- *Laminated wood arches.* These structures are similar in function to steel rigid frames and share the same design concepts with their steel brethren. The major advantage of wood arches lies in their charming and warm appearance, as opposed to a cold, utilitarian look of steel frames. Wood arches in combination with timber roof decking and masonry walls are used for churches, community buildings, and upscale residences. Laminated wood arches are cost-effective for spans from 30 to 70 ft. Roof slopes range from 3:12 to 14:12. This system offers a unique combination of beauty, strength, ease of installation, and cost efficiency. Among the disadvantages is the fact that wood, unlike steel, can rot and be infested by termites.
- *Precast concrete framing.* Precast concrete is heavier and usually more expensive than metal building systems, but in some circumstances factors like fire resistance and sound protection are more important than cost. Concrete offers both. Precast, prestressed hollow-core planks are commonly available from 6 to 12 in deep and can span distances from 20 to 50 ft. Double-tee panels, 12 to 32 in in depth, are able to span distances from 12 to 100 ft. Precast roof panels are normally supported on precast concrete frames or masonry walls and rely on shear walls for lateral resistance. Building structures made completely of precast concrete offer some of the same advantages as metal building systems: speed of erection (some projects have been erected in $2^1/_2$ weeks—during the winter), single-source responsibility for structural work, and even flexibility of expansion.
- *Special construction.* Some truly extraordinary structural systems have been developed for applications requiring bold appearance, very long spans, and other unusual criteria. Suspension systems using exterior steel cables for roof support are more common for bridge applications but occasionally find their way into building construction as well. Air-supported fabric structures, such as the one used in Denver International Airport, offer a breathtaking way of covering massive amounts of space. The special structures can be used for clear spans in excess of 1000 ft. As the name suggests, specialists should be sought to help with this type of design.

3.5 THE DECISION TIME

How and when do architects and engineers decide whether or not to specify metal building systems for the project? How and when do they compare the systems with the other available types of framing? These are not idle questions. Specified too early by enthusiastic designers, before the project requirements are fully established, metal building systems may end up being stretched beyond their optimum range of applications. Specified too late in the design process, the systems might prove incompatible with the project items that have already been selected.

Let us look briefly at the milestones of a typical building project, which starts when the designers learn that the client has a problem to solve. The problem could be anything ranging from a lack of operating space to a need for new equipment.

During the first phase, *programming,* the problem is studied and analyzed. The program report summarizes the designers' recommendations on the amount of new space actually needed and establishes basic requirements for the proposed building. At this stage, it is too early to discuss structural systems, unless the only solution is already obvious.

During *conceptual design* and *preliminary design,* the program requirements are translated into a proposed layout, size, and mass of the building; various building code aspects are studied; and a preliminary cost estimate is prepared. This is the best time to get the structural engineers involved. Unfortunately, all too often the engineers are not brought on board until the preliminary design is completed, and an opportunity to influence the design decisions dealing with shape and clear span of the building is missed. Moreover, some large clients prefer to perform schematic design in-house.

Eli Cohen, one of the most respected engineers of our time, when asked about lessons he had learned, replied, "You have to spend more time in the conceptual design, because with the first 10 percent of your time you can save 25 percent of the cost of the building."[14]

At this point, the project can go in one of three directions:

1. *Conventional delivery.* The building is designed by an outside architect-engineer and later constructed by a general contractor selected via public bidding or negotiated process.
2. *Design-build.* The building is designed and constructed by a single entity that includes both designers and constructors.
3. *Directly sold pre-engineered construction.* A local builder, acting as a dealer for the metal building system manufacturer, contracts directly with the owner, who may or may not be assisted by an architect.

Obviously, selection of the third method indicates that a metal building system has been already chosen for the job. If, however, one of the first two delivery methods is pursued, a decision whether to use metal building systems, and of what type, will be made during the next design phase, *design development.* At that time, armed with the information about the building from the preliminary drawings, and after the building code research, structural engineers will determine the design loads on the structure and evaluate various framing alternatives.

3.6 STRUCTURAL SYSTEM SELECTION CRITERIA

Having discussed the topics of structural loads, design philosophies, the available framing systems, and project delivery methods we can at last consider some of the criteria for system selection.

3.6.1 Architectural Requirements

The system of choice should satisfy both architectural and structural requirements; the relative importance of each needs to be established during the schematic design. It is wise to put in practice the timeless words of Louis Sullivan, "Form follows function." For most buildings in manufacturing and other "utilitarian" occupancies, such as factory, storage, and warehouse space, the harmony of function and structural form is obvious. For other uses such as churches, community, and commercial, architectural expression is probably of dominant importance and might override considerations of pure structural efficiency.

3.6.2 Fire Resistance

Fire protection requirements specified in local building codes often dictate the choice of structure. Pre-engineered buildings of light-gage steel construction, trusses, and bar joists systems are difficult to cover with spray fireproofing; these should be specified with caution when the fireproofing is needed. Fortunately, this is rarely required for single-story buildings that conform to the "noncombustible, unprotected" classification.

Still, there are circumstances when the building structure must possess a fire rating of one or two hours. The metal building industry has developed some fire-rated systems that rely on several layers of gypsum board supported on hat channels spanning between the wall girts. The roofs of metal buildings are often high enough as not to need any fireproofing, but they too could be covered in gypsum board if needed. The main problem with these designs is, of course, cost: The multiple layers of gypsum board plus metal siding and wall framing might cost the same or more than the walls made of concrete block or precast concrete. Also, as discussed in Chap. 11, attaching gypsum board to the metal building frame dramatically increases the requirements for lateral rigidity of the building, raising its cost even more. It is often more economical to use "hard" walls, either as part of metal building systems or their competition, when fire rating is required.