



Design Guide

for Improving School Safety in Earthquakes, Floods, and High Winds

1 An Overview of the School Design and Construction Process

1.1 Introduction

This chapter presents an overview of the school building to provide a context for the chapters that follow. Every building is unique and school designs vary greatly; however, the purpose of schools, their occupancy, their economic basis, and their role in society dictate certain common features that distinguish them from other building types.

A summary of the national public school inventory is also presented (i.e., the number of students housed and the number of schools included) and projections of future needs are outlined. The sections that follow describe school design of the past, because many older schools are still in use and must be renovated periodically to meet today's needs, and current school design with some trends and ideas that might influence the design of future schools.

1.2 School Construction: The National Picture

In 2005, the estimated value of the nation's public school inventory was well over $361.6 billion.[1] In 2009, of the almost 98,800 public elementary and secondary schools, 31 percent were located in small towns and rural areas and served 43 percent of the students, while 69 percent were located in cities and suburban areas and served 57 percent of the students (U.S. Department of Education, 2009).

The total number of schools in the U.S. increased by 10,600 between 1997 and 2007 (U.S. Department of Education, 2009). More than half of all schools are at least 40 years old and, even with minor renovations, many have passed their prime in terms of adaptability to modern teaching methods and tools (e.g., computers, in-class electronic information displays, and group learning activities). Almost all States require school facilities to be replaced with new construction once renovation costs reach a specified level (usually 60 percent).[2] Estimates from the late 1990s indicated approximately $100 to over $300 billion would be needed to bring our nation's schools up to conditions considered to meet then-current standards.

> The purpose of schools, their occupancy, their economic basis, and their role in society dictate certain common features that distinguish them from other building types.

In 2001, the decade-long growth in kindergarten to grade 12 (K–12) new school construction peaked while deferred maintenance and poor construction quality of many post-World War II schools resulted in a huge renovation demand. From 1999 through 2008, the National Clearinghouse for Educational Facilities reported that $298.16 billion was spent on the construction of nearly 15,000 elementary, middle, and high schools (National Clearinghouse for Educational Facilities, 2010).

1.3 Past School Design

Schools are typically in use for long periods of time. As a result, even today, instruction continues in facilities that were designed and constructed at the beginning of the 20th century. Early 20th-century school design was based on late 19th-century models and few design changes were implemented until after World War II. Schools ranged from one-room rural school houses to major symbolic civic

1 Conservative estimate based upon elementary and secondary school averages developed with the help of Paul Abramson, President of Stanton Leggett & Associates, Education Consultants.

2 Use of this estimate as a decision tool was developed by Basil Castaldi, *Education Facilities, Planning, Modernization and Management* (1994).

structures in large cities (Figures 1-1 and 1-2). Many inner city schools were more modest, inserted into small sites on busy streets and constrained by budget limitations (Figure 1-3).

Figure 1-1: One-room schoolhouse, Christiana, DE, 1923

Figure 1-2: High school, New York City, NY, 1929

The typical city school was one to three stories in height and consisted of rows of classrooms on either side of a wide, noisy corridor lined with metal lockers. Typical outdoor recreational areas were asphalt play courts and rooftops. The larger schools sometimes had libraries, special rooms for art, science, and shop, and auditoriums.

The construction surge to meet the demands of the post-war baby boom was primarily a suburban development. Much larger sites were available, buildings were one or two stories in height, auditoriums became multi-use facilities, and large parking lots appeared.

Figure 1-3: Elementary school, Washington, DC, constructed in 1930

Despite the growth of suburban construction, the fundamental design with classrooms along double-loaded corridors did not change very much. However, in warm climates, the one-story “finger plan” school, typically constructed of wood and a small quantity of steel, was both economical and less institutional in feel. For this design, the noisy double-loaded corridor is replaced by a covered walkway, often open to the air, with the classrooms on one side and a grassed court on the other (Figure 1-4). The cross-section diagram in Figure 1-4 shows the simple and effective means this configuration allowed for day lighting and ventilation. Compact versions of these plans appeared as schools became larger and sites smaller (Figure 1-5).

Historically, inner-city high schools have been large facilities, housing 2,000 to 3,000 students (Figure 1-6). In the 1960s and 1970s, educational methods such as team teaching prompted large open classrooms with poor acoustics (Figure 1-7). Some of these new large high schools were built as air-conditioned enclosures, with many windowless classrooms, in buildings that resembled the shopping malls that were replacing the main street retail centers (Figure 1-7). At the same time, many schools were expanded by adding classrooms to accommodate increasing enrollments. Although portable classrooms were originally intended as temporary space, many are now used as permanent classrooms (Figure 1-8).

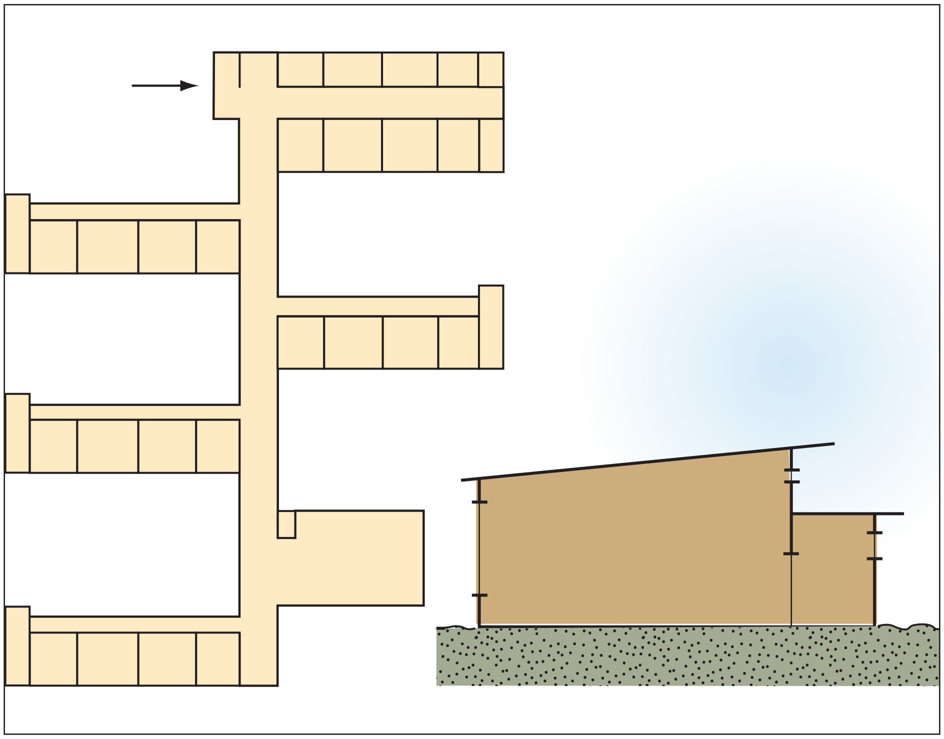

Figure 1-4:
Typical finger plan school, 1940s

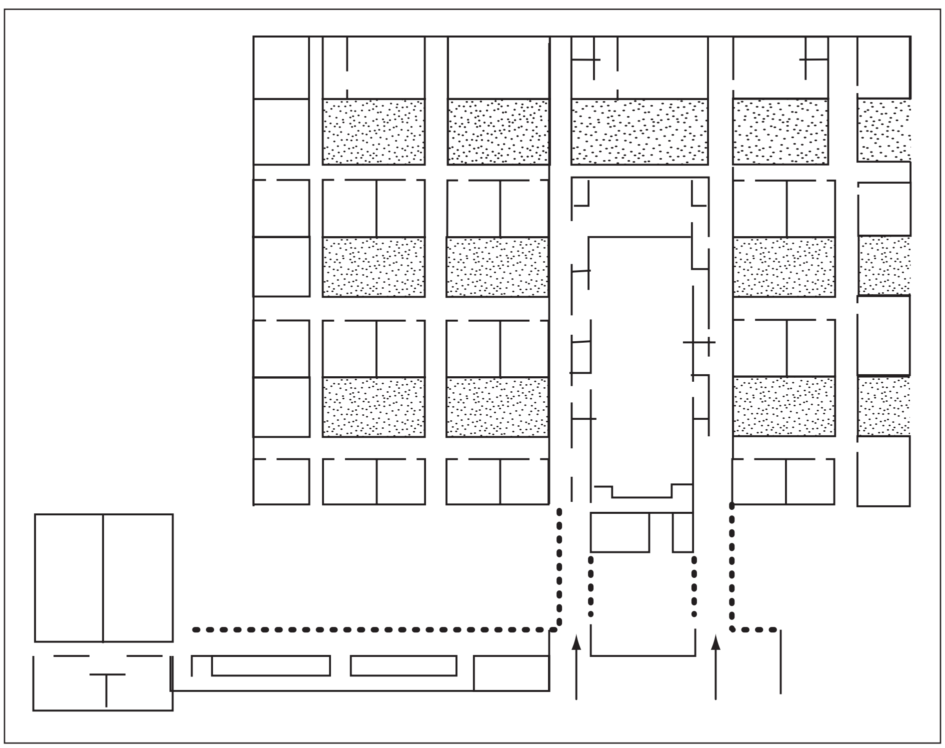

Figure 1-5:
Compact courtyard plan, 1960s

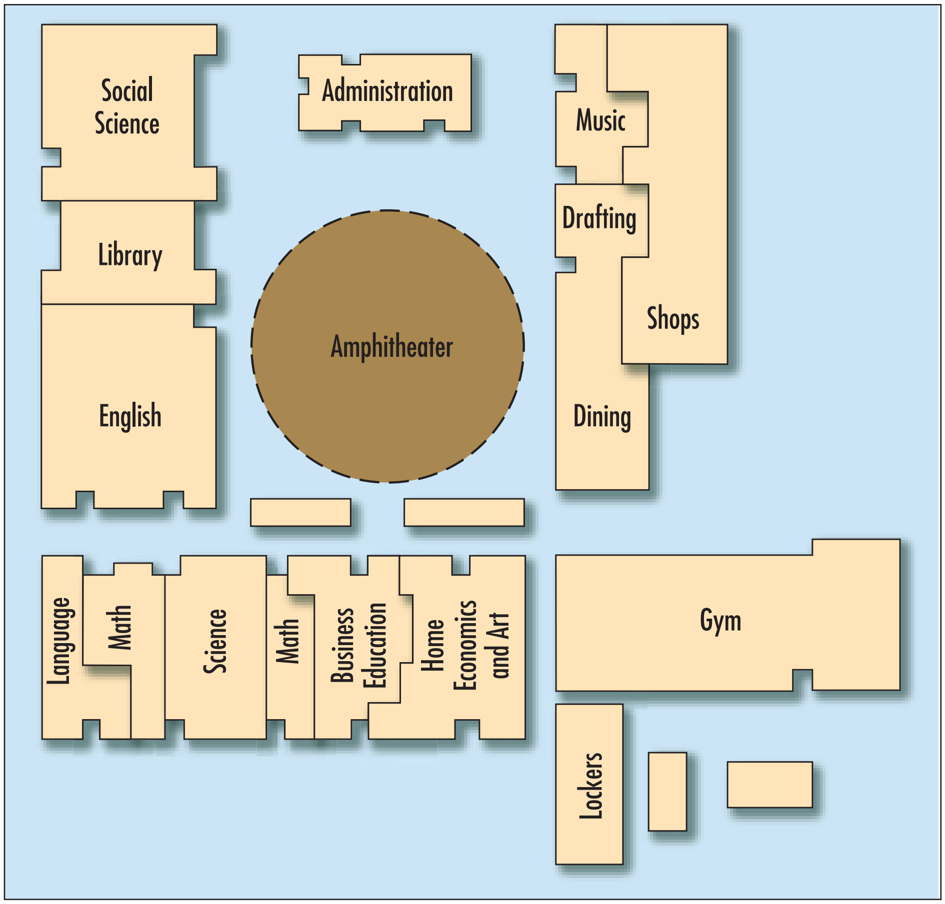

Figure 1-6:
Fountain Valley High School, Huntington Beach, CA, 1964

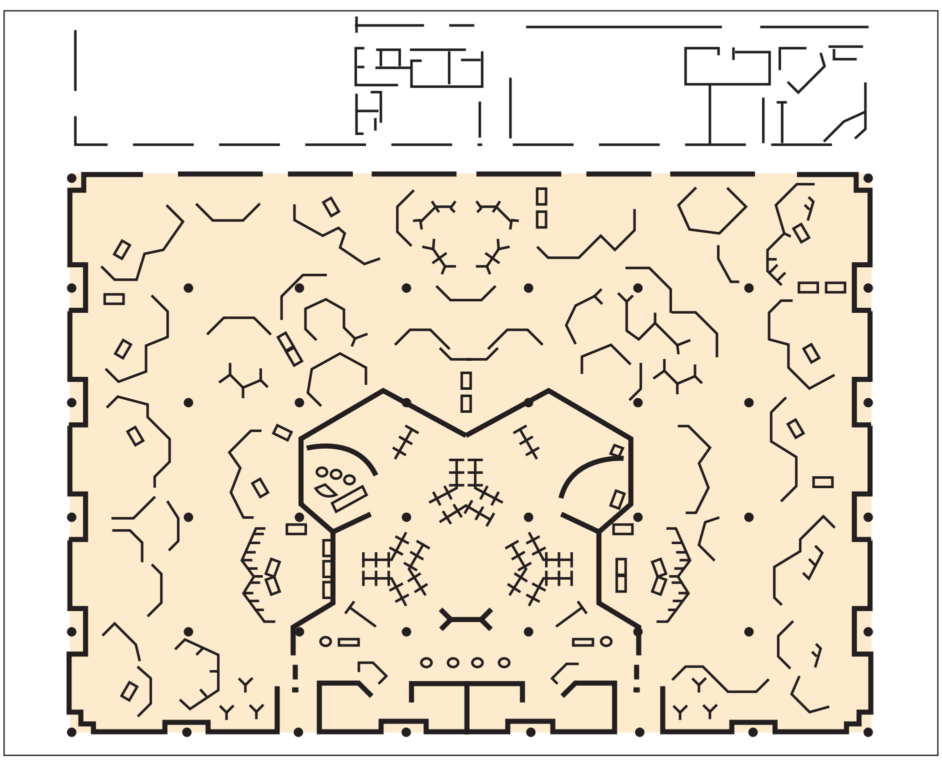

Figure 1-7:
Open enclosure plan teaching area, with movable screens and storage, Rhode Island, 1970

Figure 1-8: Typical portable classrooms, 1980s, still in use

Schools built in the 1980s and 1990s assumed a wide variety of forms, often combining classrooms into clusters and focusing on providing an attractive learning environment (Figure 1-9). However, demographic needs, shortage of affordable land, and limited construction budgets also resulted in some conversions of existing buildings not originally intended for educational purposes (Figure 1-10). Note the exterior cross bracing for the converted industrial building in Figure 1-10. The building required extensive retrofitting to meet California's seismic requirements for schools.

Figure 1-9: Elementary school, Fairfield, PA, 1980s

Figure 1-10: Private high school located in a remodeled industrial building, Palo Alto, CA

1.4 Present School Design

At the beginning of the 21st century, evolving social, economic, and educational concerns prompted a number of changes in school design. New design goals have begun to emerge, though some of the following have always been considered:

- The building should provide for health, safety, and security.
- The learning environment should enhance teaching and learning and accommodate the needs of all learners.
- The learning environment should serve as a center for the community.
- The learning environment should result from a planning/design process that involves all stakeholders.
- The learning environment should allow for flexibility and adaptability to changing needs.
- The learning environment should make effective use of all available resources.

These goals have lead, in turn, to a number of current design principles, including:

- Design for protection against natural hazards
- Design with increased attention to occupant security
- Design with increased use of day lighting and comfort control
- Design for durability

- Long-life/loose-fit approach: design for internal change and flexibility
- Design for sustainability (also referred to as environmentally friendly construction, green construction, and green building)

Some new schools already respond to these needs and, indeed, their originators, school districts, communities, and designers are among those defining school design for the future. Some of the changes are the result of ideology and analysis. Other changes reflect efforts to provide an improved learning environment and enhanced learning resources in an economy with increasingly limited funding for school construction. Some school districts will be faced with having to provide a minimal learning environment with buildings of the utmost simplicity, while meeting the requirements for health, safety, and security.

In recent years, building methods that recognize "green" building practices for both new construction and renovation have become increasingly available. One example is the California Green Building Standards Code, which became effective in August 2009 (California Building Standards Commission, 2009). As interest in sustainability increases and more school districts seek to implement various aspects of green building design, construction, and maintenance practices, design professionals are incorporating new approaches to make buildings more energy efficient and sustainable with respect to impacts on the environment. These approaches are already having a significant influence on building construction, and are likely to have greater influence as proven, innovative designs are incorporated into regular practice. A wealth of guidance on green design and construction practices that is specific to schools—both for new construction and renovations—is being developed, and rating systems are being strengthened and utilized to better guide those involved in the process to more sustainable solutions.

1.5 Future School Design

Schools will continue to vary widely in size. However, even in many suburban areas suitable land has become increasingly scarce and expensive. Sprawling one-story campuses will become less common and more schools will be more compact and multi-story (Figure 1-11). The desire for more humanistic environments and the rejection of traditional school plans will likely result in more imaginative and more complex layouts (Figure 1-12), while the move to re-populate inner cities may result in the construction of dense and compact schools. Despite evidence of a trend towards larger buildings, many educational researchers believe that students improve their learning skills best in smaller schools.

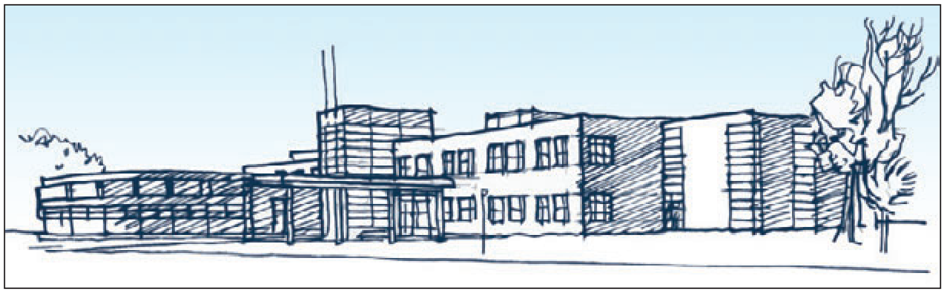

Figure 1-11:
West High School,
Aurora, IL, 2000

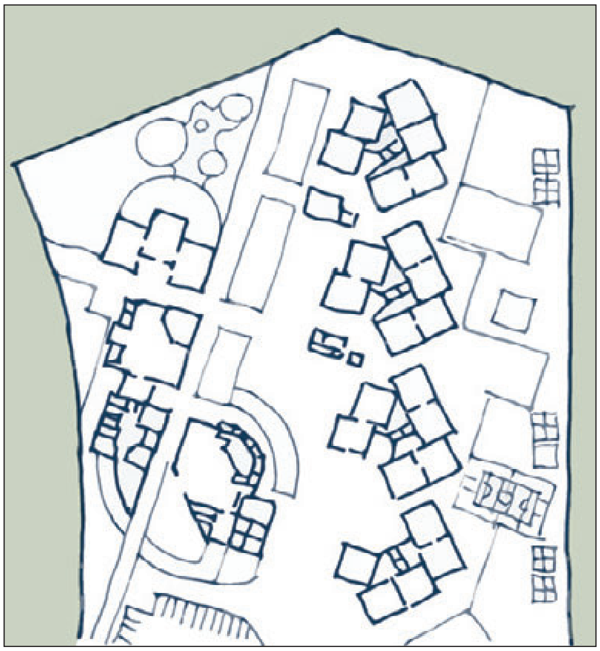

Figure 1-12:
Elementary school,
Oxnard, CA, 2000

Although constructing more small schools may be economically unrealistic, methods of organization are being explored that provide some of the benefits of small size within a large physical complex. Some schools are organized into "learning academies" for each grade, with classrooms that can expand and contract, along with other activity rooms of various sizes.

Other researchers believe that the conventional library will disappear. The trend in many new schools is for the library to take the form of a multi-media center and material collections, including laptop computers that are distributed from mobile units to "classroom clusters."

Schools are increasingly seen as community resources that go beyond their primary educational functions. Adult education and community events now take place on evenings, weekends, and throughout traditional vacation periods. These uses provide affordable means to enhance community service resources by maximizing a facility's utilization.

There is a growing awareness of the importance of recognizing natural hazards that may affect schools. The likelihood of earthquakes, floods, hurricanes, and tornadoes will continue to be, at some locations, a source of worry and fear. Aside from protecting students, schools in earthquake-prone regions are often used as post-earthquake shelters and schools in hurricane- and tornado-prone regions are also used as shelters. In California, the State's Field Act, enacted in 1933 following the Long Beach earthquake, requires public schools to be designed by a licensed architect or engineer and the Department of the State Architect is required to check plans and inspect construction. Elsewhere, floods and high winds occur with sufficient frequency that resistance to their effects must be addressed by knowledgeable designers and good construction practices.

1.6 The Design and Construction Process

Certain basic steps are necessary and certain basic procedures must be followed for any school construction program. The actual procedures followed will vary greatly in scope between the design of a single small elementary school and the development of a multi-school program that involves both new and remedial construction. Review and regulation procedures by outside agencies will also vary. Internal decisions by a school district regarding the design and construction process (e.g., conventional architect design and competitive construction bid, design/build, or construction manager) will affect the scope and timing of some of the activities.

Many of the steps in the design and construction process are appropriate when evaluating existing schools for proposed renovation. Specific factors to consider when evaluating seismic, flood, and wind hazards at existing schools are described in this design guide.

Regardless of the size and scope of a project, a number of planning steps should be taken by school districts and their design teams. For a small project, the steps may entail relatively informal meetings among a few district staff, the school board, and others. For a larger program, formal procedures should be established to include the following steps.

- Conduct an in-house assessment of the educational needs, often with the assistance of a public education committee and consultants. Contributions of the committee continue throughout the programming and design process, and may involve acquiring input from specialists as necessary at different stages for a large program.
- Determine the size and scope of the proposed program. (In a small district, an architect may be employed to assist the school district with this task; the architect may later become the design architect.)
- Conduct a siting assessment to determine the size and availability of sites (and lease/purchase as necessary) and to identify avoidable site constraints such as the presence of flood hazard areas, wetlands, and steep slopes.
- Develop educational specifications by in-house staff and/or consultants.
- Conduct a financial assessment.
- Identify financial resources, including alternative sources of funding (e.g., State and Federal programs, local taxes, bond issues).
- Ensure funding is made available (e.g., obtain State grants or pass bond issue).

- Appoint district building program management staff (appointed officials or a committee).
- Determine the design and construction process (i.e., conventional design and bid, design/build, or construction management).
- Select and hire architects and other special design consultants or design/build team members; the timing of hiring will vary depending on the number of projects, whether programming is involved, and other variables.
- Develop building programs, including building size, room size, equipment, and environmental requirements; this may be done by in-house staff and/or architects or independent program consultants.
- Appoint a district staff and public stakeholders committee for the design phase.
- Develop designs (architects) and cost estimates. Hold public meetings with architects and encourage public input into the design; conduct district progress reviews.
- Complete design and conduct district review of contract documents.
- Submit construction documents to permitting agencies for review and approval.
- Submit documents to building department and other required agencies.
- Select the contractor (bidding) or finalize design/build or construction management contracts.
- Begin school construction.
- Administer construction contract.
- Initiate architect observations and inspections as required.
- Complete school construction.
- Obtain occupancy permit from the building department.
- Obtain architect acceptance.
- Obtain school district acceptance.
- Commission and occupy school.

The sequence of the above steps may vary, depending on the complexity of the program, and some steps may be implemented simultaneously. The flow chart in Figure 1-13 illustrates the typical process and identifies how specific activities related to design for natural hazards fit into the general planning and design process.

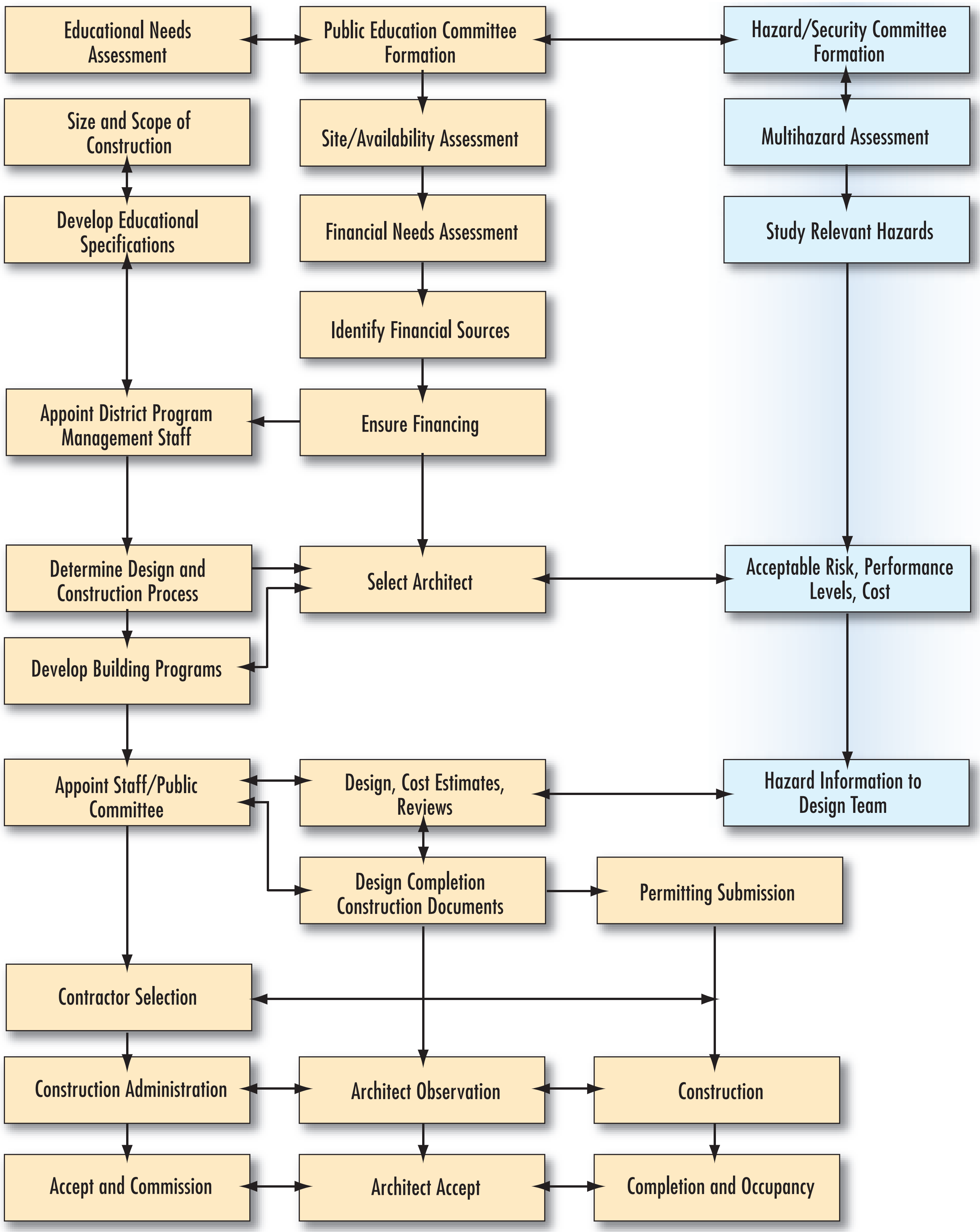

Figure 1-13: Design and construction process flow chart

1.7 References

Castaldi, Basil, 1994. *Education Facilities, Planning, Modernization and Management*, Fourth edition, Boston, MA: Allyn & Bacon.

California Building Standards Commission, 2009. 2008 California Green Building Standards Code, Sacramento, CA, January 2009.

National Clearinghouse for Educational Facilities, *U.S. K-12 School Construction Data 1999–2008*, http://www.ncef.org/cd/School-Construction-Data-1999-2008.pdf, accessed April 21, 2010, citing McGraw-Hill Construction Data 1998–2008.

U.S. Department of Education, 2009. *The Digest of Education Statistics, 2008*, National Center of Education Statistics, Washington, DC, March 18, 2009.