the horizontal elements.
	✓	✓	Vertical Elements	Moment Frames	Beam Column Connection	Steel or concrete with improved connections to increase strength. Improvements will not result in unintentional increase in seismic vulnerability.	This assures the adequacy of the frame elements to resist loads. Improvements may be made by the addition of steel plates with bolting or welding.
Definition			Vertical Elements	Shear Walls		Walls that brace the building against earthquakes	Brace the structure
	✓	✓	Vertical Elements	Shear Walls	Capacity	Capacity equals strength	Building walls can act as lateral load resisting elements. They must be connected to the horizontal elements.
	✓	✓	Vertical Elements	Shear Walls	Continuity	Shear walls should be continuous from the foundation to the roof	Discontinuities of lateral resisting elements create load transfer demands. Design standards may impose higher loads for this condition. This is one of the most cost effective improvements in buildings.
	✓	✓	Vertical Elements	Shear Walls	Extension of Wood Interior Walls to Roof	Extending interior wood walls to diaphragms in URM and other buildings	Permits walls that were not constructed full height to be used as shear walls in buildings with wood interior walls.
	✓	✓	Vertical Elements	Shear Walls	Lateral Stability	Tall walls may buckle and need bracing	Prevents buckling and possible wall collapse. Walls must be anchored at the top or may have other bracing elements such as diagonal or vertical braces.
✓	✓	✓	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall	Connections from the walls to the floors and roof	Prevents walls from falling outward due to inadequate connections between the wall and the diaphragms. A cost effective mitigation measure for bearing wall buildings.
✓	✓	✓	All Elements		Load Path and Collectors	Distribute loads from diaphragms into elements that resist lateral force	These are straps of steel or wood that "collect" load and distribute it into the vertical lateral force resisting elements. Connections may be with bolts, nails, or welding depending on the material and location.

Appendix. Additional Information on School Facility Management

Introduction: Typical Facility Management for Schools

The typical facility management process for existing school buildings consists of five phases of activities: Current Building Use, Planning, Maintenance & Rehabilitation Budgeting, Maintenance & Rehabilitation Funding, and Maintenance & Rehabilitation Implementation, as diagrammed in Figure 1. This process is sequential, progressing from left to right in any given building. A school district that has a large inventory of buildings is likely to have ongoing activities in all of these phases.

Figure 1: Typical Management Process

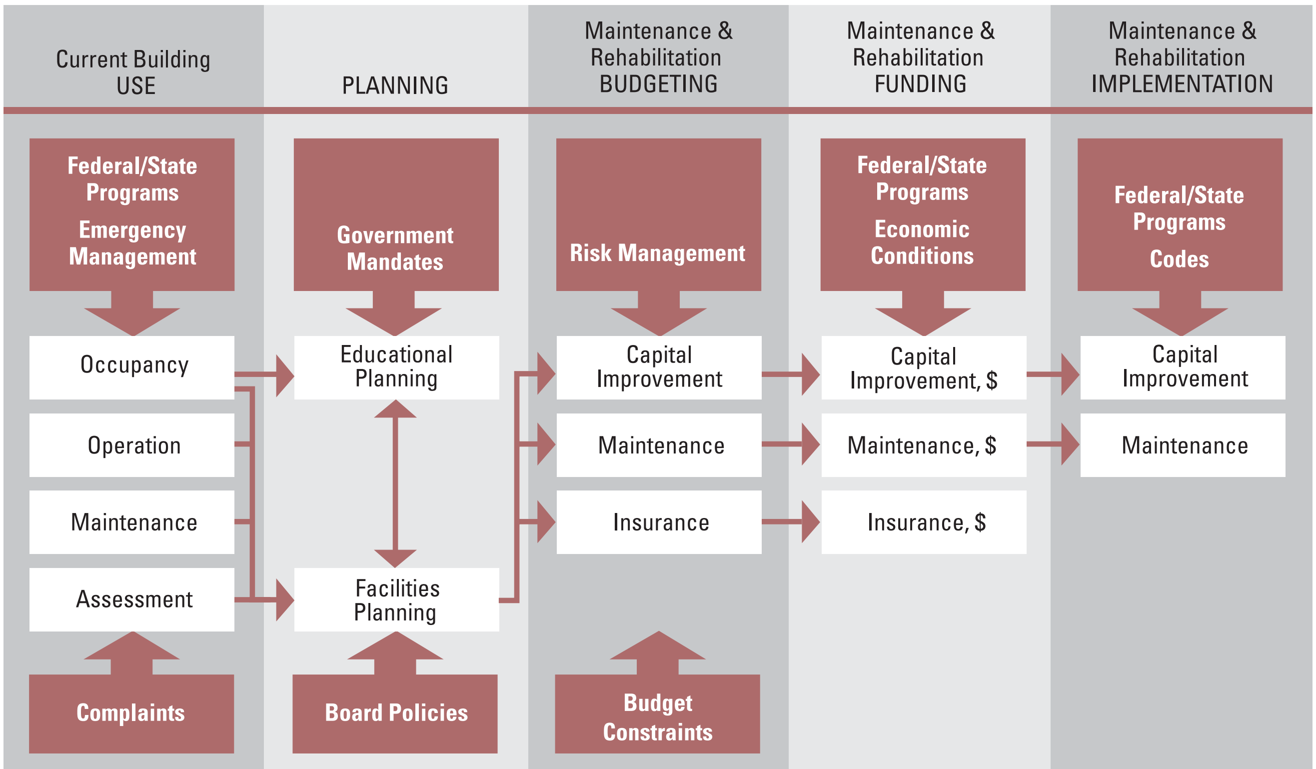


This process is generic and, while local variations occur, it is generally followed by school administrators, either explicitly or implicitly.

Both internal and external factors typically influence the school facility management process in its various phases. Internal factors (represented by up arrows in Figure 2) are generated within the school district and its administration. External factors (down arrows) are imposed on school districts by outside entities.

This Appendix describes the activities and influences within each phase.

Figure 2: Management Process Influences



1. The Current Building USE Phase of School Facility Management

Typical Process

The current building use phase of the typical school facility management process consists of four categories of activities and is influenced by significant internal and external pressures, as depicted in Figure 3.

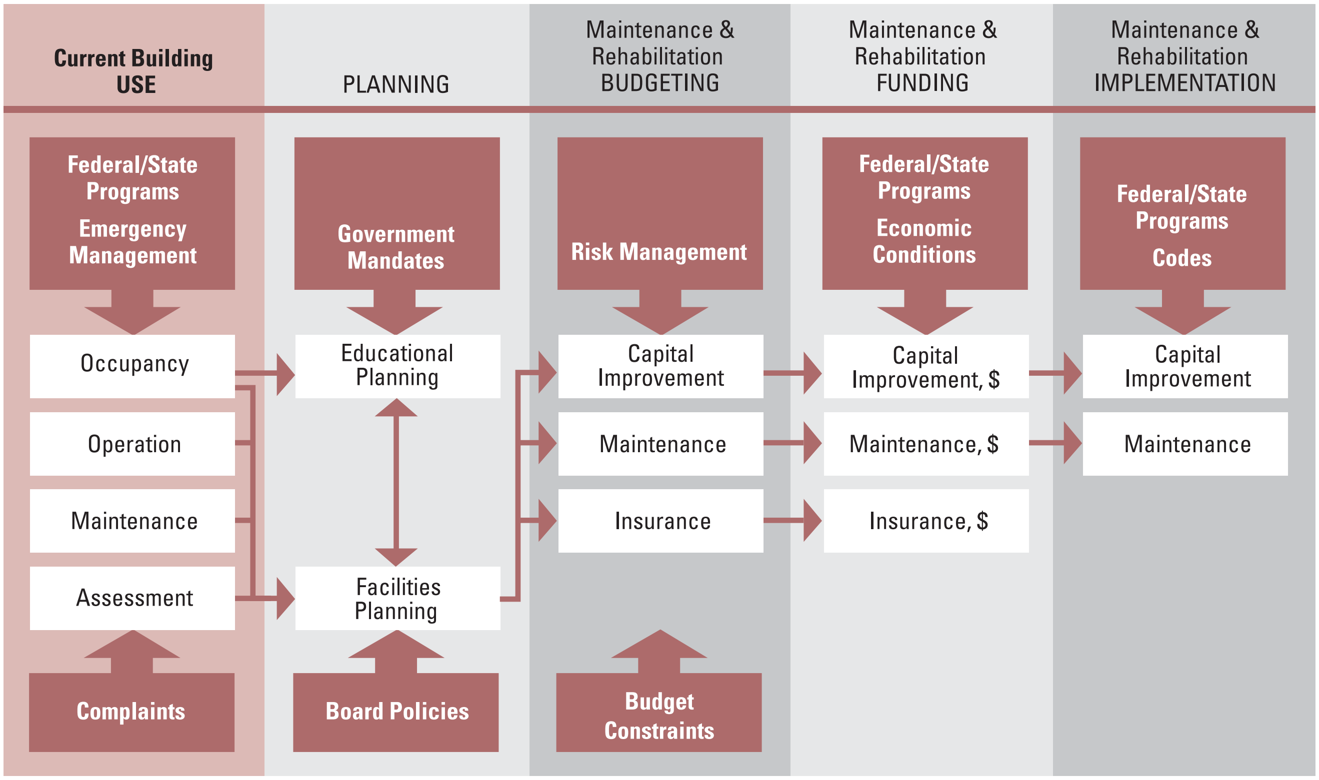
Occupancy: This category of activity consists of all the functions that the school is intended to shelter and to support. These include educational, support, and ancillary functions. The educational functions are determined by educational philosophy, demographics, sociological and anthropological factors, civil rights, resources, etc. Support functions are administrative. Ancillary functions may be recreational, community support, and emergency uses.

Occupancy functions are carried out in each facility under the authority of the principal by the principal, teachers, students, and others. Each of these functions is subject to seismic risk and can be disrupted by seismic damage.

Operation: Facility operation consists of all the activities and functions that the facility and its components must perform in order to support the occupancy. Examples are the mechanical functions (heating, cooling, ventilation), electrical functions (lighting, communications, alarm), and plumbing functions.

Operation functions may be carried out by custodial staff of the district or the individual facilities and/or by contractors. Each of these functions is subject to seismic risk and can be disrupted by seismic damage.

Figure 3: Use



Maintenance: Maintenance includes all the activities required to enable the occupancy and operation of the building to be carried out continuously over time. They can be broken down into custodial maintenance, routine maintenance, and repair.

Maintenance functions may be carried out by custodial staff of the individual facilities, by district staff, and/or by contractors.

Facility Assessment: Facility assessment, which some schools may not carry out systematically, consists of surveying or inspecting the school facilities on a scheduled basis. It may also include a review of documents, such as archival building plans, for retrieving specific information. The purpose(s) of the surveys or inspections is to determine facility conditions in relation to one or more of the following categories:

- user complaints
- maintenance needs
- preventive maintenance needs
- specific environmental hazards
  - asbestos
  - lead paint
  - lead
  - radon
- structural hazards
- fire/life safety
- environmental quality
- educational adequacy
- energy use/conservation
- accessibility
- other

These surveys may or may not be coordinated as to schedule, content, personnel, etc. Districts may or may not use prepared inspection forms or checklists. Finally, districts may vary as to the extent and specific nature of their record keeping and reporting.

Influences and Related Seismic Considerations

As indicated in Figure 3, two external factors (down arrows) and one internal factor (up arrow) influence current building use phase decision making.

Federal and state programs: Various external programs may establish requirements affecting the use of a school district's facilities (e.g., ADA and OSHA requirements). Additionally, governmental funding programs may mandate facility requirements in participating school districts (e.g., energy conservation).

Seismic Consideration

Currently there are no seismic rehabilitation mandates or implications in any federal or state programs related to schools outside of California.

Specific surveys or inspections may be mandated by federal, state, or local laws/programs. Others may be required by the district's own management practices. These surveys/inspections may be carried out by:

- Federal personnel (e.g., from OSHA or the EPA)
- State, county, or city personnel (e.g., the fire marshal or code enforcement, environmental, health, or education officials)
- School district personnel (e.g., custodial or facility managers)
- School district contracted personnel (e.g., asbestos inspectors)
- Consultants

In the case of smaller districts, it is likely that principals are involved in facility assessments.

Seismic Consideration

Currently there are no seismic survey or inspection mandates or implications in any federal or state programs related to schools outside of California. However, local emergency management plans may assign a specific function that a specific school should perform in a disaster. In such cases, a legitimate question is "In what condition will the building in question be following an earthquake?" Answering this question requires some form of seismic inspection.

Emergency Management: External state or local emergency management agencies may assign specific roles school buildings must perform in case of emergencies, including earthquakes. This may affect the occupancy activities by requiring periodic exercises involving building occupants.

Seismic Consideration

Emergency management plans related to the role of school facilities in a disaster may be general and broad, or detailed and specific. In some cases, specific schools are assigned a particular function they are to perform in an emergency.

Complaints by Occupants: Internal complaints are a potentially significant pressure on the facility management process. In reactive school districts, they are often the only motivators to action. In other districts, those engaged in proactive strategic facility planning activities, complaints may become the vehicle for channeling internal pressures of all kinds, including policies adopted by the Board and complaints generated in the occupancy phase, into capital improvements and maintenance.

Seismic Consideration

Rarely have there been complaints about seismic vulnerability generated by school building occupants outside of California. This is because seismic risk and seismic damage are not routine experiences in most regions of the United States. However, to cite two examples, the responses to the 1949 earthquake damage in Seattle and to the damage experienced by a school in the moderate Northwest Oregon Earthquake

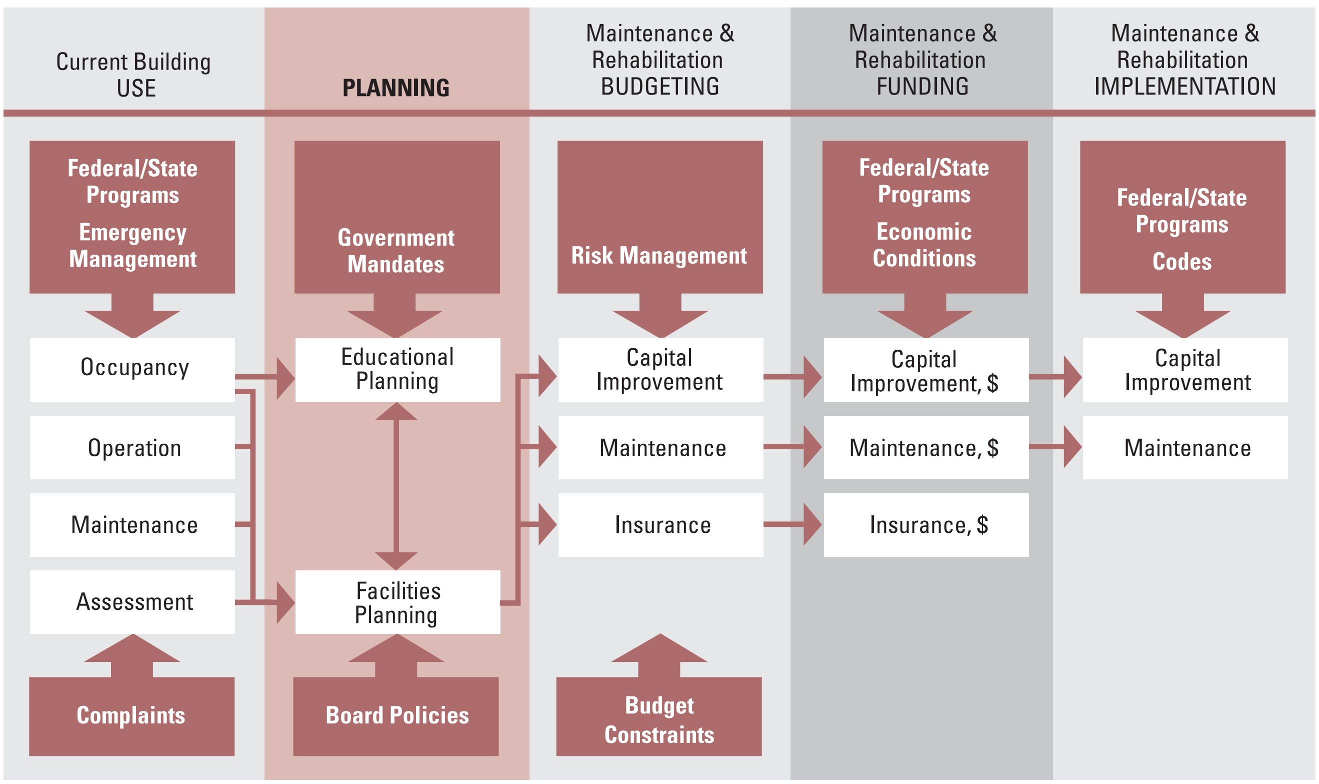
of March 25, 1993 suggest that informed occupants of schools in these regions may just become an effective constituency for seismic rehabilitation.

2. The PLANNING Phase of School Facility Management

Typical Process

The planning phase consists of projecting and forecasting future needs. It can be carried out periodically or continuously, and may vary as to the amount of time covered by the projections and forecasts. Planning functions may be carried out by the school district administration, with or without the assistance of consultants. Planning consists of two separate but related activities—educational planning and facility planning—and is affected by both external government requirements and internal board policies.

Figure 4: Planning



Educational Planning: Educational planning attempts to formulate future educational programs and their support needs by analyzing and forecasting several factors, such as:

- Demographics (population growth or decline, neighborhood shifts)
- Educational philosophy, including special education, adult education
- Educational technology
- Cultural and sociological factors
- Federal and state mandates
- Equity and civil rights

Facility Planning: Facility planning consists of preparing long-range facility plans, strategic facility plans, or some similar document, which some districts may not carry out systematically. It combines the products of two distinct activities—the educational plan and the facility assessment (see Figure 4)—

into a detailed projection of facility requirements. The projection may cover a defined time frame, such as 5 years.

Different districts may use different classifications of projects in their facility plans, reflecting a variety of legal, administrative, jurisdictional, and other factors. However they may be classified, a comprehensive facility plan should include the following elements:

- New construction
- Additions to existing buildings
- Renovations of existing buildings
- Building systems replacements
- Building systems repairs
- Scheduled maintenance
- Preventive maintenance
- Building disposition (change of use, sale, demolition)

The plan will identify the time frames in which each project is to be accomplished and may include cost estimates. Some experts have conceptualized the facility plan as consisting of four general categories, which may provide guidance for budgeting:

- Physical plant renewal
- Physical plant adaptation
- Catch-up maintenance
- New construction

If effective, the facility plan will be used as a budgeting tool and will provide valuable information for the budget process. It should be revised and updated on a routine basis to reflect:

- Changes in the educational plan
- Revised facility assessments
- Budgeting and funding realities

Influences and Related Seismic Considerations

Board Policies: In terms of internal influences, school boards may occasionally adopt written policies on issues of political and social significance that can affect both educational and facility planning. These policies guide the actions of the district administration.

Seismic Consideration

School boards may adopt policies addressing seismic issues, including seismic performance objectives and rehabilitation of school buildings, as either a one-time task or a recurring incremental program.

Government Mandates: Federal, state, and local government agencies have historically established external requirements affecting both educational and facility planning. These requirements may have facility rehabilitation implications. Some of these requirements may be accompanied by funding, perhaps providing an opportunity to integrate disparate objectives into coordinated actions.

Seismic Consideration

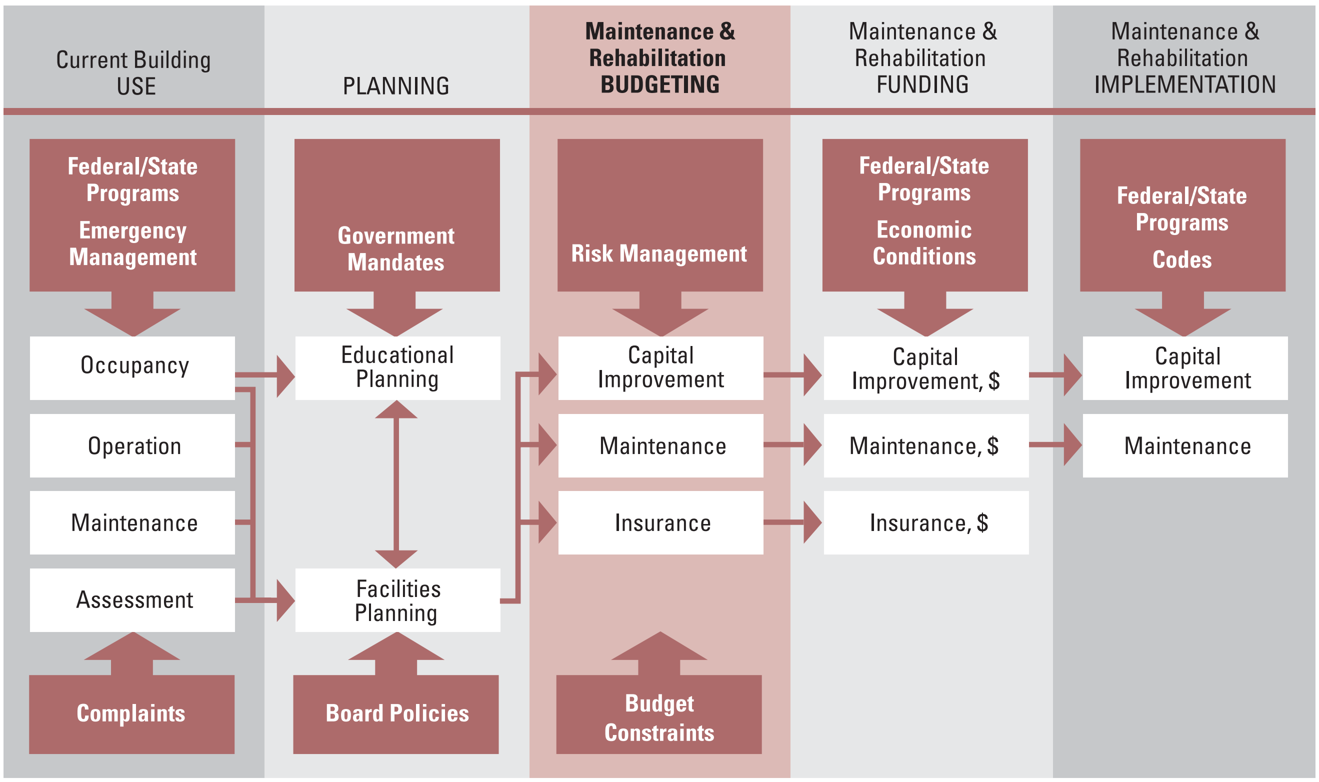
Currently there are no seismic rehabilitation mandates or implications in any federal or state programs related to existing schools outside of California.

3. The Maintenance and Rehabilitation BUDGETING Phase of School Facility Management

Typical Process

The budgeting phase consists of the projection of future financial resources required to meet future needs. It is carried out annually (covering a period of one or more years) by the school district administration (superintendent, business manager) and the board. It is affected by external risk management policies and internal budget constraints.

Figure 5: Budgeting



Three elements of the budget are relevant to the discussion of facility management:

- Capital improvements
- Maintenance
- Insurance

Capital Improvement Budgets: Capital improvement budgets generally relate to the acquisition of buildings and major systems, the occurrence of which is not annual or repetitive, and which can therefore be amortized. The distinction between capital improvement and maintenance budgets varies widely among school districts. At one extreme is a total separation, mandated by law, labor jurisdiction, or other factors. At the other extreme is a rather unclear separation between the two funding mechanisms.

Maintenance Budgets: Maintenance budgets generally relate to recurring annual expenditures and address existing inventories of buildings and systems without adding to the inventories. Maintenance activities are often part of operations budgets or general fund budgets. Reportedly, maintenance funds are often used to cover shortfalls in operations, which may have contributed to the proliferation of deferred maintenance in many school districts.

Insurance Budgets: Financial resources earmarked for insurance may be used in different ways, including purchasing third-party insurance, contributing to a regional or statewide risk and insurance pool, or funding a self-insurance reserve. Property and general liability insurance are relevant to facility management considerations.

Influences and Related Seismic Considerations

Budgetary Constraints: Internally, political and economic conditions may place limits on school capital and maintenance budgets. The problem is often exacerbated by unfunded mandates imposed on school districts by federal and state agencies.

> **Seismic Consideration**
> **The strategy of integrating incremental seismic rehabilitation with other work, which is an integral part of this facility and financial management model, can provide a method for addressing seismic risk reduction within budget constraints. See full discussion of this opportunity under Recommended Activities in Section B.2.2.4, Seismic Rehabilitation Planning for Specific Buildings.**

Risk and Insurance Management: Externally or internally, state and/or local school district risk and insurance management requirements may have a direct or indirect role in the budget phase of the process regarding the decisions related to insurance.

> **Seismic Consideration**
> **In areas of seismic hazard, the risks of building loss or damage, occupant death or injury, and school district liability must all be assessed. It must be decided whether to seek earthquake property and casualty insurance coverage and general liability coverage. Insurance companies that offer such coverage do not usually offer incentives to customers to undertake loss reduction measures in the form of seismic rehabilitation. However, this situation might change, and the question may be subject to negotiation.**

4. The Maintenance and Rehabilitation FUNDING Phase of School Facility Management

Typical Process

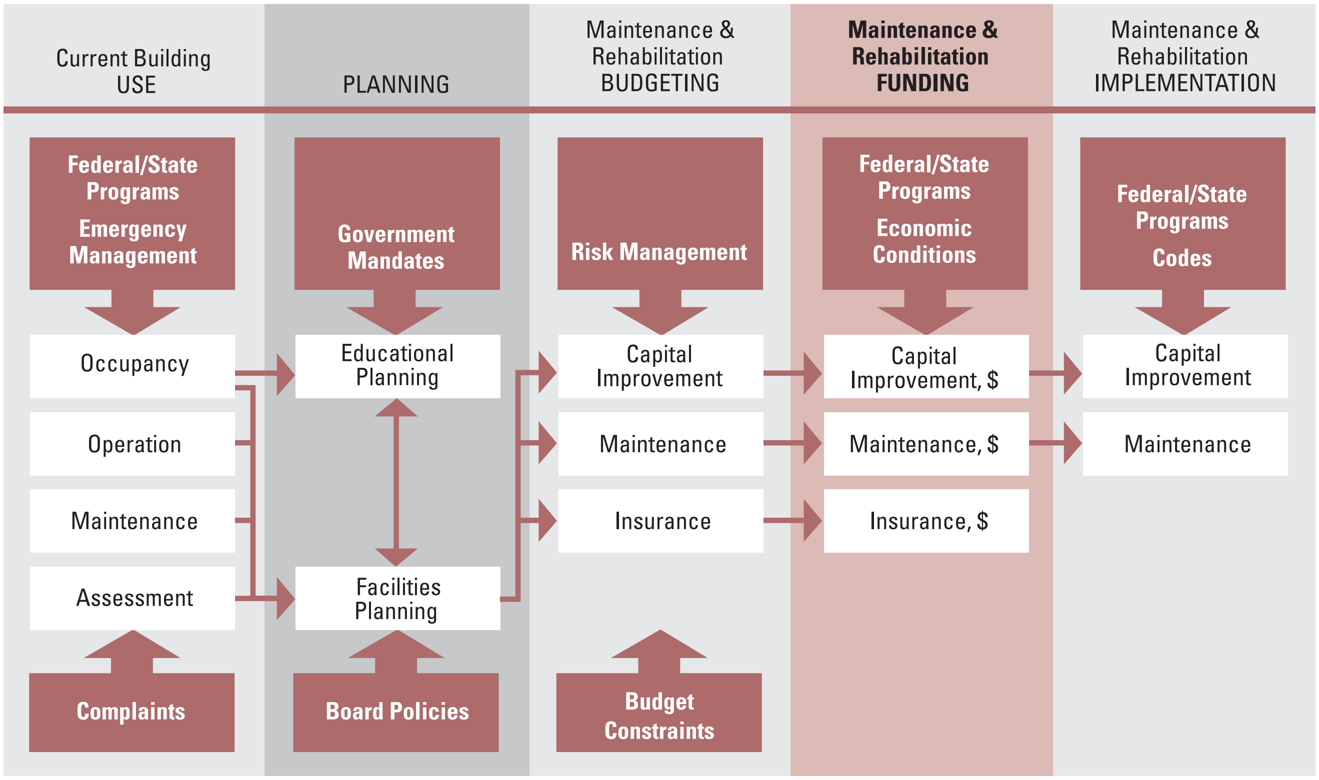
The funding phase consists of obtaining the financial resources to meet school needs. The funding of school budgets in general, and of the three budget elements of capital improvement, maintenance, and insurance, varies from district to district. Funding is influenced externally by regional and local economic conditions, federal and state programs, and bond financing regulations.

There is great variation from state to state, and often within a state, of the state contribution to local school budgets. Some states limit their contribution to capital improvement budgets and others contribute to a general fund. States may use different formulas for the allocation of resources to school districts in order to achieve equalization.

School districts can fund their budgets by various combinations of taxation and debt, both of which are in some cases controlled or limited by state constitutions or by periodic voter initiatives. Different school budgets may be subject to varying requirements of approval of taxation and/or debt by the electorate. At one extreme, some school boards are free to issue bonds without additional approval. At the other extreme, there are districts where local school budgets must be voted on at town meetings.

There are many local variations in funding where school districts, municipalities, and counties have overlapping jurisdictions.

Figure 6: Funding



Influences and Related Seismic Considerations

Regional and Local Economic Conditions: Externally, the funding of school construction is subject to local and national socioeconomic conditions well beyond the control of the school district. It depends on interest rates, the region's and school district's bond rating, and similar parameters.

> **Seismic Consideration**
> **Even though seismic rehabilitation is clearly a risk reduction activity, there is no evidence that any school district has improved its bond rating as the result of undertaking seismic mitigation activities of any kind.**

Federal and State Programs: The funding of school construction and rehabilitation may be subject to federal and state programs beyond the control of the school district, but that should be taken advantage of to the fullest extent possible for seismic rehabilitation purposes.

Bond Financing Regulations: The administrative procedures and structure locally in place to obtain bond financing will have a significant impact on the ability of a school district to achieve its objectives, regardless of whether or not they include seismic risk reduction. Certain types of expenditures out of the proceeds of a bond issue, such as operations or maintenance, may be prohibited by the conditions of the bond.

> **Seismic Consideration**
> **Some seismic rehabilitation increments may be classified as repair or maintenance work, and thereby be precluded from a capital improvement bond. As explained in Section B.2.2.7, Seattle Public Schools used two types of bonds to cover the funding of its incremental seismic rehabilitation program because of Washington state law.**

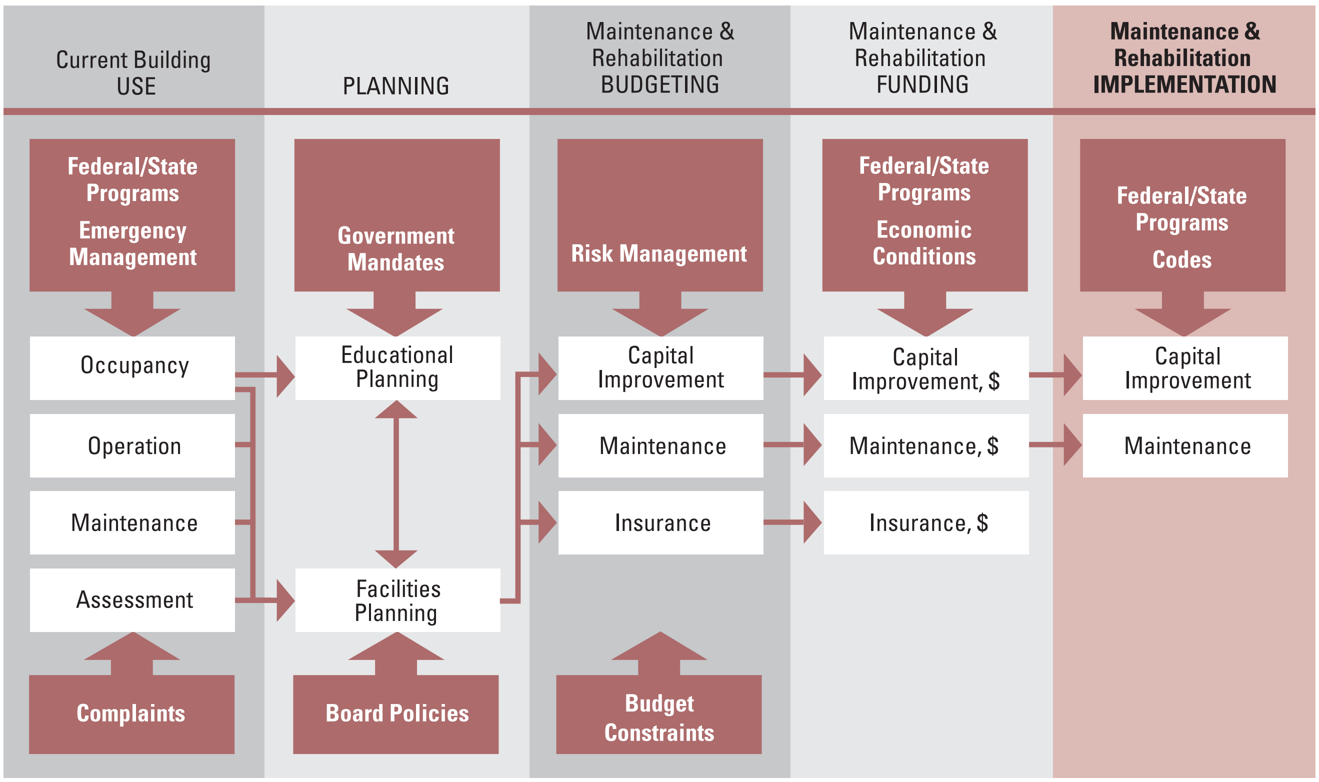
5. The Maintenance and Rehabilitation IMPLEMENTATION Phase of School Facility Management

Typical Process

The implementation phase includes design and construction, and can be broken into three categories of projects, of which the latter two are relevant to existing buildings:

- New building acquisition projects
- Capital improvement projects
- Maintenance projects

Figure 7: Implementation



The implementation phase is primarily affected by federal and state programs and external building code requirements.

Capital improvement and maintenance projects are managed by district staff and carried out by district staff and contractors. The management of these two categories may be separated or combined, depending on issues of labor jurisdiction and legal authority.

Influences and Related Seismic Considerations

Federal and State Mandates and Programs: Externally, federal and state programs may establish requirements affecting the implementation phase (e.g., ADA and OSHA requirements). Additionally, governmental funding programs may mandate requirements for facilities in participating school districts (e.g., energy conservation).

Seismic Consideration

Currently there are no seismic rehabilitation mandates or implications in any federal programs related to existing schools.

Codes and Code Enforcement: Also externally, building codes impose requirements on the implementation phase in cases of repair, alteration, or addition to existing buildings. These requirements may be enforced by a state or local agency, or there may be a requirement that school district staff be responsible for the enforcement (for example, in the state of Utah). Such requirements can add costs to a project and jeopardize feasibility.

Seismic Consideration

Codes do not mandate seismic rehabilitation in repair and alteration project, though additions must comply with building code seismic requirements. Incremental seismic rehabilitation is consistent with most building code requirements applicable to existing buildings.