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 there is great variety in school design; however, the purpose of schools, their occupancy, their economic basis, and their role in the social scene mean that there are certain common features of schools that distinguish them from other building types.

A summary of the national public school inventory is presented (i.e., how many students it houses and how many schools it contains) and projections of future needs are also outlined. School design of the past is discussed, because many older schools are still in use and must be renovated periodically to meet today's needs. The present state of school design is also discussed and some trends and ideas that might influence future schools are identified.

1.2 SCHOOL CONSTRUCTION: THE NATIONAL PICTURE

The estimated value of the national public school inventory is well over $361.6 billion.[1] Of the almost 15,000 local education agencies found throughout the United States (U.S.), 41.9 percent are in small towns and rural areas, and enroll 30.4 percent of the students; 25.9 percent are in large towns and cities, and enroll 30.7 percent of the students; and 32.2 percent of the education agencies are in suburban areas, and enroll 39 percent of the students.[2]

Over half of our school facilities are at least 40 years old[3] and, even with minor renovations, have passed their prime in terms of adapt-

[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] U.S. Department of Education, National Center of Education Statistics; *The Digest of Education Statistics*, 2001.

[3] U.S. Department of Education, National Center of Education Statistics, *The Digest of Education Statistics*, 2001.

ability to modern teaching methods and tools (e.g., computers, in-class electronic information displays, and group learning activities). Almost all states require new construction once replacement costs reach a certain level (usually 60 percent[4]). The most recent studies (completed at the close of the last decade) show a range of $100 to over $300 billion would be needed to bring our nation's schools into good teaching condition.

In 2001, the decade-long growth in kindergarten to grade 12 (K-12) school construction reached a peak. A propensity for deferred maintenance and the poor construction quality of many post-World War II schools have resulted in a huge renovation demand, and population increases mean that additional space will also be necessary.

If new construction, remodeled space, and additions are included, 2001 witnessed over $29.5 billion in school construction throughout the United States, with primary school projects slightly edging out high school projects in total number, but not in construction dollars. The overall school construction intensity dropped slightly to $28.2 billion, but is forecast to rise to $29.15 billion by mid-decade. From 2001 through 2005, it is estimated that almost a billion square feet of either new, renovated, or additional square feet will be added to the national school inventory.

1.3 PAST SCHOOL DESIGN

Schools are typically in use for long periods of time; as a result, teaching continues to be conducted 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 was relatively static until after World War II. Schools ranged from one-room rural school houses to major symbolic civic structures in large cities. Other inner city schools were more modest, inserted into small sites on busy streets and constrained by budget limits (see Figures 1-1, 1-2, and 1-3).

[4] Use of this estimate as a decision tool was developed by Basil Castoldi, *Education Facilities, Planning, Modernization and Management*, fourth edition, Allyn & Bacon publishers, page 385.

Figure 1-1
One-room schoolhouse, Christiana, DE, 1923
SKETCH BY: CHRIS ARNOLD

Figure 1-2
High school, New York City, 1929
SKETCH BY: CHRIS ARNOLD

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; asphalt play courts; and, sometimes, rooftop recreational areas. The larger schools sometimes had a library, special rooms for art, science, and shop, and an auditorium.

The surge to meet the school construction demands of the post war baby-boom was primarily a suburban development. Much larger sites were available, schools were one or two stories in height, auditoriums became multiuse buildings, and large parking lots appeared. However, many rural schools were located far away from towns and their resources, such as fire departments and other services.

Figure 1-3
Elementary school,
Washington, DC, 1930

But the fundamental school program of classrooms along double-loaded corridors did not change very much. However, in warm climates, the one-story finger plan school, constructed of wood and a small quantity of steel, was both economical and more human, and the noisy tiled double-loaded corridor became a covered walk, open to the air, with the classrooms on one side and a grassed court on the other (see Figure 1-4). Compact versions of these plans appeared as schools became larger and sites smaller (see Figure 1-5).

Inner-city high schools were usually large facilities, housing 2,000 to 3,000 students (basically small towns with complex social, economic, and class systems; see Figure 1-6). In the 1960s and 1970s, some design experiments were tried, such as team teaching, which spawned large open classrooms with poor acoustics (see Figure 1-7). Some of the new large high schools were built as air-conditioned enclosures, with many windowless classrooms, in buildings similar to the shopping malls that replaced the main street retail centers (see Figure 1-7). At the same time, many schools were expanded by adding prefabricated classrooms to accommodate a surge in enrollment. Although the prefabricated classrooms were originally intended as temporary space, many are now used as permanent classrooms (see Figure 1-8).

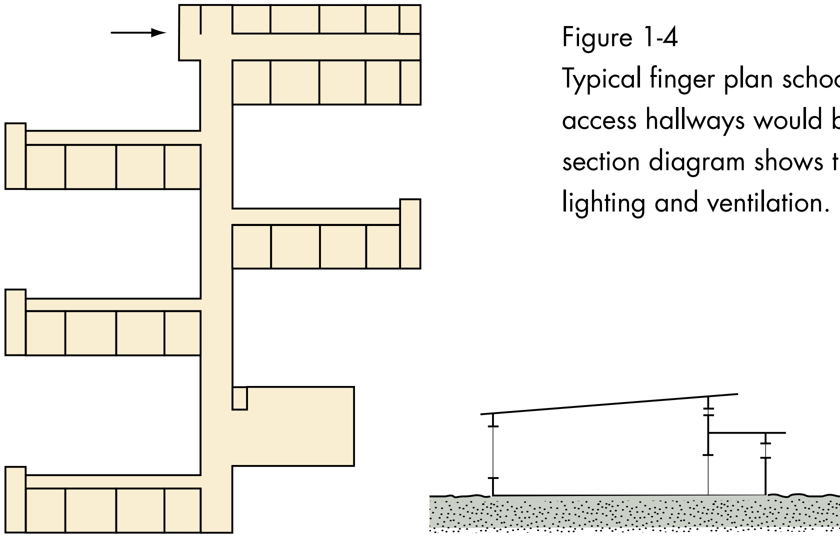

Figure 1-4
Typical finger plan school, 1940s. In California, the access hallways would be open to the air. The cross-section diagram shows the simple and effective day lighting and ventilation.

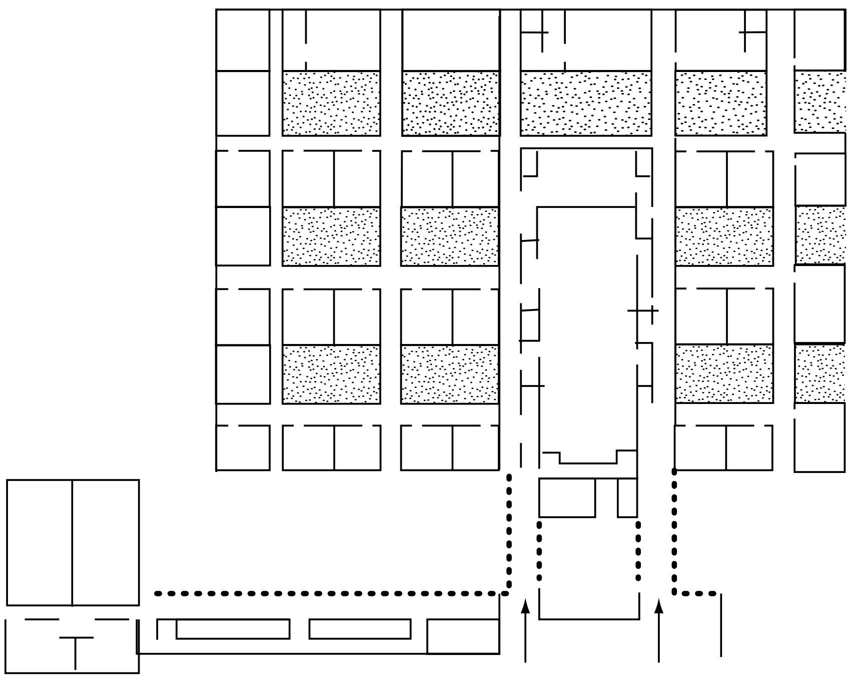

Figure 1-5
Compact courtyard plan, 1960s

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 (see Figure 1-9). However, demographic needs, shortage of affordable land, and limited funding has also resulted in instances of the adaptation of existing non-educational buildings into schools (see Figure 1-10).

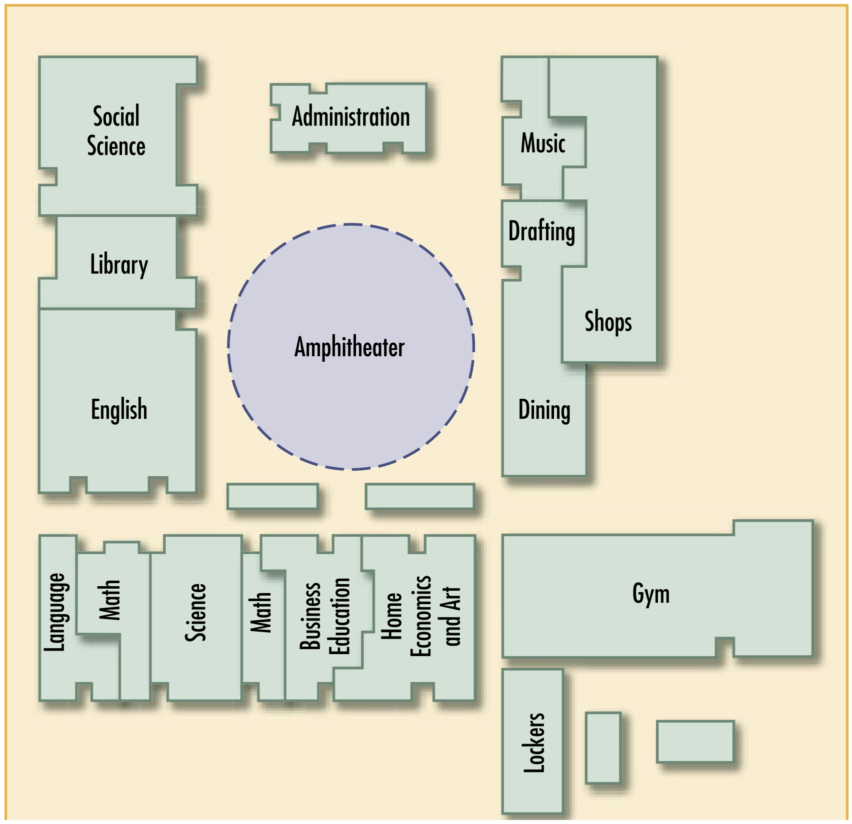

Figure 1-6
Fountain Valley High School, Huntington Beach, CA, 1964
(330 students)

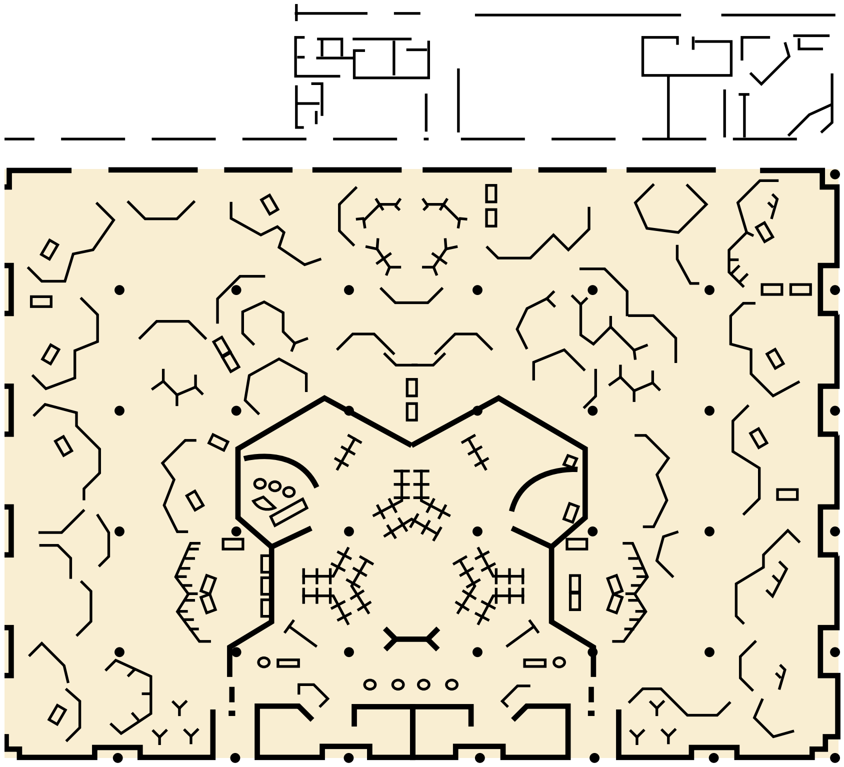

Figure 1-7
Open enclosure plan teaching area, with movable screens and storage, Rhode Island, 1970

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

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

Figure 1-10
Private high school, Palo Alto, CA, located in a remodeled industrial building. Note the exterior cross bracing; the building required extensive retrofitting to meet school seismic requirements.

1.4 PRESENT SCHOOL DESIGN

As the U.S. begins a new century, there are indications that a new era of social, economic, and educational concerns is evolving that will impact school design. New statements of design principles are beginning to emerge, although some of the following represent perennial concerns:

- 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 the center of 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 principles lead, in turn, to a number of current design principles, including:

- Design for protection against natural hazards
- Increased design attention to occupant security
- Careful lighting design and 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, including energy efficiency and the use of "green" materials

Some new schools already respond to these needs[5] and, indeed, their originators, school districts, communities, and designers are among those defining the schools of the next decade. Some of the changes are the result of ideology and analysis; others are enforced by the effort to provide an improved learning environment and enhanced learning resources in an increasingly financially limited school construction economy. Some school districts will be hard pressed to provide a minimal learning environment with buildings of the utmost simplicity, while meeting the requirements for health, safety, and security.

1.5 FUTURE SCHOOL DESIGN

Schools will continue to vary widely in size; however, even in the suburbs, land has become scarce and expensive. New schools will be more compact and the sprawling one-story campus will become less common (see Figure 1-11). The desire for more supportive environments and the rejection of traditional school plans will result in more imaginative and often more complex layouts (see Figure 1-12). Moreover, the move to repopulate the inner cities will result in the construction of even more dense and compact schools.

However, many educational researchers believe that students improve their learning skills in smaller schools.

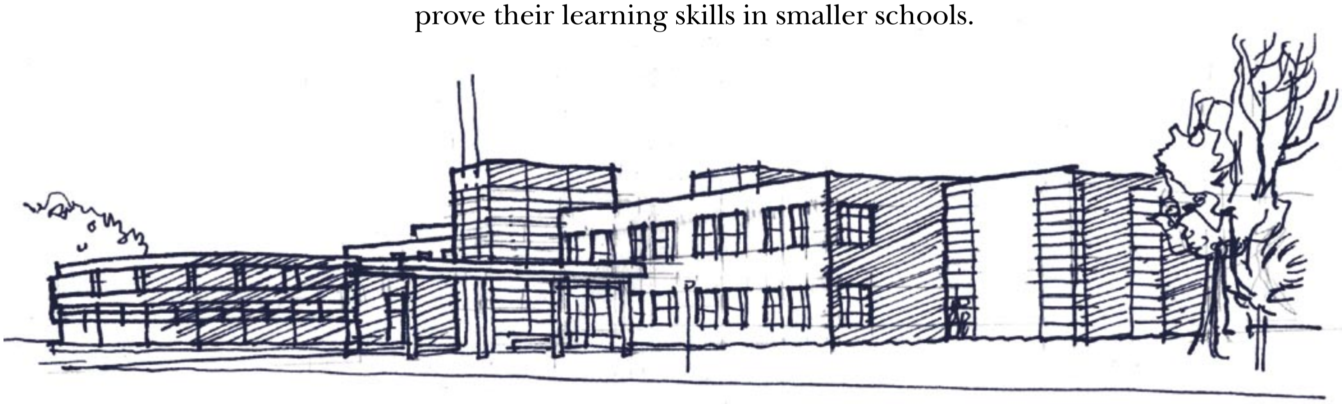

Figure 1-11 West High School, Aurora, IL, 2000

SKETCH BY: CHRIS ARNOLD

[5] Data provided by the National Clearinghouse for Educational Facilities, Washington, DC.

Although 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, and other activity rooms of various sizes.

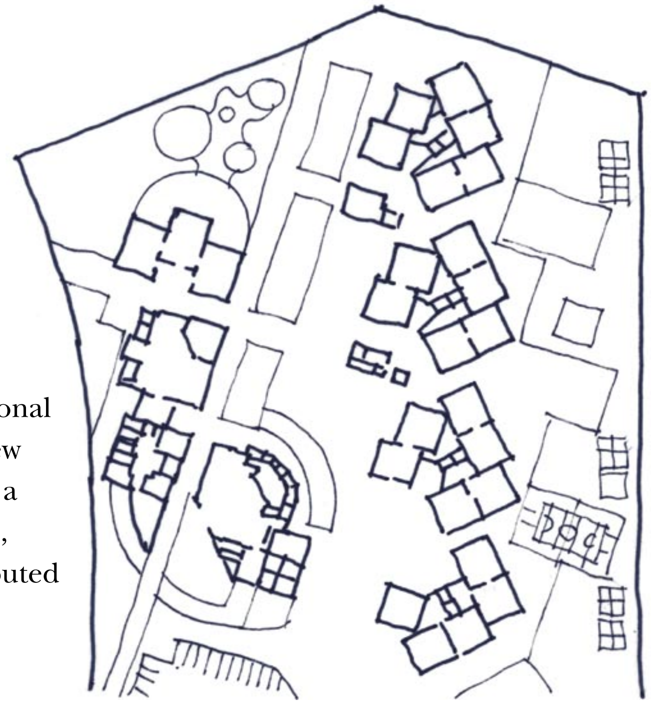

Figure1-12
Elementary school, Oxnard, CA, 2000
SKETCH BY: CHRIS ARNOLD

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 the educational functions. Adult education and community events now take place on evenings, weekends, and throughout the traditional vacation periods; therefore, the school day and week have been expanded. These uses are seen as ways of finding affordable methods of enhancing community service resources by ensuring that a facility’s utilization is maximized.

Indications are that the school building will probably increase in importance to the community, as its roles expand beyond that of merely providing a K-12 education for students during a school year. At the same time, modern technology means that today’s schools, already far more complex than the relatively simple buildings of a few decades ago, will tend to be more fragile and consequently more vulnerable to nature’s and society’s threats unless special attention is paid to their design and construction.

The natural hazards will remain: earthquakes and tornadoes will continue to be, for some locations, a source of worry and fear. Besides protecting their occupants, schools in earthquake-prone regions are often used as post-earthquake shelters. In California, this is particularly appropriate because the State's Field Act, enacted in 1933, following the Long Beach earthquake, requires that public schools be designed by a licensed architect or engineer, their plans checked, and the construction on site inspected by staff of the Department of State of Architecture. Elsewhere, floods and high winds are a familiar threat that also must be addressed by knowledgeable design and good construction practice. Schools, or designated areas within them, located in hurricane- and tornado-prone areas are increasingly being constructed to provide shelter for the occupants.

1.6 THE DESIGN AND CONSTRUCTION PROCESS

Regardless of the size of a school construction program, certain steps are necessary and certain procedures must be followed. These will vary greatly in scope between the design of a small elementary school and the development of a multi-school program of new and remedial construction. Review and regulation procedures by outside agencies will also vary. Internal district decisions as to 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.

However, regardless of the size and scope of the project, the following steps should be taken; for a small project, they may entail relatively informal meetings among a few district staff, the school board, and others; for a large program, formal procedures must be established. These steps are summarized in a flow chart (see Figure 1-13) that follows this listing.

- Conduct an in-house assessment of the educational needs, with the assistance of a public education committee and consultants. Public committees continue throughout the programming and design process, acquiring specialist members 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, who may later become the design architect).
- Conduct an assessment of the site needs to determine the size and availability of sites (and lease/purchase as necessary).
- Develop educational specifications, both in-house and/or consultants.
- Conduct an assessment of financial needs.
- Identify financial resources, including alternative sources of funding (e.g., state and federal programs, local taxes, bond issues).
- Ensure funding (e.g., pass bond issue).
- Appoint a 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 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 in-house and/or architects or independent program consultants may assist.
- Appoint the district staff and public stakeholders committee for the design phase.
- Develop designs (architects), together with cost estimates. Hold public meetings with architects and encourage public input into the design, together with district progress reviews.
- Design completion, district review of contract documents.

- ❍ Submit construction documents to the district and any 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.
- ❍ School construction.
- ❍ School district administration of construction contract.
- ❍ Observation by architect and inspection as required.
- ❍ School completed by contractor
- ❍ School inspected and accepted by architect.
- ❍ School inspected and accepted by school district.
- ❍ School commissioned and occupied.

The sequence of the above steps may vary, depending on the complexity of the program; some steps may be implemented simultaneously.

Figure 1-13 shows a flow chart of this typical process. Also shown (in the five boxes to the right) are specific activities related to design for multihazards and how these fit into the general construction process.

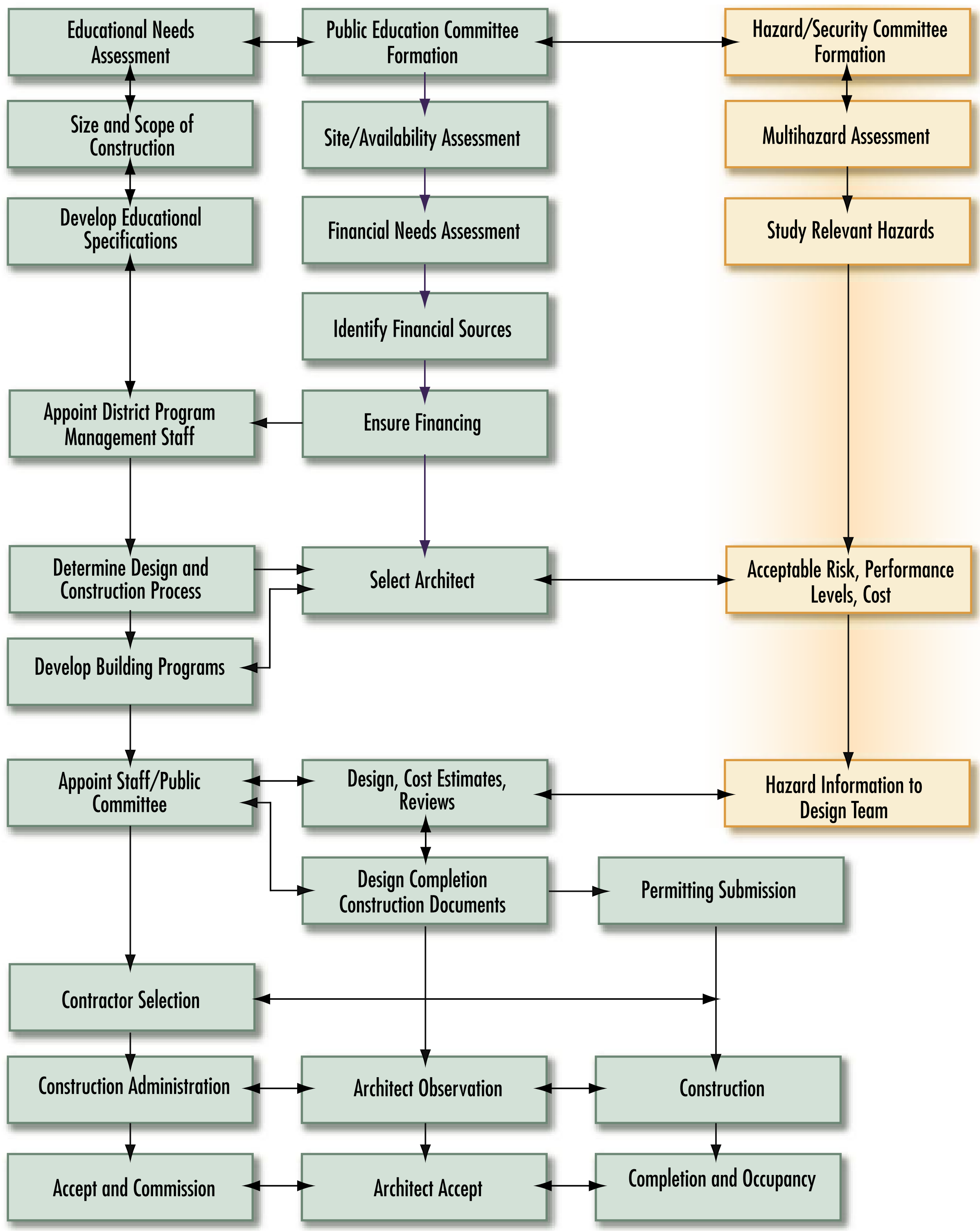

Figure 1-13 The design and construction process flow chart

1.7 SCHOOL DESIGN AND CONSTRUCTION

1.7.1 Structure

The structure provides support for all the elements of a building and ensures that the building can sustain all the loads and forces that it will encounter during its life. Often concealed behind ceilings, exterior cladding, and decorative facing materials, the structure plays a critical role in providing a safe and secure school building.

Because of the relatively small size of most school buildings and the simplicity of design of the traditional school, with numerous internal walls, structural design is relatively simple and a well designed and constructed school should not collapse unless struck by a severe tornado or terrorist.

Most suburban schools built in the last few decades are typically one or two stories in height, with light steel frames or mixed structures of steel and wood frames and also with some concrete or concrete masonry walls. Except in the western states, and the Atlantic and Gulf coasts, concrete masonry walls may have nominal or no steel reinforcing. Reinforced masonry perimeter and/or interior classroom separation walls sometimes are used as shear walls to provide lateral support. First floors are generally concrete slab-on-grade.

Many schools may have long-span gymnasiums or assembly spaces, using glued-laminated wood beams, steel trusses, or precast reinforced concrete tees or double tees. In these long span structures, large diaphragm and wind uplift forces must be transmitted to the perimeter walls or frames and the design and construction of wall/roof connections are critical.

Typical prefabricated teaching spaces consist of classroom-sized wood frame boxes, are air-conditioned where necessary, and generally have minimally adequate lighting and electrical services. They provide an economical way of solving a problem, but rows of prefabricated classroom boxes do not provide an appropriate long-term learning and social environment. Also, they are typically less resistant to natural hazards.

Inner city schools may be three or four stories in height and are often built on congested sites. Structurally, they are usually constructed of reinforced masonry, reinforced concrete, and/or steel frames, and sometimes are a mix of these types of systems.

Older structures (i.e., pre-World War II) often had unreinforced masonry walls with wood floors and roof structures. Another common type was a lightly reinforced concrete frame infilled with hollow tile or masonry for walls, together with a wood floor and roof structure. Small schools were often of wood frame construction throughout, and basements and crawl spaces were common in these structures. Older structures are particularly vulnerable to natural hazards. Unreinforced masonry structures have performed very poorly in earthquakes and high winds, as have older reinforced concrete frames with infill. Older wood frame structures are often deficient in their design and construction detailing and are frequently weakened by insect attack or dry rot.

1.7.2 Nonstructural Systems and Components

Nonstructural components and systems comprise architectural components such as ceilings and partitions, mechanical, plumbing, and electrical items that provide utilities and services to the building and cladding and roofing that provide weather protection and insulation.

A wide variety of exterior cladding materials are used for schools. The most common materials include brick or concrete masonry, stucco on metal or wood stud frame walls, exterior insulation finish systems (EIFS), and various natural and synthetic sidings on wood frame structures. Metal or stucco faced insulated panels are also used. Metal and glass curtain walls are used infrequently, generally in an urban setting.

Newer schools usually have suspended grid ceilings that support light acoustic panels and inset lighting fixtures. Pendant fixtures are also used, in the form of rows of linear fluorescent fixtures or single high intensity (HID) fixtures. The latter are often large in size when used in assembly spaces or gymnasiums. Incandescent fixtures may still be found in older school buildings, but are a source of high energy use and should be replaced.

Non-load bearing partitions are often of hollow tile or concrete masonry: however, especially in the western states, partitions are of gypsum board over wood or metal framing, although concrete masonry or tile may be used in restrooms or other service areas.

School mechanical systems are relatively simple. Older schools and some new ones employ perimeter hot water heating together with natural ventilation or forced air. Very old schools may still employ steam heating, but most of these systems should have been replaced by hydronic systems. Newer schools, particularly when large, often employ forced air heating, ventilating, and cooling systems. Concern for energy conservation has resulted in the use of innovative systems, including a return to the use of natural ventilation and day lighting.

Plumbing tends to be concentrated in restroom areas, although science, art spaces, and school kitchens require more complex plumbing services. Specialized plumbing will also be found in mechanical/boiler rooms, the water service and fire protection service entrances, and domestic water heaters.

Electrical services have become increasingly complex with the need for ready access to power and communications services. The trend in communications devices to become wireless may serve to slightly reduce the extent of hard wired communications. Fire alarm and security services, however, require increasingly extensive electrical and electronic services.

Fixed classroom desks and teachers units have been replaced by lighter mobile furniture. Libraries still require extensive shelving, although ready access to the internet may tend to reduce the use of hard-copy materials.

Some special spaces, such as science labs, shop, and art rooms, need storage for hazardous chemicals and operate heavy equipment, and are vulnerable to earthquake damage. Music spaces and gymnasiums all have special equipment and storage needs, some of which would be costly to replace in the event of damage.