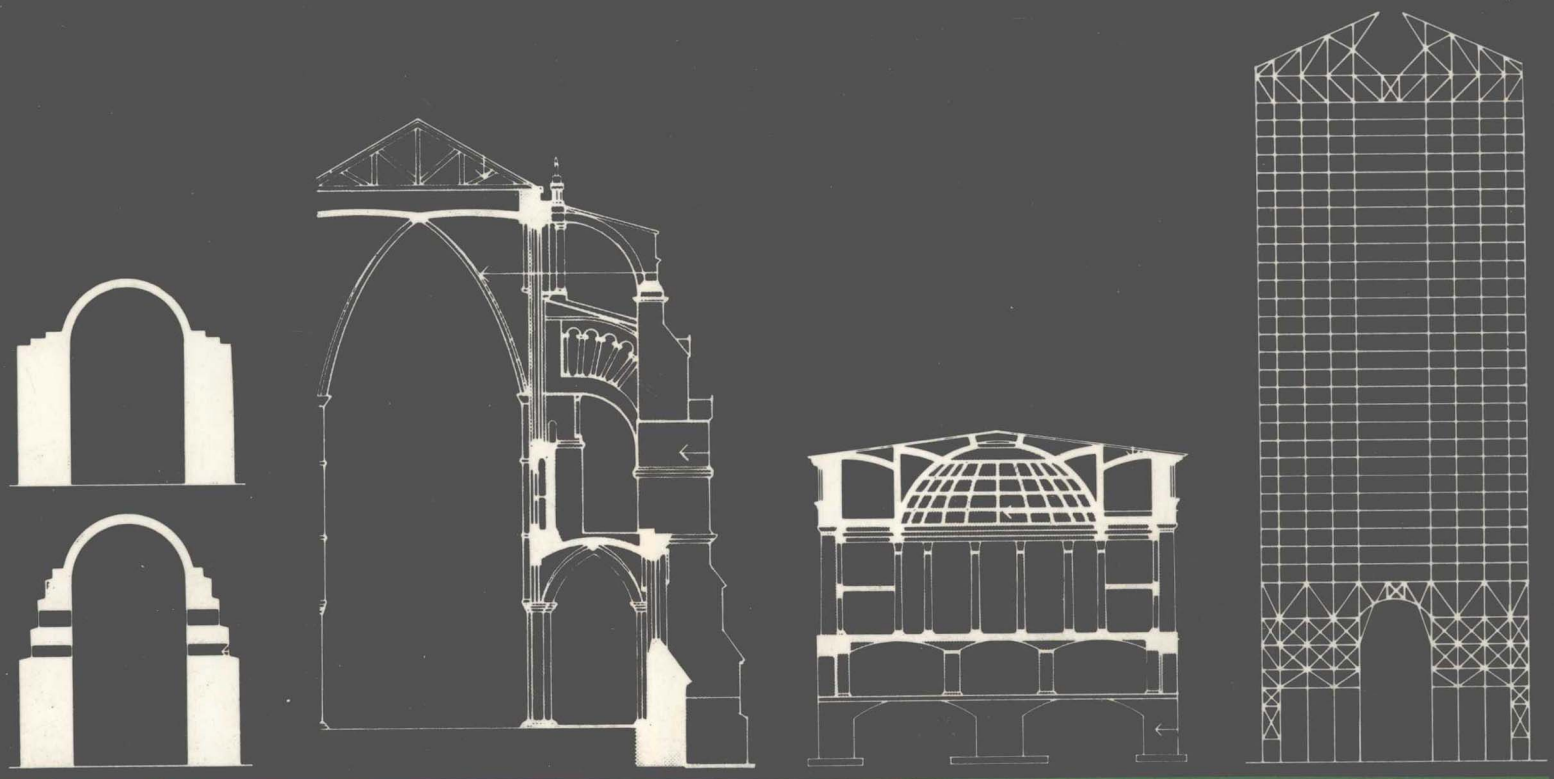
Construction Economics and Building Design

A HISTORICAL APPROACH

R. Gregory Turner, AIA



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For my mother and father,
Kathleen and Jack Turner

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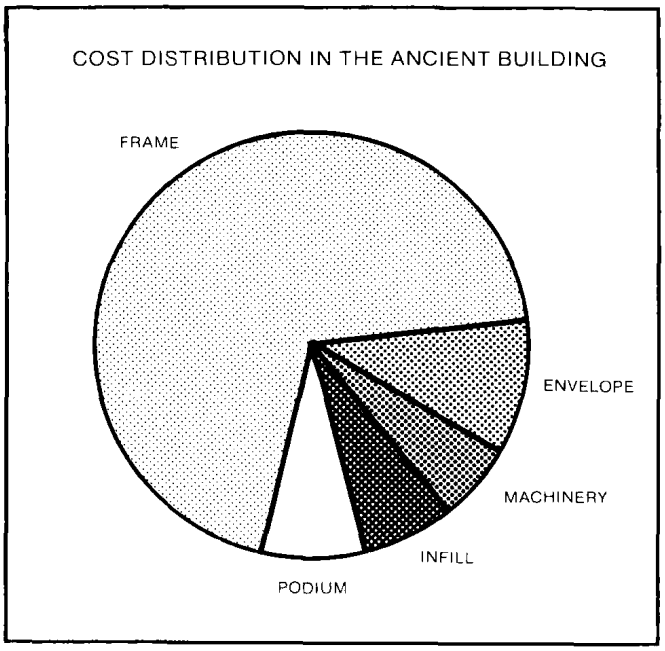
Preface

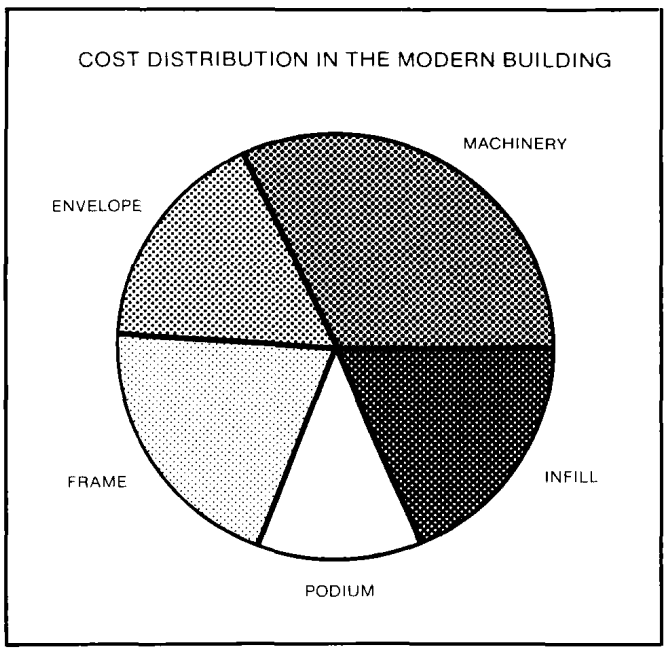
Before the Industrial Revolution, major buildings in the Western world were essentially composed of one technological component serving a variety of structural, environmental, and functional purposes. Since the onset of industrialization, discrete specialized components have been developed to satisfy the requirements of building. At one time the large building consisted of a masonry structural frame, abetted by foundations and minor amounts of glass and applied finishes. Now a structural podium and frame are made to support an envelope that seals off the interior environment; this environment is modified by machinery that weaves through the web of the frame. All of this is in turn covered by nonstructural infill materials that also serve to create the smaller spaces needed for living and working.

Although the technological changes wrought by industrialization to small-scale residential building types have been less monumental than those to major buildings, they have nevertheless been profound. The preindustrial small building consisted of a masonry or wood frame integrated with its enclosure, sitting on top of a masonry podium. Although applied finishes, particularly plaster and wood moldings, might adorn the interior, the shape of the frame largely defined the shapes and sizes of interior spaces. Today, the wood or masonry frame still sits atop the podium, and the infill still consists largely of applied finishes. Industrialization has changed all else. Despite outward appearances, the envelope is now a discrete veneer, and the interjection of machinery into the interior environment is no less significant than in major buildings. The principal impact of the industrial age upon the podium, frame, and infill has been in material substitutions and erection procedures.

As the technology of building has changed, so has the structure of the



P-1. Cost Distribution in the Ancient Building.



P-2. Cost Distribution in the Modern Building.

professions and trades involved in the construction process. In many cases these alterations have changed the technologies as well. We now have specialized design professions for each technological component, as well as specialized construction trades for each. Before the 1800s, master masons or master builders directed crews composed chiefly of masons and carpenters. These master builders were generally responsible for design as well.

Such monumental changes in the way buildings are made have a concomitant effect on the way in which the financial resources for buildings are applied. In fact, decisions regarding economics are more the cause than the effect of changes in technology, and the allocation of moneys to particular parts of the building is the primary basis of architectural style.

An examination of the history of cost allocation in buildings will show the reasons for the development of the major stylistic eras in Western architecture. A further examination of recent cost history will illuminate the probable path of stylistic development in the future.

Historical accounts of the evolution of each building component can be an invaluable asset in estimating the relative cost of each component through the years. Such accounts were compiled by reviewing literature regarding architecture and technology. In addition, engineers, contractors,

and materials suppliers were consulted with. Some observations from the author's own experience were recorded. Highlights from these sources are presented in the Appendix. They formed the basis of, and supplied the details for, the accounts of the historical development of building components that follow.

The underlying socioeconomic roots of building technologies and costs will not be at issue here and will only be mentioned to stress particular points. This investigation was approached as a microeconomic study, concentrating on the allocation of monetary resources within the building itself.

CHAPTER 1

The Component Technologies of Buildings

Through the centuries five basic technological components have been used in the construction of buildings. These are the podium, frame, envelope, machinery, and infill. In various historical periods, each has been used to varying extents, and some components once served functions now fulfilled by others.

The *podium* is defined as the base of the building and the devices used for vertical transit. It includes foundations, subgrade floors, the grade-level floor, special at-grade structures that are integral to the below-grade construction, and elevators. This component is foundation- and transportation-oriented.

The *frame* consists of the load-bearing members of the building aside from the podium; these components carry both live (people and furniture) and dead (building weight) loads. It also consists of finishes that are integral to the structural material or are necessary for its structural soundness. Thus, sculpted granite blocks, if load-bearing, are frame members, although the sculpting may not in itself contribute to the strength of the stone. Spray-on fireproofing used on structural steel is also a frame-related cost item. Likewise, plywood sheathing on a balloon-frame house is considered part of the frame.

The *envelope* is the building enclosure that separates the interior environment from the exterior environment. It carries no load save its own. A modern curtain-wall system on a high-rise building and the stained glass that adorned Gothic cathedrals are both envelope items. So is the brick veneer on a residence.

The *machinery* consists of the environmental, sanitary, and life-safety equipment that is routed through the interstices of the frame. Heating,

ventilation, and air-conditioning equipment are part of the machinery, as is electrical work. Plumbing, fire-extinguishing, and alarm systems are also included.

The *infill* consists of nonstructural, nonmechanical interior materials used for space-dividing and/or decorative purposes; specialty items are also considered to be infill. Partitions, applied finishes—such as plaster and paint—casework, and fixed equipment help make up the infill. Fixtures, furnishings, and movable equipment are not considered as infill with regard to building cost.

This five-part categorization is based on several factors. First, each component serves a unique purpose in the physical constitution of the building. Second, the materials and techniques used in the construction of each component are different. Third, the complexity of construction on a project today requires a division of labor and a sequencing of construction according to easily identifiable tasks; the purpose and materials of the components help to identify these tasks. Fourth, as the number of people and materials involved in building has multiplied, construction trades and design professions have organized into specialties that make possible proficiency in one particular component.

Building Systems Identified by Cost Estimating Guides

Building Component	Means Systems Costs 1983	Dodge Construction Systems Costs 1984
Podium	Foundations Substructures Conveying	Foundations Floors on Grade Conveying Systems
Frame	Superstructure	Superstructure
Envelope	Exterior Closure Roofing	Exterior Walls Roofing
Machinery	Mechanical Electrical	HVAC Plumbing Electrical
Infill	Interior Construction	Partitions Wall Finishes Floor Finishes Ceiling Finishes Specialties Fixed Equipment

1-1.

Identification of the podium, frame, envelope, machinery, and infill is not inconsistent with the categorizations for building systems delineated by the principal construction cost-estimating resources in the nation. Systems identified by the R.S. Means Company in its 1983 edition of *Means Systems Costs*, those pinpointed in McGraw-Hill's *Dodge Construction Systems Costs 1984*, and the five components outlined here are compared in Figure 1-1. Note that the cost guidebooks merely take finer slices through the building.

Major buildings are identified here as those whose size makes the use of a wood-frame, load-bearing wall structure impossible. Although this encompasses a wide variety of building types and sizes, they are all analogous with regard to their basic materials and construction techniques. Historically, major buildings have generally been dedicated to civic and religious purposes in classical times; ecclesiastical, monastic, and civic uses in the Middle Ages; and office, industrial, mercantile, and institutional purposes in recent eras.

Small-scale structures are identified here as residential buildings. It is true now, as it has been throughout history, that residences most often use the load-bearing wall structural system, especially if it is of timber.

Evolution of the Component Technologies in Major Buildings

The Podium

Although the basic technology of the podium remained essentially unchanged until the latter part of the nineteenth century, different civilizations made varying use of the spaces made possible by podium construction. The Parthenon in ancient Athens used a simple stone base to distribute the compressive forces transmitted down through the columns into the ground, as shown in Figure 1-2. The foundations of Winchester Cathedral, seen in Figure 1-3, are representative of the Gothic era in the Middle Ages, and show little advancement beyond the technology of the Parthenon. At Winchester, maximum compressive forces are accommodated at points or lines under piers or walls by rubble fill foundations made by filling trenches with rough-cut stones bound in mortar. As in the Parthenon, little use of subterranean space is evident.

Between the Greek and Gothic periods, the Romans exploited their technical aptitude with arches by constructing below-grade spaces, as at the Colosseum. With the fall of the Empire, this technology fell into disuse. It was rediscovered during the Renaissance, after which extensive use of

1-2. The Classical Podium.