Types, Elements and Essentials of Building and Construction

Virginia Brackett

Alvin Shinn

First Edition, 2012

ISBN 978-81-323-0996-3

Published by:
Academic Studio
4735/22 Prakashdeep Bldg,
Ansari Road, Darya Ganj,
Delhi - 110002
Email: info@wtbooks.com

Table of Contents

Chapter- 1

Construction

In large construction projects, such as this skyscraper in Melbourne, cranes are essential.

In the fields of architecture and civil engineering, **construction** is a process that consists of the **building** or assembling of infrastructure. Far from being a single activity, large scale construction is a feat of human multitasking. Normally, the job is managed by a project manager, and supervised by a construction manager, design engineer, construction engineer, or project architect.

For the successful execution of a project, effective planning is essential. Those involved with the design and execution of the infrastructure in question must consider the environmental impact of the job, the successful scheduling, budgeting, construction site safety, availability of building materials, logistics, inconvenience to the public caused by construction delays, and bidding, etc.

Types of construction projects

Construction of a prefabricated home

In general, there are three types of construction:

1. Building construction
2. Heavy / civil construction
3. Industrial construction

Each type of construction project requires a unique team to plan, design, construct, and maintain the project.

Building construction

A building site for a row of riverside apartment blocks in Cambridge

A large unfinished building

Building construction is the process of adding structure to real property. The vast majority of building construction projects are small renovations, such as addition of a room, or renovation of a bathroom. Often, the owner of the property acts as laborer, paymaster, and design team for the entire project. However, all building construction projects include some elements in common - design, financial, and legal considerations. Many projects of varying sizes reach undesirable end results, such as structural collapse, cost overruns, and/or litigation reason, those with experience in the field make detailed plans and maintain careful oversight during the project to ensure a positive outcome.

Building construction is procured privately or publicly utilizing various delivery methodologies, including hard bid, negotiated price, traditional, management contracting, construction management-at-risk, design & build and design-build bridging.

Residential construction practices, technologies, and resources must conform to local building authority regulations and codes of practice. Materials readily available in the area generally dictate the construction materials used (e.g. brick versus stone, versus timber). Cost of construction on a per square metre (or per square foot) basis for houses can vary dramatically based on site conditions, local regulations, economies of scale (custom designed homes are always more expensive to build) and the availability of skilled tradespeople. As residential (as well as all other types of construction) can generate a lot of waste, careful planning again is needed here.

The most popular method of residential construction in the United States is wood framed construction. As efficiency codes have come into effect in recent years, new construction technologies and methods have emerged. University Construction Management departments are on the cutting edge of the newest methods of construction intended to improve efficiency, performance and reduce construction waste.

Heavy / civil construction

Civil engineering deals with the design, construction and maintenance of the physical and naturally built environment, including works such as bridges, roads, canals, dams and buildings.

Industrial construction

Industrial construction, though a relatively small part of the entire construction industry, is a very important component. Owners of these projects are usually large, for-profit, industrial corporations. These corporations can be found in such industries as medicine, petroleum, chemical, power generation, manufacturing, etc. Processes in these industries require highly specialized expertise in planning, design, and construction. As in building and heavy/highway construction, this type of construction requires a team of individuals to ensure a successful project. Industrial construction is very important.Sometimes it may cause or harm the environment.

Construction processes

Design team

Shasta Dam under construction in June 1942

In the modern industrialized world, construction usually involves the translation of designs into reality. A formal design team may be assembled to plan the physical proceedings, and to integrate those proceedings with the other parts. The design usually consists of drawings and specifications, usually prepared by a design team including surveyors, civil engineers, cost engineers (or quantity surveyors), mechanical engineers, electrical engineers, structural engineers, and fire protection engineers. The design team is most commonly employed by (i.e. in contract with) the property owner. Under this system, once the design is completed by the design team, a number of construction companies or construction management companies may then be asked to make a bid for the work, either based directly on the design, or on the basis of drawings and a bill of quantities provided by a quantity surveyor. Following evaluation of bids, the owner will typically award a contract to the most cost efficient bidder.

The modern trend in design is toward integration of previously separated specialties, especially among large firms. In the past, architects, interior designers, engineers, developers, construction managers, and general contractors were more likely to be entirely separate companies, even in the larger firms. Presently, a firm that is nominally an "architecture" or "construction management" firm may have experts from all related fields as employees, or to have an associated company that provides each necessary skill. Thus, each such firm may offer itself as "one-stop shopping" for a construction project, from beginning to end. This is designated as a "design Build" contract where the contractor is given a performance specification, and must undertake the project from design to construction, while adhering to the performance specifications.

Several project structures can assist the owner in this integration, including design-build, partnering, and construction management. In general, each of these project structures allows the owner to integrate the services of architects, interior designers, engineers, and constructors throughout design and construction. In response, many companies are growing beyond traditional offerings of design or construction services alone, and are placing more emphasis on establishing relationships with other necessary participants through the design-build process.

The increasing complexity of construction projects creates the need for design professionals trained in all phases of the project's life-cycle and develop an appreciation of the building as an advanced technological system requiring close integration of many sub-systems and their individual components, including sustainability. **Building engineering** is an emerging discipline that attempts to meet this new challenge.

Financial advisors

Trump International Hotel and Tower (Chicago)

May 23, 2006

September 14, 2007 (3 months before completion)

Many construction projects suffer from preventable financial problems. **Underbids** ask for too little money to complete the project. Cash flow problems exist when the present amount of funding cannot cover the current costs for labour and materials, and because they are a matter of having sufficient funds at a specific time, can arise even when the overall total is enough. Fraud is a problem in many fields, but is notoriously prevalent in the construction field. Financial planning for the project is intended to ensure that a solid plan, with adequate safeguards and contingency plans, is in place before the project is started, and is required to ensure that the plan is properly executed over the life of the project.

Mortgage bankers, accountants, and cost engineers are likely participants in creating an overall plan for the financial management of the building construction project. The presence of the mortgage banker is highly likely even in relatively small projects, since the owner's equity in the property is the most obvious source of funding for a building project. Accountants act to study the expected monetary flow over the life of the project, and to monitor the payouts throughout the process. Cost engineers apply expertise to relate the work and materials involved to a proper valuation. Cost overruns with government projects have occurred when the contractor was able to identify change orders or changes in the project resulting in large increases in cost, which are not subject to competition by other firm as they have already been eliminated from consideration after the initial bid.

Large projects can involve highly complex financial plans. As portions of a project are completed, they may be sold, supplanting one lender or owner for another, while the logistical requirements of having the right trades and materials available for each stage of the building construction project carries forward. In many English-speaking countries, but not the United States, projects typically use quantity surveyors.

Legal considerations

Construction along Ontario Highway 401, widening the road from six to twelve travel lanes

A construction project must fit into the legal framework governing the property. These include governmental regulations on the use of property, and obligations that are created in the process of construction.

The project must adhere to zoning and building code requirements. Constructing a project that fails to adhere to codes will not benefit the owner. Some legal requirements come from malum in se considerations, or the desire to prevent things that are indisputably bad - bridge collapses or explosions. Other legal requirements come from malum prohibitum considerations, or things that are a matter of custom or expectation, such as isolating businesses to a business district and residences to a residential district. An attorney may seek changes or exemptions in the law governing the land where the building will be built, either by arguing that a rule is inapplicable (the bridge design will not collapse), or that the custom is no longer needed (acceptance of live-work spaces has grown in the community).

A construction project is a complex net of contracts and other legal obligations, each of which must be carefully considered. A contract is the exchange of a set of obligations between two or more parties, but it is not so simple a matter as trying to get the other side to agree to as much as possible in exchange for as little as possible. The time element in construction means that a delay costs money, and in cases of bottlenecks, the delay can be extremely expensive. Thus, the contracts must be designed to ensure that each side is capable of performing the obligations set out. Contracts that set out clear expectations and clear paths to accomplishing those expectations are far more likely to result in the project flowing smoothly, whereas poorly drafted contracts lead to confusion and collapse.

Legal advisors in the beginning of a construction project seek to identify ambiguities and other potential sources of trouble in the contract structure, and to present options for preventing problems. Throughout the process of the project, they work to avoid and resolve conflicts that arise. In each case, the lawyer facilitates an exchange of obligations that matches the reality of the project.

Interaction of expertise

Apartment complex under construction in Daegu, South Korea

Design, finance, and legal aspects overlap and interrelate. The design must be not only structurally sound and appropriate for the use and location, but must also be financially possible to build, and legal to use. The financial structure must accommodate the need for building the design provided, and must pay amounts that are legally owed. The legal structure must integrate the design into the surrounding legal framework, and enforce the financial consequences of the construction process.

Procurement

Procurement describes the merging of activities undertaken by the client to obtain a building. There are many different methods of construction procurement; however the three most common types of procurement are:

1. Traditional (Design-bid-build)
2. Design and Build
3. Management Contracting

There is also a growing number of new forms of procurement that involve relationship contracting where the emphasis is on a co-operative relationship between the principal and contractor and other stakeholders within a construction project. New forms include partnering such as Public-Private Partnering (PPPs) aka Private Finance Initiatives (PFIs) and alliances such as "pure" or "project" alliances and "impure" or "strategic" alliances. The focus on co-operation is to ameliorate the many problems that arise from the often highly competitive and adversarial practices within the construction industry.

Traditional

This is the most common method of construction procurement and is well established and recognized. In this arrangement, the architect or engineer acts as the project coordinator. His or her role is to design the works, prepare the specifications and produce construction drawings, administer the contract, tender the works, and manage the works from inception to completion. There are direct contractual links between the architect's client and the main contractor. Any subcontractor will have a direct contractual relationship with the main contractor.

Design and build

Construction of the *Phase-1* (first two towers) of the Havelock City Project, Sri Lanka.

This approach has become more common in recent years and includes an entire completed package, including fixtures, fittings and equipment where necessary, to produce a completed fully functional building. In some cases, the Design and Build (D & B) package can also include finding the site, arranging funding and applying for all necessary statutory consents.

The owner produces a list of requirements for a project, giving an overall view of the project's goals. Several D&B contractors present different ideas about how to accomplish these goals. The owner selects the ideas he likes best and hires the appropriate contractor. Often, it is not just one contractor, but a consortium of several contractors working together. Once a contractor (or a consortium/consortia) has been hired, they begin building the first phase of the project. As they build phase 1, they design phase 2. This is in contrast to a design-bid-build contract, where the project is completely designed by the owner, then bid on, then completed.

Kent Hansen, director of engineering for the National Asphalt Pavement Association (NAPA), pointed out that state departments of transportation (DOTs) usually use design build contracts as a way of getting projects done when states don't have the resources. In DOTs, design build contracts are usually used for very large projects.

Management procurement systems

In this arrangement the client plays an active role in the procurement system by entering into separate contracts with the designer (architect or engineer), the construction manager, and individual trade contractors. The client takes on the contractual role, while the construction or project manager provides the active role of managing the separate trade contracts, and ensuring that they all work smoothly and effectively together.

Management procurement systems are often used to speed up the procurement processes, allow the client greater flexibility in design variation throughout the contract, the ability to appoint individual work contractors, separate contractual responsibility on each individual throughout the contract, and to provide greater client control.

Authority having jurisdiction

Construction on a building in Kansas City, Missouri

In construction, the **authority having jurisdiction** (AHJ) is the governmental agency or sub-agency which regulates the construction process. In most cases, this is the municipality in which the building is located. However, construction performed for supra-municipal authorities are usually regulated directly by the owning authority, which becomes the AHJ.

During the planning of a building, the zoning and planning boards of the AHJ will review the overall compliance of the proposed building with the municipal General Plan and zoning regulations. Once the proposed building has been approved, detailed civil, architectural, and structural plans must be submitted to the municipal **building department** (and sometimes the public works department) to determine compliance with the building code and sometimes for fit with existing infrastructure. Often, the municipal fire department will review the plans for compliance with fire-safety ordinances and regulations.

Before the foundation can be dug, contractors are typically required to notify utility companies, either directly or through a company such as Dig Safe to ensure that underground utility lines can be marked. This lessens the likelihood of damage to the existing electrical, water, sewage, phone, and cable facilities, which could cause outages and potentially hazardous situations. During the construction of a building, the municipal building inspector inspects the building periodically to ensure that the construction adheres to the approved plans and the local **building code**. Once construction is complete and a final inspection has been passed, an **occupancy permit** may be issued.

An operating building must remain in compliance with the **fire code**. The fire code is enforced by the local fire department.

Changes made to a building that affect safety, including its use, expansion, structural integrity, and fire protection items, usually require approval of the AHJ for review concerning the building code.

Construction careers

Ironworkers erecting the steel frame of a new building at Massachusetts General Hospital, Boston

There are many routes to the different careers within the construction industry which vary by country. However, there are three main tiers of careers based on educational background which are common internationally:

- Unskilled and Semi-Skilled - General site labour with little or no construction qualifications.

- Skilled - On-site managers whom possess extensive knowledge and experience in their craft or profession.
- Technical and Management - Personnel with the greatest educational qualifications, usually graduate degrees, trained to design, manage and instruct the construction process.

Skilled occupations in the UK require further education qualifications, often in vocational subject areas. These qualifications are either obtained directly after the completion of compulsory education or through "on the job" apprenticeship training. In the UK, 8500 construction-related apprenticeships were commenced in 2007. Skills in the United States and abroad differ very little: the very simple change that can be obviously perceived is language: some of the latest skills required in the United States can be interpreted by contacting Construction Citizen s in America and abroad.

Technical and specialised occupations require more training as a greater technical knowledge is required. These professions also hold more legal responsibility. A short list of the main careers with an outline of the educational requirements are given below:

- Architect - Typically holds at least a 5 to 6-year degree in architecture. To use the title "architect" the individual must hold chartered status with the Royal Institute of British Architects and be on the Architects Registration Board.
- Civil Engineer - Typically holds a degree in a related subject. The Chartered Engineer qualification is controlled by the Institution of Civil Engineers. A new university graduate must hold a master's degree to become chartered, persons with bachelor's degrees may become an Incorporated Engineer.
- Building Services Engineer - Often referred to as an "M&E Engineer" typically holds a degree in mechanical or electrical engineering. Chartered Engineer status is governed by the Chartered Institution of Building Services Engineers.
- Project Manager - Typically holds a 4-year or greater higher education qualification, but are often also qualified in another field such as quantity surveying or civil engineering.
- Quantity Surveyor - Typically holds a master's degree in quantity surveying. Chartered status is gained from the Royal Institution of Chartered Surveyors.
- Structural Engineer - Typically holds a bachelors or master's degree in structural engineering, new university graduates must hold a master's degree to gain chartered status from the Institution of Structural Engineers.

History

The first buildings were huts and shelters, constructed by hand or with simple tools. As cities grew during the Bronze Age, a class of professional craftsmen, like bricklayers and carpenters, appeared. Occasionally, slaves were used for construction work. In the Middle Ages, these were organized into guilds. In the 19th century, steam-powered machinery appeared, and later diesel- and electric powered vehicles such as cranes, excavators and bulldozers. Modern-day Construction involves creating awesome structures that can show the beauty and creativity of the human intellect. Some great examples of art in buildings or architecture include the London Shard, which can be viewed on Construction Citizen, a website updated daily for increasing construction labor.

Chapter- 2

Building

A building and skybridge in Munich, Germany

Example of a religious building : the Great Mosque of Kairouan, founded in 670, dates in its present state from the 9th century; situated in Kairouan, Tunisia.

In architecture, construction, engineering and real estate development the word **building** may refer to one of the following:

1. Any human-made structure used or intended for supporting or sheltering any use or continuous occupancy, or
2. An act of construction (i.e. the activity of building)

Buildings come in a wide amount of shapes and functions, and have been adapted throughout history for a wide number of factors, from building materials available, to weather conditions, to land prices, ground conditions, specific uses and aesthetic reasons.

Buildings serve several needs of society – primarily as shelter from weather and as general living space, to provide privacy, to store belongings and to comfortably live and work. A building as a shelter represents a physical division of the human habitat (a place of comfort and safety) and the *outside* (a place that at times may be harsh and harmful).

Ever since the first cave paintings, buildings have also become objects or canvasess of artistic expression. David found in recent years, interest in sustainable planning and building practices has also become part of the design process of many new buildings.

Definitions

Building is defined in many aspects as:

- As a Civil Engineering structures such as a house,worship center,Factories etc. that has a foundation,wall,roof etc. that protect human being and their properties from direct harsh effect of weather like rain,wind,sun etc.
- The act of constructing, erecting, or establishing.
- The art of constructing edifices, or the practice of civil architecture.
- That which is built; a fabric or edifice constructed, as a house, a church, castle, arena/ stadium, etc.
- The act of constructing or building something; "during the construction we had to take a detour"; "his hobby was the building of boats"
- The commercial activity involved in constructing buildings; "their main business is home construction"; "workers in the building trades"
- A structure that has a roof and walls and stands more or less permanently in one place; "there was a three-storey building on the corner"; "it was an imposing edifice"
- The occupants of a building; "the entire building complained about the noise"

Structural height in technical usage is the height to the highest architectural detail on building from street-level. Depending on how they are classified, spires and masts may or may not be included in this height. Spires and masts used as antennas are not generally included.

The definition of a *low-rise vs. a high-rise* building is a matter of debate, but generally three stories or less is considered low-rise.

History

The first shelter on Earth constructed by a relatively close ancestor to humans is believed to be built 500,000 years ago by an early ancestor of humans, Homo erectus.

Types

A timber framing house in Marburg, Germany.

Residential

Residential buildings are called houses/homes, though buildings containing large numbers of separate dwelling units are often called apartment buildings / blocks to differentiate them from the more 'individual' house.

Building types may range from one-room wood-framed, masonry, or adobe dwellings to multi-million dollar high-rise buildings able to house thousands of people. Increasing settlement density in buildings (and closer distances between buildings) is usually a response to high ground prices resulting from many people wanting to live close to work or similar attractors.

Multi-storey

Some of Denver's multi-storey buildings.

A multi-storey building is a building that has multiple floors above ground in the building.

Multi-storey buildings aim to increase the area of the building without increasing the area of the land the building is built on, hence saving land and, in most cases, money (depending on material used and land prices in the area).

Creation

The practice of designing, constructing, and operating buildings is most usually a collective effort of different groups of professionals and trades. Depending on the size, complexity, and purpose of a particular building project, the project team may include:

- A real estate developer who secures funding for the project;
- One or more financial institutions or other investors that provide the funding
- Local planning and code authorities
- A Surveyor who performs an ALTA/ACSM and construction surveys throughout the project;
- Construction managers who coordinate the effort of different groups of project participants;
- Licensed architects and engineers who provide building design and prepare construction documents;
- Landscape architects;

- Interior designers;
- Other consultants;
- Contractors who provide construction services and install building systems such as climate control, electrical, plumbing, Decoration, fire protection, security and telecommunications;
- Marketing or leasing agents;
- Facility managers who are responsible for operating the building.

Regardless of their size or intended use, all buildings in the US must comply with zoning ordinances, building codes and other regulations such as fire codes, life safety codes and related standards.

Vehicles—such as trailers, caravans, ships and passenger aircraft—are treated as "buildings" for life safety purposes.

Ownership and funding

- Mortgage loan
- Real estate developer

Planning and design

- Architecture
- Building construction
- Civil engineering
- Mechanical, electrical, and plumbing design
- Quantity surveying
- Structural engineering
- Urban planning

Building services

Physical plant

Any building requires a certain amount of internal infrastructure to function, which includes such elements like heating / cooling, power and telecommunications, water and wastewater etc. Especially in commercial buildings (such as offices or factories), these can be extremely intricate systems taking up large amounts of space (sometimes located in separate areas or double floors / false ceilings) and constitute a big part of the regular maintenance required.

Conveying systems

Systems for transport of people within buildings:

- Elevator
- Escalator
- Moving sidewalk (horizontal and inclined)

Systems for transport of people between interconnected buildings:

- Skyway
- Underground city

Building damage

A building in Massueville, Quebec, Canada engulfed by fire.

Buildings may be damaged during the construction of the building or during maintenance. There are several other reasons behind building damage like accident. Buildings also may suffer from fire damage and flooding in special circumstances.

Chapter- 3

Agricultural Buildings

Barn

A barn in Pennsylvania, U.S.

A **barn** is an agricultural building used for storage and as a covered workplace. It may sometimes be used to house livestock or to store farming vehicles and equipment. Barns are most commonly found on a farm or former farm.

A barn meant for keeping cattle may be known as a **byre**.

Construction

The skeleton of a post and beam horse barn just after raising

Thomas Ranck Round Barn in Fayette County, Indiana, U.S.

Older barns were usually built from lumber sawn from timber on the farm, although stone barns were sometimes built in areas where stone was a cheaper building material.

Modern barns are more typically steel buildings. Prior to the 1900s, most barns were timber framed (also known as post and beam) forming very strong structures to withstand storms and heavy loads of animal feed. From about 1900 to 1940, many large dairy barns were built in northern USA. These commonly have gambrel or hip roofs to maximize the size of the hayloft above the dairy roof, and have become associated in the popular image of a dairy farm. The barns that were common to the wheatbelt held large numbers of pulling horses such as Clydesdales or Percherons. These large wooden barns, especially when filled with hay, could make spectacular fires that were usually total losses for the farmers. With the advent of balers it became possible to store hay and straw outdoors in stacks surrounded by a plowed fireguard. Many barns in the northern United States are painted red with a white trim. One possible reason for this is that ferric oxide, which is used to create red paint, was the cheapest and most readily available chemical for farmers in New England and nearby areas. Another possible reason is that ferric oxide acts a preservative and so painting a barn with it would help to protect the structure.

With the popularity of tractors following World War II many barns were taken down or replaced with modern Quonset huts made of plywood or galvanized steel. Beef ranches and dairies began building smaller loftless barns often of Quonset huts or of steel walls on a treated wood frame (old telephone or power poles). By the 1960s it was found that cattle receive sufficient shelter from trees or wind fences (usually wooden slabs 20% open).

Stable

The interior of a stable built for horses

A horse in a box stall, inside a stable

Stables of the Einsiedeln Abbey in Switzerland

A horse stable, over 100 years old, still in use

Traditional style barn, built 1802, still used as a horse stable

A modest stable with a few stalls

A shed row-style stable at a riding club in Panama

A **stable** is a building in which livestock, especially horses, are kept. It most commonly means a building that is divided into separate stalls for individual animals. There are many different types of stables in use today such as the American barn which is a large barn with a door each end and individual stalls inside or free standing stables with the classic top and bottom opening doors. The term "stable" is also used to describe a group of animals kept by one owner, regardless of housing or location.

The exterior design of a stable can vary widely, based on climate, building materials, historical period, and cultural styles of architecture. A wide range of building materials can be used, including masonry (bricks or stone), wood, and steel. Stables can range widely in size, from a small building to house only one or two animals, to facilities used at agricultural shows or at race tracks, which can house hundreds of animals.

Other uses

Historically, the headquarters of a unit of cavalry, not simply their horses' accommodation, would be called a stable.

Used metaphorically from this origin, a stable is a collection of people (e.g. professional wrestlers) working under a single manager.

Historical stables in Great Britain had a hayloft on the first floor and a pitching door at the front. Doors and windows were symmetrically arranged. Interior was divided into stalls - a large stall was for a foaling mare or sick horse. The floors were cobbled, and later of brick, with drainage channels laid across the floors. Outside steps to the first floor were common for farm hands to live in the building.

The stable is typically historically the second oldest building type on the farm. Free-standing stables began to be built from the 16th century. They were well built and placed near the house due to the value that the horses had as draught animals. High-status examples could have plastered ceilings to prevent dust falling through into the horses' eyes. Complete interiors – with stalls, mangers and feed racks – of the 19th century and earlier are rare.

Chapter- 4

Tower Block

A high-rise residential apartment building in Hong Kong

A 16 floor tower block in Charlestown, Greater Manchester, United Kingdom

A **tower block**, **high-rise**, **apartment tower**, **office tower**, **apartment block**, or **block of flats**, is a tall building or structure used as a residential and/or office building. In some areas they may be referred to as "MDU" standing for "Multi Dwelling Unit".

High-rise buildings became possible with the invention of the elevator (lift) and cheaper, more abundant building materials. The materials used for the structural system of high-rise buildings are reinforced concrete and steel. Most North American style skyscrapers have a steel frame, while residential blocks are usually constructed out of concrete.

High-rise structures pose particular design challenges for structural and geotechnical engineers, particularly if situated in a seismically active region or if the underlying soils have geotechnical risk factors such as high compressibility or bay mud. They also pose serious challenges to firefighters during emergencies in high-rise structures. New and old building design, building systems like the building standpipe system, HVAC systems (Heating, Ventilation and Air conditioning), fire sprinkler system and other things like stairwell and elevator evacuations pose significant problems.

Apartment blocks have technical and economic advantages in areas with high population density. They have become a distinguished form of housing accommodation in virtually all densely populated urban areas around the world. In contrast with low-rise and single-family houses, apartment blocks accommodate more inhabitants per unit of area of land they occupy and also decrease the cost of municipal infrastructure.

History

These tower blocks were built in Shibam, Yemen in the 16th century, and are the tallest mudbrick buildings in the world

High-rise apartment buildings had already appeared in antiquity: the insulae in ancient Rome and several other cities in the Roman Empire, some of which might have reached up to 10 or more stories, one reportedly having 200 stairs. Because of the destruction caused by poorly-built high-rise insulae collapsing, several Roman emperors, beginning with Augustus (r. 30 BC - 14 AD), set limits of 20–25 metres for multi-story buildings, but met with limited success, as these limits were often ignored despite the likelihood of taller insulae collapsing. The lower floors were typically occupied by either shops or wealthy families, while the upper stories were rented out to the lower classes. Surviving Oxyrhynchus Papyri indicate that seven-storey buildings even existed in provincial towns, such as in 3rd century AD Hermopolis in Roman Egypt.

In Arab Egypt, the initial capital city was Fustat. It housed many high-rise residential buildings, some seven stories tall that could reportedly accommodate hundreds of people. Al-Muqaddasi in the 10th century described them as resembling minarets, while Nasir Khusraw in the early 11th century described some of them rising up to 14 stories, with roof gardens on the top storey complete with ox-drawn water wheels for irrigating them. By the 16th century, Cairo also had high-rise apartment buildings where the two lower floors were for commercial and storage purposes and the multiple stories above them were rented out to tenants.

The skyline of many important medieval cities was dominated by large numbers of high-rising urban towers which fulfilled defensive, but also representative purposes. The residential Towers of Bologna numbered between 80 to 100 at a time, the largest of which still rise to 97.2 m. In Florence, a law of 1251 decreed that all urban buildings should be reduced to a height of less than 26 m, the regulation immediately put into effect. Even medium-sized towns such as San Gimignano are known to have featured 72 towers up to 51 m height.

Tower blocks were built in the Yemeni city of Shibam in the 16th century. The houses of Shibam are all made out of mud bricks, but about 500 of them are tower houses, which rise 5 to 16 stories high, with each floor having one or two apartments. This technique of building was implemented in order to protect residents from Bedouin attacks. While Shibam has existed for around 2,000 years, most of the city's houses come mainly from the 16th century. The city has the tallest mud buildings in the world, with some of them over 30 meters (100 feet) high. Shibam has been called "one of the oldest and best examples of urban planning based on the principle of vertical construction" or "Manhattan of the desert".

Currently, the tallest high-rise apartment building in the world is Chicago's John Hancock Center, constructed under the supervision of Skidmore, Owings & Merrill and completed in 1969. The building has 100 stories and stands at 344 meters tall.

Modern development

United Kingdom

The three tower blocks of the Crossways Estate in Bow, London, United Kingdom

Tower blocks were built in the UK after the Second World War. The first residential tower block, "The Lawn" was constructed in Harlow, Essex in 1951; it is now a Grade II listed building. In many cases Tower Blocks were seen as a "quick-fix" to cure problems caused by crumbling and unsanitary 19th century dwellings or to replace buildings destroyed by German aerial bombing. Initially, they were welcomed, and their excellent views made them popular living places. Later, as the buildings themselves deteriorated, they grew a reputation for being undesirable low cost housing, and many tower blocks saw rising crime levels, increasing their unpopularity. One response to this was the great increase in the number of housing estates built, which in turn brings its own problems. In the UK, tower blocks particularly lost popularity after the partial collapse of Ronan Point in 1968. Glasgow, the largest city in Scotland, is believed to contain the highest concentration of tower blocks in the UK - examples include the Hutchesontown C blocks in the Gorbals, the 20-storey blocks in Sighthill, and the 31-storey Red Road flats in the city's north east. However, on the whole, London has the largest number of high-rise residential buildings in the UK.

The post-war British tower block vision

Post-war Britain was the stage for a tower block building 'boom'; from the 1950s to the late 1970s there was a dramatic increase in tower block construction. During this time, local authorities desired to impress their voters by building futuristic and imposing tower blocks, which would signify post-war progress. Both Patrick Dunleavy and Lynsey Hanley agree that architects and planners were influenced by Le Corbusier's promotion of high-rise architecture. The modern tower blocks were to include features that would foster desired forms of resident interaction, an example being the inclusion of Le Corbusier's streets in the sky in some estates.

As well as inspiring residents, local authority planners believed that the way tower blocks were constructed would save money. Generally, the tower blocks were built on cheap greenfield land skirting established cities. Although the property prices for these periphery sites were markedly cheaper than their inner city counterparts, they often had little access to public amenities, such as public transport. It was thought that the implementation of industrialised building techniques would lower costs too, as similar tower blocks would be replicated over many sites. Uniform and standardised parts, such as toilet fittings and door handles, would be fitted throughout many tower blocks – planners deemed that buying in bulk would reduce overall costs.

Another key aspect of the tower block vision was the 'Brutalist' architectural method, popular with architects and planners at the time. The Brutalist emphasis led to the construction of stark and striking tower blocks with large sections of exposed concrete. Concrete was to be an integral part of the tower block designs; it could be poured on site, offering boundless flexibility to the building designers. To the planners, concrete was a silver bullet for the construction process – it was economical, and 'was vaunted as being long-lasting, if not indestructible'.

The post war British tower block reality

Elmet Towers in Swarcliffe, Leeds, showing the dereliction that led to its demolition

Coleman's 1985 work argues that in trying to emulate Le Corbusier's ideas, the tower block planners only succeeded in encouraging social problems. Although architects and local authorities intended the opposite, tower blocks quickly became, as Hanley sharply stated, 'slums in the sky'. Due to demanding deadlines, complicated construction practices were rushed and many tower blocks experienced structural decay as a result – roofs leaked, concrete suffered spalling, steel corroded, and damp penetrated the buildings. Unfortunately, by replicating tower blocks across the nation, planners 'disastrously' replicated design faults. In many tower blocks, concrete quickly exhibited signs of decay; cracks soon formed and destabilised the buildings. The partial collapse of the Ronan Point tower block is an infamous example of the hasty and substandard construction that occurred in a number of the towers. The tower blocks quickly lost their 'futuristic' look; concrete turned from the crisp white the designers had imagined to a dull grey, stained by pollution.

Poor design decisions ruined the anticipated benefits of the buildings. Open spaces, which were supposed to benefit the residents, were instead unattractive, unused and inadequately supervised. Residents felt it was difficult to maintain the large open spaces around the blocks because they realistically belonged to no one. Social problems increased as the tower blocks quickly degraded through poor maintenance and an insecure communal environment. Apart from frequent break-downs, communal lifts were a source of fear for people travelling alone. It was a rarity to 'enter a clean-smelling, undefaced lift'. The tower blocks, many of which were located on the periphery of the city, made residents feel isolated and cut off from society. Outsiders and newcomers were also affected; they felt the overbearing design of the tower blocks made them fearsome and unsociable.

Power argues that as a direct consequence of their design and construction, security problems were prevalent in many of the tower blocks. Break-ins, vandalism and muggings were common, which were aided by the buildings' concealed areas, the mazes of internal corridors, and dark corners. Police were often required in the tower blocks, but their infrequent presence did little to pacify towers rife with delinquency. In order to contain disruptive behaviour, local authorities began to place 'problem families' in the same blocks; Hanley argues that this policy only led to 'further alienation …nihilism and a creeping sense of lawlessness'. Dunleavy seconds this, suggesting that the mental health of long term tower block residents may have been detrimentally affected.

While local authorities and their architects intended to create tower blocks that encouraged harmonious and vibrant communities, often the results were far from ideal. Post-war tower blocks were compromised from the outset by a combination of faults: local authorities advocated impractical architectural methods; design and construction faults were frequently reproduced; and there appeared to be a lack of understanding about the social consequences of certain design features. Collectively, these oversights transformed many tower blocks into undesirable places to live.

Towards the present day

In recent years, some council or ex-council high-rises in the United Kingdom, including Trellick Tower, Keeling House, Sivill House and The Barbican Estate, have become popular with young professionals due to their excellent views, desirable locations and architectural pedigrees, and now command high prices. There are plans to redevelop the Little London and Lovell Park areas on the fringes of Leeds city centre into luxury flats for 'Young Urban Professionals'. The plans entail demolishing all of the council housing and refurbishing the highrise flats. This demand has led to many councils rethinking plans regarding their demolition.

After a gap of around 30 years, new high-rise flats are once again being built in Belfast, Birmingham, Cardiff, Glasgow, Leeds, Liverpool, London, Manchester and Newcastle; but this time for wealthy professionals, rather than the `lower classes`. Their developers market these properties by using the American term 'apartment buildings', perhaps in an effort to distance these newer buildings from the older tower blocks from the 1950s and 1960s. These are usually taller than their older counterparts and generally built in and around these provincial city centres. They are often glass and aluminum clad. Tonight with Trevor McDonald highlighted that in Leeds and Manchester (perhaps the cities that had seen most development) only approximately half were occupied and with owner occupation often being as low as 10%.

Tower blocks in Northern Ireland were never built to the frequency as they were in other cities in Britain and Ireland. Most tower blocks and flat complexes are found in Belfast and Derry, although many of these have been demolished in recent years and replaced with traditional public housing units. The Divis flats complex in west Belfast was built in between 1968 and 1972 was demolished in the early 1990s as the residents demanded new houses due to mounting problems with the flats. Divis Tower, built separately in 1966, still stands, however; and, in 2007, work began to convert the former British Army base at the top two floors into new dwellings.

In the north of the City, the iconic 7 towers complex in the New Lodge remains, although so too the problems that residents face, such as poor piping and inadequate sanitation. Farther north, the 4 tower blocks in Rathcoole still dominate the local skyline, while in south Belfast, the tower blocks in Seymour Hill also remain standing.

Ireland

Flats in Ballymun, Dublin, Ireland

Most of the tower blocks in Northern Ireland are in Belfast. All of Belfast's flat complexes were built by Belfast Corporation as part of Belfast slum clearances and to solve the housing problem. The Ballymun Flats were built between 1966 and 1969 consisting of seven 15-storey towers, nineteen 8 storey blocks and ten 4 storey blocks. Inner Dublin flat complexs include Sheriff Street (demolished), Fatima Mansions (demolished and redeveloped), St. Joseph's Gardens (demolished; replaced by Killarney Court flat complex), St. Teresa's Gardens, Dolphin House, Liberty House, St. Michael's Estate and O'Devaney Gardens and a lot more mainly throughout the North and South Inner City of Dublin. Suburban flat complexes were built exclusively on the northside of the city in Ballymun, Coolock and Kilbarrack. These flats were badly affected by a heroin epidemic that hit working-class areas of Dublin in the 1980s and early 90s.

Over the last five years the largest cities such as Dublin, Cork, Limerick and Galway have witnessed new large apartment building. Some large towns such as Navan, Drogheda, Dundalk and Mullingar have also witnessed lots of modern apartments being built.

Eastern Europe

Russia is currently undergoing a dramatic buildout, growing a commercially-shaped skyline. Russians, both poor and wealthy, from Soviet time had conserved the impression of prestige about tower blocks.

East Asia

The unpopularity of tower blocks in Europe is in marked contrast to many Asian countries.

Typical Tower block apartment in South Korea

In South Korea the tower blocks are called "Apartment Complex *(Apartment Danji)*". The first residential towers began to be built after the Korean War. The South Korean government needed to build many apartment complexes in the cities to be able to accommodate the citizens. In the 60 years since, as the population increased considerably, tower blocks have become more common. This time however the new tower blocks integrated shopping malls, parking system and other convenient facilities.

In Singapore and urban Hong Kong, land prices are so high that almost the entire population lives in high-rise apartments. In fact, over 60% of Hong Kong residents live in apartments, many of them condominiums. Tower Palace in Seoul, South Korea, is the tallest apartment complex in Asia.

Canada

In Canada tower blocks are usually known as *apartment buildings* or *apartment blocks*. Toronto contains the second largest concentration of high-rise apartment buildings in North America. Many were built in the 1950s and 1960s to provide modern affordable housing in what was then the periphery of the city, following what had become popular in many European nations; notably France. Today, many lie isolated from amenities and rapid transit corridors, and a few have become plagued by crime such as those around Jane and Finch, Malvern, and Regent Park neighbourhoods. Except for public housing, the construction of apartment blocks has declined in Toronto since the 1970s, and most multi-unit buildings since then have been built as condominiums. Furthermore, public housing is increasingly being combined with private condominium development, such as with the redevelopment of Regent Park.

"Residential high-rises" are also extensively used in Vancouver downtown, leading to very high population downtown. Many of the newly built high-rises are luxury apartments that command prices higher than those than detached housing in the area.

United States

In the United States tower blocks are commonly referred to as "midrise" or "highrise apartment buildings", depending on their height, while buildings that house fewer flats (apartments), or are not as tall as the tower blocks, are called "lowrise apartment buildings".

Some of the first residential towers were the Castle Village towers in New York City completed in 1939. Their cross-shaped design was copied in towers in Parkchester and Stuyvesant Town residential developments.

The government's experiments in the 1960s and 70s to use high-rise apartments as a means of providing the housing solution for the poor resulted in a spectacular failure. All but a few high-rise housing projects in the nation's largest cities, such as Cabrini–Green and Robert Taylor Homes in Chicago, Penn South in New York and the Desire projects in New Orleans, fell victim to the "ghettofication" and are now being torn down, renovated, or replaced.

In contrast to their public housing cousins, commercially developed high-rise apartment buildings continue to flourish in cities around the country largely due to high land prices and the housing boom of the 2000s. The Upper East Side in New York City and Chicago's Gold Coast, both featuring high-rise apartments, are the wealthiest urban neighborhoods in the United States.

Currently, the tallest high-rise apartment building and tower block in the world is Chicago's John Hancock Center, constructed by Bangladeshi engineer Fazlur Khan in 1969. The building has 100 stories and stands at 344 meters tall.

Australia

Housing commission towers in Waterloo, Sydney, Australia

High-rise living in Australia was limited to small pockets of bohemian inner Sydney until the 1960s, where a short-lived fashion saw public housing tenants located in new high-rise developments, especially in Sydney and Melbourne. Due to the stigma these enormous and impersonal developments gained, high-rise living fell out of favour until a new wave of developments aimed at the affluent inner urban middle class began from the 1970s onwards. Developers have enthusiastically adopted the term 'apartment' for these new high-rise blocks, perhaps to avoid the stigma still attached to housing commission flats.

Definition

Although there is no precise definition that is universally accepted, various bodies have tried to define what 'high-rise' means:

- Emporis Standards defines a high-rise as "A multi-story structure between 35-100 meters tall, or a building of unknown height from 12-39 floors."
- According to the building code of Hyderabad, India, a high-rise building is one with four floors or more, or one 15 meters or more in height.
- The *New Shorter Oxford English Dictionary* defines a high-rise as "a building having many stories".
- The *International Conference on Fire Safety in High-Rise Buildings* defined a high-rise as "any structure where the height can have a serious impact on evacuation"
- Massachusetts, United States General Laws define a high-rise as being higher than 70 feet (21 m).
- Most building engineers, inspectors, architects and similar professions define a high-rise as a building that is at least 75 feet (23 m) tall.

Streets in the sky

"Street in the sky" at Park Hill

Streets in the sky is a term used to describe a style of architecture that emerged in Britain in the 1960s and 1970s. Generally built to replace run-down terraced housing, the new designs included not only modern improvements such as inside toilets, but also shops and other community facilities within high-rise blocks. Examples of the buildings and developments are Trellick Tower, Balfron Tower, Robin Hood Gardens and Keeling House in London, Hunslet Grange in Leeds and Park Hill, Sheffield. These were an attempt to develop a new architecture, differentiated from earlier large housing estates, such as Quarry Hill flats in Leeds.

Alison and Peter Smithson were the architects of Robin Hood Gardens. Another large example, the Aylesbury Estate in South London, built in 1970, is about to be demolished.

Deck access

Deck access is a term used to describe flats that are accessed from a walkway that is open to the elements, as opposed to flats that are accessed from fully enclosed internal corridors. Deck access blocks of flats are usually fairly low-rise structures. The decks can vary from simple walkways, which may be covered or uncovered, to decks wide enough for small vehicles. The best known example of deck-access flats in the UK is Park Hill, Sheffield, where the decks are wide enough to allow electric vehicles, however the design is inspired by French Modernist architect Le Corbusier, particularly his Unite D'Habitation in Marseilles.

Chapter- 5

Skyscraper

A **skyscraper** is a tall, continuously habitable building. There is no official definition or height above which a building may clearly be classified as a skyscraper. Most cities define the term empirically; even a building of 80 meters (262 feet) may be considered a skyscraper if it protrudes above its built environment and changes the overall skyline.

Definition

The Burj Khalifa in Dubai, UAE is currently the tallest skyscraper in the world

The word "skyscraper" originally was a nautical term referring to a small triangular sail set above the skysail on a sailing ship. The term was first applied to buildings in the late 19th century as a result of public amazement at the tall buildings being built in Chicago and New York City. The first skyscraper was for many years thought to be the Home Insurance Building built in Chicago, Illinois in 1885. More recent arguments point to New York's seven floor Equitable Life Assurance Building built in 1870 and it was arguably the first office building built using a kind of skeletal frame but it depends on what factors are chosen and even the scholars making the argument find it academic.

The structural definition of the word *skyscraper* was refined later by architectural historians, based on engineering developments of the 1880s that had enabled construction of tall multi-storey buildings. This definition was based on the steel skeleton—-as opposed to constructions of load-bearing masonry, which passed their practical limit in 1891 with Chicago's Monadnock Building. Philadelphia's City Hall, completed in 1901, still holds claim as the world's tallest load-bearing masonry structure at 167 m (548 ft). The steel frame developed in stages of increasing self-sufficiency, with several buildings in Chicago and New York advancing the technology that allowed the steel frame to carry a building on its own. Today, however, many of the tallest skyscrapers are built almost entirely with reinforced concrete. Pumps and storage tanks maintain water pressure at the top of skyscrapers.

Skyscraper and supertall

A loose convention in the United States and Europe now draws the lower limit of a skyscraper at 150 meters (~500 ft). A skyscraper taller than 300 meters (~1000 ft) may be referred to as *supertall*. Shorter buildings are still sometimes referred to as skyscrapers if they appear to dominate their surroundings.

The somewhat arbitrary term *skyscraper* should not be confused with the also ill-defined term *high-rise*. The Emporis Standards Committee defines a high-rise building as "a multi-story structure between 35-100 meters tall, or a building of unknown height from 12-39 floors" and a skyscraper as "a multi-story building whose architectural height is at least 100 meters." Some structural engineers define a highrise as any vertical construction for which wind is a more significant load factor than earthquake or weight. Note that this criterion fits not only high rises but some other tall structures, such as towers.

The word *skyscraper* often carries a connotation of pride and achievement. The skyscraper, in name and social function, is a modern expression of the age-old symbol of the world center or *axis mundi*: a pillar that connects earth to heaven and the four compass directions to one another.

History

Before the 19th century

The Great Pyramid of Giza, *circa* 2560 BC, was 146 m tall and its height was unsurpassed until at least the 14th century AD.

The Two Towers of Bologna in the 12th century reached 97.2 m in height.

The 16th-century city of Shibam consisted entirely of over 500 high-rise tower houses.

Modern skyscrapers are built with materials such as steel, glass, reinforced concrete and granite, and routinely utilize mechanical equipment such as water pumps and elevators. Until the 19th century, buildings of over six stories were rare, as having great numbers of stairs to climb was impractical for inhabitants, and water pressure was usually insufficient to supply running water above 50 m (164 ft).

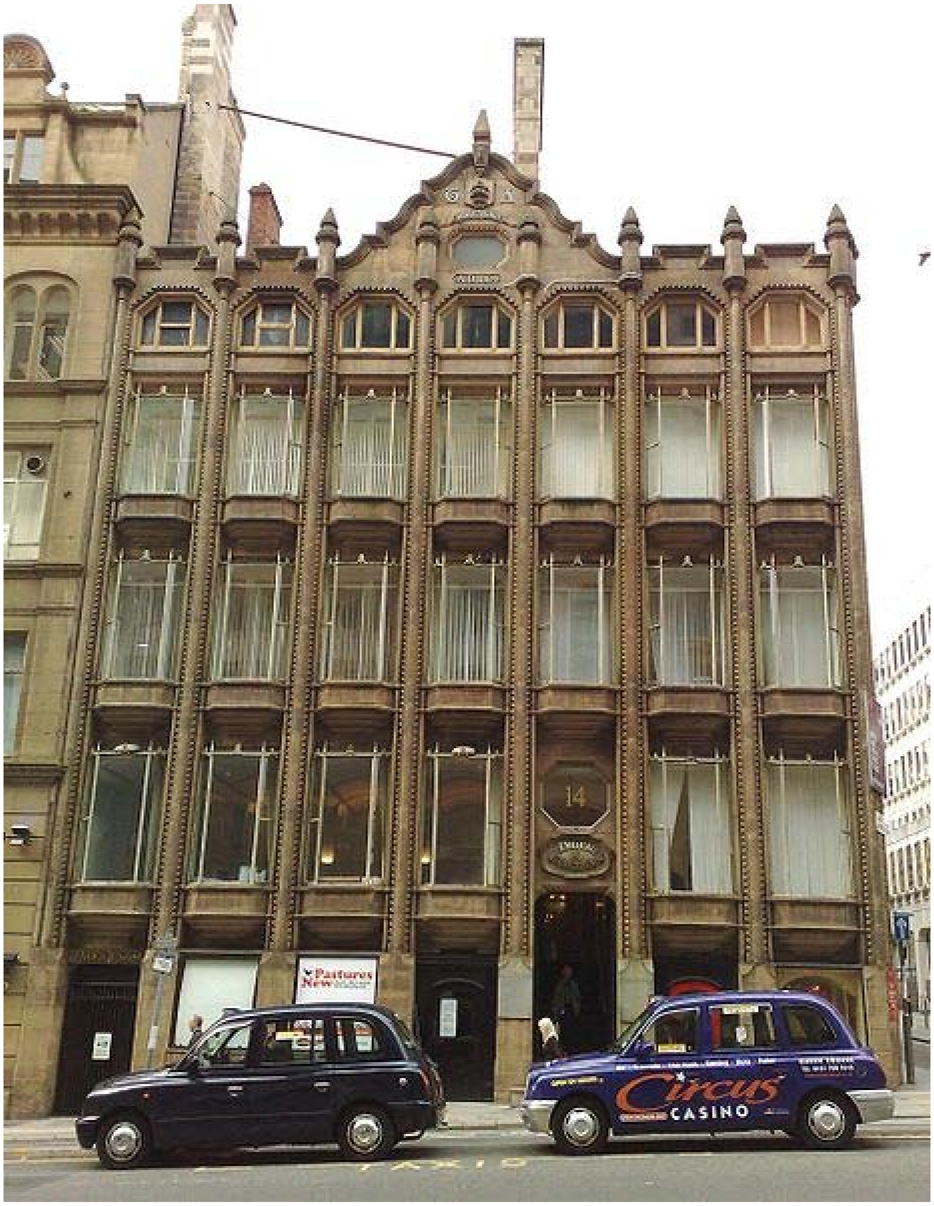
The tallest building in ancient times was the Great Pyramid of Giza in ancient Egypt, which was 146 metres (479 ft) tall and was built in the 26th century BC. Its height was not surpassed for thousands of years, possibly until the 14th century AD with the construction of Lincoln Cathedral (though its height is disputed), which in turn was not surpassed in height until the Washington Monument in 1884. However, being uninhabited buildings, none of these buildings actually complies with the definition of a skyscraper.

High-rise apartment buildings already flourished in classical antiquity: ancient Roman insulae in Rome and other imperial cities reached up to 10 and more stories. Several emperors, beginning with Augustus (r. 30 BC-14 AD), attempted to establish limits of 20–25 m for multi-storey buildings, but met with only limited success. The lower floors were typically occupied by either shops or wealthy families, while the upper stories were rented out to the lower classes. Surviving Oxyrhynchus Papyri indicate that seven-storey buildings even existed in provincial towns, such as in 3rd century AD Hermopolis in Roman Egypt.

The skylines of many important medieval cities had large numbers of high-rise urban towers. Wealthy families built these towers for defensive purposes and as status symbols. The residential Towers of Bologna in the 12th century, for example, numbered between 80 to 100 at a time, the largest of which (known as the "Two Towers") rise to 97.2 metres (319 ft). In Florence, a law of 1251 decreed that all urban buildings should be reduced to a height of less than 26 m, the regulation immediately put into effect. Even medium-sized towns at the time such as San Gimignano are known to have featured 72 towers up to 51 m height.

The medieval Egyptian city of Fustat housed many high-rise residential buildings, which Al-Muqaddasi in the 10th century described as resembling minarets. Nasir Khusraw in the early 11th century described some of them rising up to 14 stories, with roof gardens on the top floor complete with ox-drawn water wheels for irrigating them. Cairo in the 16th century had high-rise apartment buildings where the two lower floors were for commercial and storage purposes and the multiple stories above them were rented out to tenants. An early example of a city consisting entirely of high-rise housing is the 16th-century city of Shibam in Yemen. Shibam was made up of over 500 tower houses, each one rising 5 to 11 storeys high, with each floor being an apartment occupied by a single family. The city was built in this way in order to protect it from Bedouin attacks. Shibam still has the tallest mudbrick buildings in the world, with many of them over 100 feet (30 m) high.

An early modern example of high-rise housing was in 17th-century Edinburgh, Scotland, where a defensive city wall defined the boundaries of the city. Due to the restricted land area available for development, the houses increased in height instead. Buildings of 11 stories were common, and there are records of buildings as high as 14 stories. Many of the stone-built structures can still be seen today in the old town of Edinburgh. The oldest iron framed building in the world, although only partially iron framed, is The Flaxmill (also locally known as the "Maltings"), in Shrewsbury, England. Built in 1797, it is seen as the "grandfather of skyscrapers", since its fireproof combination of cast iron columns and cast iron beams developed into the modern steel frame that made modern skyscrapers possible. Unfortunately, it lies derelict and needs much investment to keep it standing.



Oriel Chambers, Liverpool. The world's first glass curtain walled building. The stone mullions are decorative.

Built in 1931, The Empire State Building in New York City is one of the oldest, yet tallest skyscrapers.

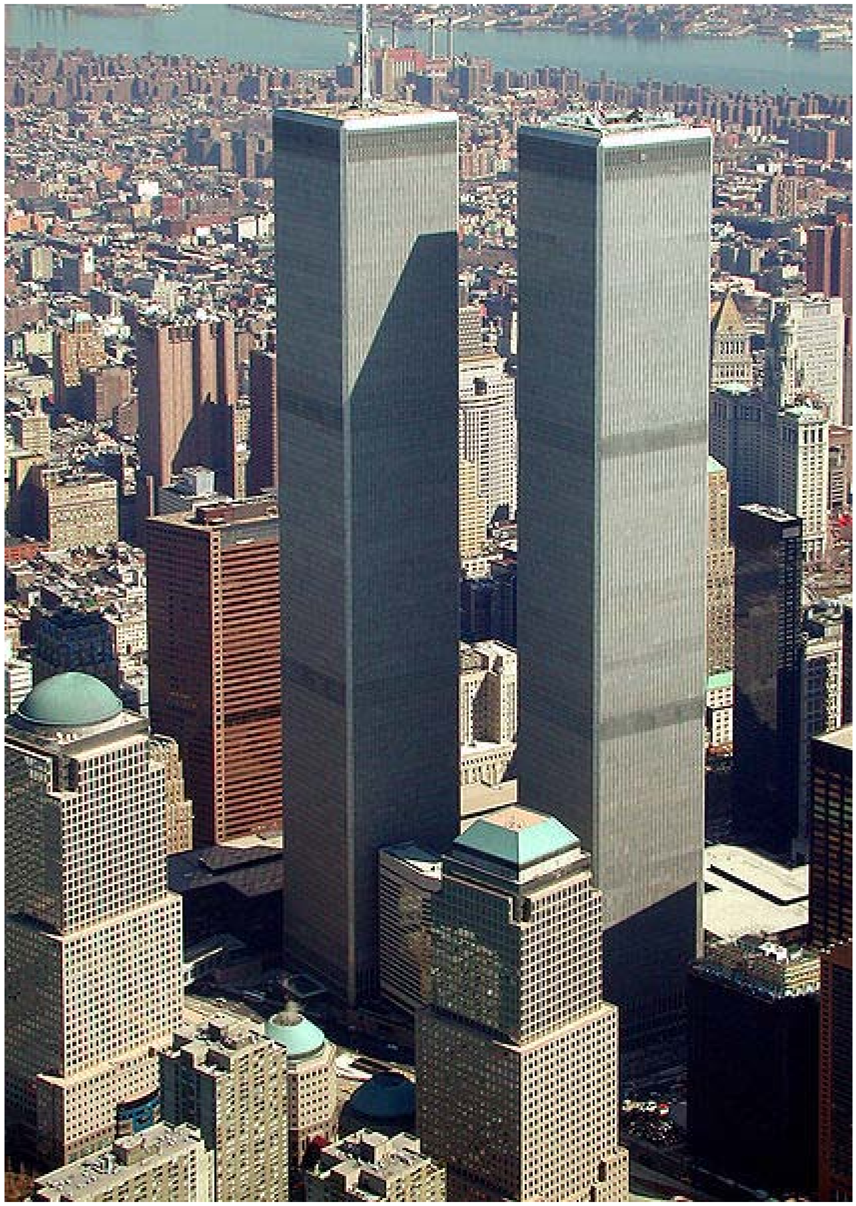
Early skyscrapers

An early development was Oriel Chambers in Liverpool. Designed by local architect Peter Ellis in 1864, the building was the world's first iron-framed, glass curtain-walled office building. It was only 5 floors high as the elevator had not yet been invented. Further developments led to the world's first skyscraper, the ten-storey Home Insurance Building in Chicago, built in 1884–1885. While its height is not considered very impressive today, it was at that time. The architect, Major William Le Baron Jenney, created a load-bearing structural frame. In this building, a steel frame supported the entire weight of the walls, instead of load-bearing walls carrying the weight of the building. This development led to the "Chicago skeleton" form of construction.

Louis Sullivan's Wainwright Building in St. Louis, 1891, was the first steel-framed building with soaring vertical bands to emphasize the height of the building and is therefore considered by some to be the first true skyscraper.

Most early skyscrapers emerged in the land-strapped areas of Chicago, London, and New York toward the end of the 19th century. A land boom in Melbourne, Australia between 1888-1891 spurred the creation of a significant number of early skyscrapers, though none of these were steel reinforced and few remain today. Height limits and fire restrictions were later introduced. London builders soon found building heights limited due to a complaint from Queen Victoria, rules that continued to exist with few exceptions until the 1950s. Concerns about aesthetics and fire safety had likewise hampered the development of skyscrapers across continental Europe for the first half of the twentieth century (with the notable exceptions of the 17-storey Kungstornen *(Kings' Towers)* in Stockholm, Sweden, which were built 1924-25, probably the first skyscrapers in Europe , the 15-storey Edificio Telefónica in Madrid, Spain, built in 1929; the 26-storey Boerentoren in Antwerp, Belgium, built in 1932; and the 31-storey Torre Piacentini in Genoa, Italy, built in 1940). After an early competition between Chicago and New York City for the world's tallest building, New York took the lead by 1895 with the completion of the American Surety Building, leaving New York with the title of tallest building for many years. New York City developers competed among themselves, with successively taller buildings claiming the title of "world's tallest" in the 1920s and early 1930s, culminating with the completion of the Chrysler Building in 1930 and the Empire State Building in 1931, the world's tallest building for forty years. The first completed World Trade Center tower became the world's tallest building in 1972. However, it was soon overtaken by the Sears Tower (now Willis Tower) in Chicago within two years. The Sears Tower stood as the world's tallest building for 24 years, from 1974 until 1998, until it was edged out by Petronas Twin Towers in Kuala Lumpur, which held the title for six years.

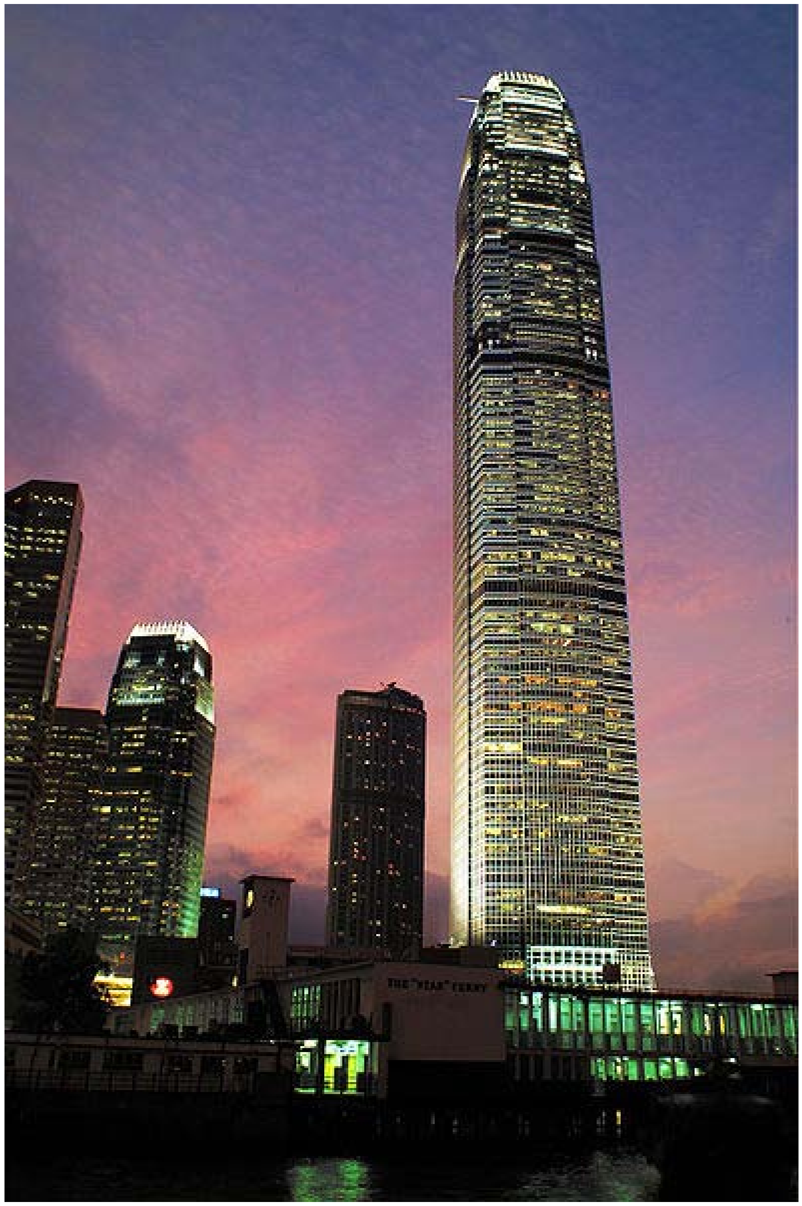
Taipei 101, formerly the world's tallest skyscraper, was the first to exceed the half-kilometer mark.



The iconic World Trade Center twin towers were destroyed in 2001.

The Willis Tower in Chicago was the world's tallest building from 1974 to 1998, and remains the tallest in the Western Hemisphere

The Petronas Twin Towers, the world's tallest twin buildings



Tower 2 of the International Finance Centre in Hong Kong is one of the 20 tallest buildings in the world.

The Commerzbank Tower in Frankfurt/Germany is the tallest completed skyscraper in the European Union.

30 St Mary Axe in London, United Kingdom is an example of a modern environmentally friendly skyscraper.

Modern skyscrapers

From the 1930s onwards, skyscrapers also began to appear in Latin America (São Paulo, Santiago, Caracas, Bogotá, Mexico City) and in Asia (Tokyo, Shanghai, Hong Kong, Manila, Singapore, Mumbai, Jakarta, Seoul, Kuala Lumpur, Taipei, Bangkok). Immediately after World War II, the Soviet Union planned eight massive skyscrapers dubbed "Stalin Towers" for Moscow; seven of these were eventually built. The rest of Europe also slowly began to permit skyscrapers, starting with Madrid, during the 1950s. Finally, skyscrapers also began to be constructed in cities of Africa, the Middle East and Oceania (mainly Australia) from the late 1950s.

In the early 1960s structural engineer Fazlur Khan realized that the rigid steel frame structure that had "dominated tall building design and construction so long was not the only system fitting for tall buildings", marking "the beginning of a new era of skyscraper revolution in terms of multiple structural systems." His central innovation in skyscraper design and construction was the idea of the "tube" structural system, including the "framed tube", "trussed tube", and "bundled tube". These systems allowed far greater economic efficiency, and also allowed efficient skyscrapers to take on various shapes, no longer needing to be box-shaped. Over the next fifteen years, many towers were built by Khan and the "Second Chicago School", including the massive 442-meter (1,451-foot) Willis Tower. Chicago is currently undergoing an epic construction boom that will greatly add to the city's skyline. Since 2000, at least 40 buildings at a minimum of 50 stories high have been built or planned. The Trump International Hotel and Tower, Waterview Tower, Mandarin Oriental Tower, 29-39 South LaSalle, Park Michigan, and Aqua are some of the more notable projects currently underway in the city. Chicago, Hong Kong, and New York City, otherwise known as "the big three," are recognized in architectural circles as having especially compelling skylines. A landmark skyscraper can inspire a boom of new high-rise projects in its city, as Taipei 101 has done in Taipei since its opening in 2004.

History of tallest skyscrapers

At the beginning of the 20th century, New York City was a center for the Beaux-Arts architectural movement, attracting the talents of such great architects as Stanford White and Carrere and Hastings. As better construction and engineering technology became available as the century progressed, New York and Chicago became the focal point of the competition for the tallest building in the world. Each city's striking skyline has been composed of numerous and varied skyscrapers, many of which are icons of 20th century architecture:

- The **Flatiron Building**, designed by Daniel Hudson Burnham and standing 285 ft (87 m) high, was one of the tallest buildings in the city upon its completion in 1902, made possible by its steel skeleton. It was one of the first buildings designed with a steel framework, and to achieve this height with other construction methods of that time would have been very difficult. (The 1889 Tower Building, designed by Bradford Gilbert and considered by some to be New York's first skyscraper, may have been the first building to use a skeletal steel frame.) Subsequent buildings such as the **Singer Building**, the **Metropolitan Life Tower** were higher still.
- The **Woolworth Building**, a neo-Gothic "Cathedral of Commerce" overlooking City Hall, was designed by Cass Gilbert. At 792 feet (241 m), it became the world's tallest building upon its completion in 1913, an honor it retained until 1930, when it was overtaken by 40 Wall Street.
- That same year, the **Chrysler Building** took the lead as the tallest building in the world, scraping the sky at 1,046 feet (319 m). Designed by William Van Alen, an art deco masterpiece with an exterior crafted of brick, the Chrysler Building continues to be a favorite of New Yorkers to this day.

- The **Empire State Building**, the first building to have more than 100 floors (it has 102), was completed the following year. It was designed by Shreve, Lamb and Harmon in the contemporary Art Deco style. The tower takes its name from the nickname of New York State. Upon its completion in 1931 at 1,250 feet (381 m), it took the top spot as tallest building, and towered above all other buildings until 1972. The antenna mast added in 1951 brought pinnacle height to 1,472 feet (449 m), lowered in 1984 to 1,454 feet (443 m).
- The **World Trade Center** officially reached full height in 1972, was completed in 1973, and consisted of two tall towers and several smaller buildings. For a short time, the first of the two towers was the world's tallest building. Upon completion, the towers stood for 28 years, until the September 11, 2001 attacks destroyed the structures. Various governmental entities, financial firms, and law firms called the towers home.
- The **Willis Tower** (formerly Sears Tower) was completed in 1974, one year after the World Trade Center, and surpassed it as the world's tallest building. It was the first building to employ the "bundled tube" structural system, designed by Fazlur Khan. The building was not surpassed in height until the Petronas Towers were constructed in 1998, but remained the tallest in some categories until Burj Khalifa surpassed it in all categories. It is currently the tallest building in the United States.

Momentum in setting records passed from the United States to other nations with the opening of the **Petronas Twin Towers** in Kuala Lumpur, Malaysia, in 1998. The record for world's tallest building remained in Asia with the opening of **Taipei 101** in Taipei, Taiwan, in 2004. A number of architectural records, including those of the world's tallest building and tallest free-standing structure, moved to the Middle East with the opening of the **Burj Khalifa** in Dubai, UAE.

This geographical transition is accompanied by a change in approach to skyscraper design. For much of the twentieth century large buildings took the form of simple geometrical shapes. This reflected the "international style" or modernist philosophy shaped by Bauhaus architects early in the century. The last of these, the Willis Tower and World Trade Center towers in New York, erected in the 1970s, reflect the philosophy. Tastes shifted in the decade which followed, and new skyscrapers began to exhibit postmodernist influences. This approach to design avails itself of historical elements, often adapted and re-interpreted, in creating technologically modern structures. The Petronas Twin Towers recall Asian pagoda architecture and Islamic geometric principles. Taipei 101 likewise reflects the pagoda tradition as it incorporates ancient motifs such as the ruyi symbol. The Burj Khalifa draws inspiration from traditional Arabic art. Architects in recent years have sought to create structures that would not appear equally at home if set in any part of the world, but that reflect the culture thriving in the spot where they stand.

The following list measures height of the **roof**. The more common gauge is the **highest architectural detail**; such ranking would have included Petronas Towers, built in 1998.

Built	Building	City	Country	Roof		Floors	Pinnacle		Current status
1873	Equitable Life Building	New York City	United States	142 ft	43 m	8			Demolished in 1912
1889	Auditorium Building	Chicago	United States	269 ft	82 m	17	349 ft	106 m	Standing
1890	New York World Building	New York City	United States	309 ft	94 m	20	349 ft	106 m	Demolished in 1955
1894	Manhattan Life Insurance Building	New York City	United States	348 ft	106 m	18			Demolished in 1930
1895	Milwaukee City Hall	Milwaukee	United States	353 ft	108 m	15			Standing
1899	Park Row Building	New York City	United States	391 ft	119 m	30			Standing
1901	Philadelphia City Hall	Philadelphia	United States	511 ft	155.8 m	9	548 ft	167 m	Standing
1908	Singer Building	New York City	United States	612 ft	187 m	47			Demolished in 1968
1909	Met Life Tower	New York City	United States	700 ft	213 m	50			Standing
1913	Woolworth Building	New York City	United States	792 ft	241 m	57			Standing
1930	40 Wall Street	New York City	United States			70	927 ft	283 m	Standing
1930	Chrysler Building	New York City	United States	927 ft	282.9 m	77	1,046 ft	319 m	Standing
1931	Empire State Building	New York City	United States	1,250 ft	381 m	102	1,454 ft	443 m	Standing
1972	World Trade Center (North tower)	New York City	United States	1,368 ft	417 m	110	1,727 ft	526.3 m	Destroyed in 2001
1974	Willis Tower (formerly Sears Tower)	Chicago	United States	1,450 ft	442 m	108	1,729 ft	527 m	Standing
2004	Taipei 101	Taipei	Taiwan	1,474 ft	449 m	101	1,671 ft	509 m	Standing
2010	Burj Khalifa	Dubai	United Arab Emirates	2,717 ft	828 m	160	2,717 ft	828 m	Standing

Today

Skyscrapers can serve as a city's identifier like Auckland's Sky Tower at 328 meters (1,076 feet). Visitors can rappell from the top.

Today, skyscrapers are an increasingly common sight where land is expensive, as in the centres of big cities, because they provide such a high ratio of rentable floor space per unit area of land. They are built not just for economy of space; like temples and palaces of the past, skyscrapers are considered symbols of a city's economic power. Not only do they define the skyline, they help to define the city's identity.

Supertall towers

At the time Taipei 101 broke the half-kilometer mark in height, it was already technically possible to build structures towering over a kilometer above the ground. Proposals for such structures have been put forward, including the Mile-High Tower to be built in Jeddah, Saudi Arabia and Burj Mubarak Al Kabir in Kuwait. Kilometer-plus structures present architectural challenges that may eventually place them in a new architectural category.

Future skyscrapers

The following skyscrapers are either approved or due to be completed in the near future:

- The **Lotte Super Tower 123**, a mixed-use skyscraper in Seoul, South Korea, will stand 555 meters (1,821 feet) in height (123 floors) upon completion (originally scheduled for 2014 after construction started in 2005, although the project is currently on hold). The tower will house retail space, residences, and a luxury hotel.
- Construction of the 133-floor, 640m supertall **Digital Media City Landmark Building** in Digital Media City, Seoul, South Korea, started in 2009, which will be the second-tallest building in the world when it is completed in 2015, housing the world's tallest observatory and hotels. Being constructed at the fastest speed among major skyscraper projects by South Korea's Samsung C&T (who also built Burj Khalifa), the supertall is the first skyscraper to contain an entire city inside a building, including the world's largest aquarium, a luxury department store, shopping malls, clinic center, high-tech offices, first-class apartments, six to eight-star hotels, a concert restaurant, a broadcasting studio and an art center.
- Construction of the **Shanghai Tower** started on 29 November 2008. The tower will be 632 m (2,073 ft) high and have 127 floors. The building will feature a glass curtain wall and nine indoor gardens when it is completed in 2014.
- Construction of the 151-floor, 610m supertall **151 Incheon Tower** in Songdo International City, Incheon, South Korea, started in 2008, which will be the tallest twin towers in the world when it is completed in 2014.
- The **Abraj Al-Bait Towers**, also known as the "Mecca Royal Clock Hotel Tower" is a complex under construction in Mecca, Saudi Arabia by the Saudi Binladin Group. The complex consists of seven towers, and the tallest tower (Hotel Tower) will have a height of 601 m (1,972 ft). Upon completion in 2011, the structure will have the largest floor area of any structure in the world, at 1,500,000 square metres (16,137,600 sq ft).
- Construction of the 110-floor, 510m supertall in **Busan Lotte World**, Busan, South Korea, started in 2009, which will be the third tallest building world when it is completed in 2013.
- **1 World Trade Center** is now under construction and is the tallest tower comprising the redevelopment of the site of the former World Trade Center following the attacks of September 11, 2001. Its pinnacle will reach a height of

541.4 m (1,776 ft), a height representing the year of the United States Declaration of Independence.

- The 528 m (1,732 ft), 102 floors **PVN Tower** locale in Hanoi, Vietnam, which was approved, scheduled to construct in 2011 and completed in 2014.The building costs almost $1.2 billions. Upon completion, it will be the tallest and most expensive building in Vietnam and South East Asia.
- **India Tower** (720 metres) is a supertall skyscraper proposed for construction in Mumbai, Maharashtra State, India. In January 2010, the Brihanmumbai Municipal Corporation gave the official go ahead for its construction on a site located at Charni Road, Marine Lines, just north of the city's historical district.
- **World One** is a residential skyscraper (442 metres) under construction in Mumbai,India. It will be located in Upper Worli of Mumbai on the plot of a 17.5 acre site, which Lodha obtained for 250 crore (US$ 56.75 million). The project will cost 2,000 crore (US$ 454 million), be completed by 2014, and will have the world's second tallest residential tower once completed.
- The **Port Tower** is a building planned for Karachi, the financial capital of Pakistan, with the collaboration of local and foreign investors, in association with the Karachi Port Trust. When completed, the new structure will be 1,947 ft (593 m) high. The height of the tower has a special significance, representing the year Pakistan gained independence.
- The 308 m (1,010 ft) **Tour Generali** in Paris La Défense, scheduled to be completed in 2013, is an entirely green building office skyscraper that is set to be the tallest building in Paris and the second tallest in the European Union after the Shard of Glass in London.
- Construction of London's **Shard of Glass** started in March 2009, and is scheduled to be completed in May 2012, in time for the London Olympics. At 310 m (1,017 ft), it is set to be the tallest building in the European Union.

A growing interest exists in a concept adapted from skyscraper, called seascraper. This is a proposed large building which will function as a floating city.

Sustainability

The skyscraper as a concept is a product of the industrialized age, made possible by cheap energy and raw materials. The amount of steel, concrete and glass needed to construct a skyscraper is vast, and these materials represent a great deal of embodied energy. Tall skyscrapers are very heavy, which means that they must be built on a sturdier foundation than would be required for shorter, lighter buildings. Building materials must also be lifted to the top of a skyscraper during construction, requiring more energy than would be necessary at lower heights. Furthermore, a skyscraper consumes a lot of electricity because potable and non-potable water must be pumped to the highest occupied floors, skyscrapers are usually designed to be mechanically ventilated, elevators are generally used instead of stairs, and natural lighting cannot be utilized in rooms far from the windows and the windowless spaces such as elevators, bathrooms and stairwells.

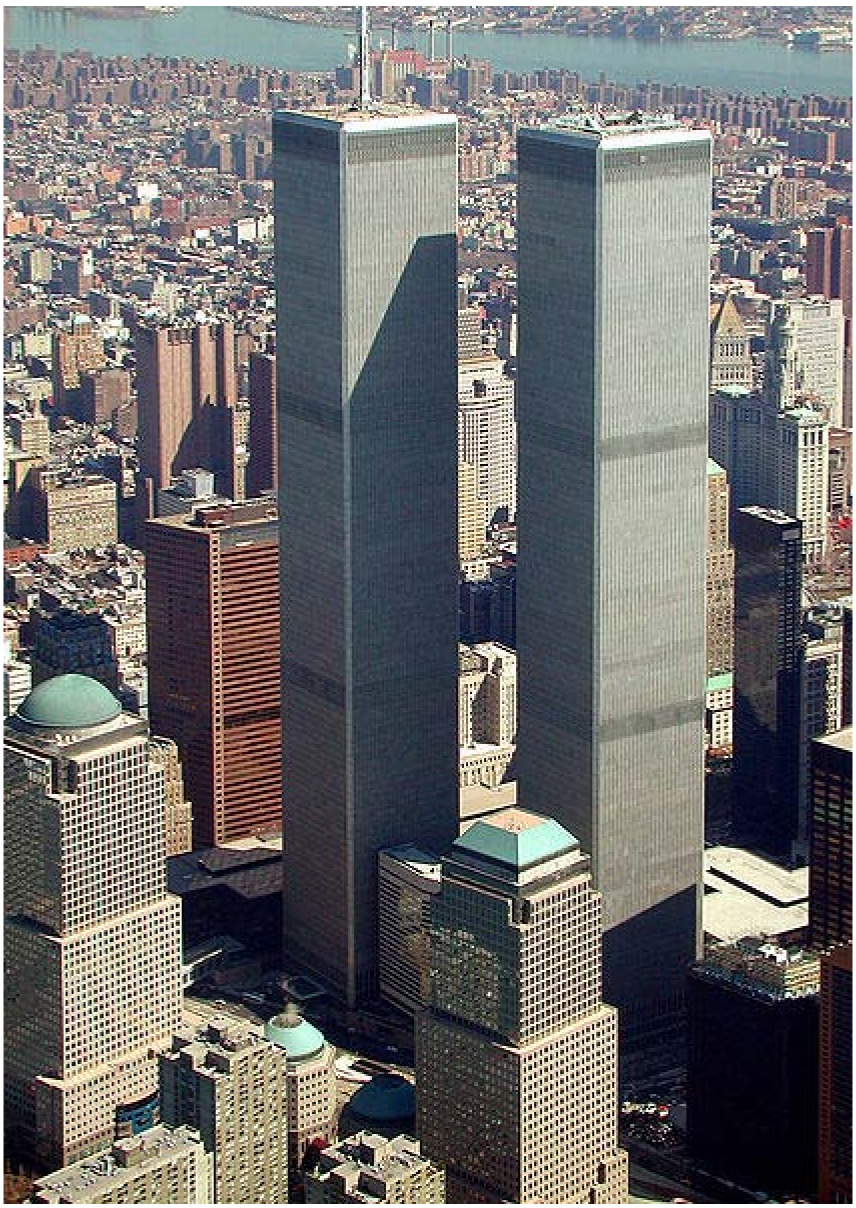
Despite these costs, the size of skyscrapers allows for high-density work and living spaces, reducing the amount of land given over to human development. Mass transit and commercial transport are economically and environmentally more efficient when serving high-density development than suburban or rural development. Also, the total energy expended towards waste disposal and climate control is relatively lower for a given number of people occupying a skyscraper than that same number of people occupying modern housing. Indeed, though the city of Paris, for example, has almost the population density of Manhattan, Paris' stringent building codes and unchanging borders have made it difficult to create the larger buildings and utilities needed for a growing population within the actual city limits. This inflexibility has led many important institutions and departments to locate outside of city limits (such as the La Défense business district).

Quotations

> “What is the chief characteristic of the tall office building? It is lofty. It must be tall. The force and power of altitude must be in it, the glory and pride of exaltation must be in it. It must be every inch a proud and soaring thing, rising in sheer exaltation that from bottom to top it is a unit without a single dissenting line.”
>
> —Louis Sullivan's *The Tall Office Building Artistically Considered* (1896)

Chapter- 6

Construction of the World Trade Center



The completed World Trade Center in March 2001

The **construction of the World Trade Center** was conceived as an urban renewal project, spearheaded by David Rockefeller, to help revitalize Lower Manhattan. The project was developed by the Port Authority of New York and New Jersey, which hired architect Minoru Yamasaki who came up with the specific idea for twin towers. After extensive negotiations, the New Jersey and New York State governments, which oversee the Port Authority, agreed to support the World Trade Center project at the Radio Row site on the lower-west side of Manhattan. To make the agreement acceptable to New Jersey, the Port Authority agreed to take over the bankrupt Hudson & Manhattan Railroad (renamed as PATH), which brought commuters from New Jersey to the Lower Manhattan site.

The towers were designed as framed tube structures, which provided tenants with open floor plans, uninterrupted by columns or walls. This was accomplished using numerous closely spaced perimeter columns to provide much of the strength to the structure, along with gravity load shared with the core columns. The elevator system, which made use of sky lobbies and a system of express and local elevators, allowed substantial floor space to be freed up for use as office space by making the structural core smaller. The design and construction of the World Trade Center twin towers involved many other innovative techniques, such as the slurry wall for digging the foundation, and wind tunnel experiments. Construction of the World Trade Center's North Tower began in August 1968, and the South Tower in 1969. Extensive use of prefabricated components helped to speed up the construction process. The first tenants moved into the North Tower in December 1970 and into the South Tower in January 1972. Four other low-level buildings were constructed as part of the World Trade Center in the 1970s, and a seventh building was constructed in the mid-1980s.

Planning

In 1942, Austin J. Tobin became the Executive Director of the Port Authority, beginning a 30-year career during which he oversaw the planning and development of the World Trade Center. The concept of establishing a "world trade center" was conceived during the post-World War II period, when the United States thrived economically and international trade was increasing. In 1946, the New York State Legislature passed a bill that called for a "world trade center" to be established. The World Trade Corporation was founded, and a board was appointed by New York Governor Thomas E. Dewey to develop plans for the project. Architect John Eberson and his son Drew devised a plan that included 21 buildings over a ten-block area, at an estimated cost of $150 million. In 1949, the World Trade Corporation was dissolved by the New York State Legislature, and plans for a "world trade center" were put on hold.

Original plans

Architect's model for the proposed World Trade Center on the East River

During the post-war period, economic growth was concentrated in Midtown Manhattan, in part stimulated by the Rockefeller Center, which was developed in the 1930s. Meanwhile, Lower Manhattan was left out of the economic boom. One exception was the construction of One Chase Manhattan Plaza in the Financial District by David Rockefeller, who led urban renewal efforts in Lower Manhattan. In 1958, Rockefeller established the Downtown-Lower Manhattan Association (DLMA), which commissioned Skidmore, Owings and Merrill to draw up plans for revitalizing Lower Manhattan. The plans, made public in 1960, called for a World Trade Center to be built on a 13-acre (53,000 m^2) site along the East River, from Old Slip to Fulton Street and between Water Street and South Street. The complex would include a 900-foot (275 m) long exhibition hall, and a 50–70 story building, with some of its upper floors used as a hotel. Other amenities would include a theater, shops, and restaurants. The plan also called for a new securities exchange building, which the Downtown-Lower Manhattan Association hoped would house the New York Stock Exchange.

David Rockefeller suggested that the Port Authority would be a logical choice for taking on the project, and argued that the Trade Center would provide great benefits in facilitating and increasing volume of international commerce coming through the Port of

New York. Given the importance of New York City in global commerce, Port Authority director Austin J. Tobin remarked that the proposed project should be *the* World Trade Center, and not just *a* "world trade center". After a year-long review of the proposal, the Port Authority formally backed the project on 11 March 1961.

Agreement

Location of World Trade Center and originally proposed site

The States of New York and New Jersey also needed to approve the project, given their control and oversight role of the Port Authority. Objections to the plan came from New Jersey Governor Robert B. Meyner, who resented that New York would be getting this $335 million project. Meanwhile, ridership on New Jersey's Hudson and Manhattan Railroad (H&M) had declined substantially from a high of 113 million riders in 1927 to 26 million in 1958, after new automobile tunnels and bridges opened across the Hudson River. Toward the end of 1961, negotiations with outgoing New Jersey Governor Meyner regarding the World Trade Center project reached a stalemate. In December 1961, Tobin met with newly elected New Jersey Governor Richard J. Hughes, and made a proposal to shift the World Trade Center project to a west side site where the Hudson Terminal was located. In acquiring the Hudson & Manhattan Railroad, the Port Authority would also acquire the Hudson Terminal and other buildings which were deemed obsolete. On 22 January 1962, the two states reached an agreement to allow the Port Authority to take over the railroad and to build the World Trade Center on Manhattan's lower west side. The shift in location for the World Trade Center to a site more convenient to New Jersey, together with Port Authority acquisition of the H&M Railroad, brought New Jersey to agreement in support of the World Trade Center project.

Controversy

Even once the agreement between the states of New Jersey, New York, and the Port Authority was finalized, the World Trade Center plan faced continued controversy. The site for the World Trade Center was the location of Radio Row, which was home to hundreds of commercial and industrial tenants, property owners, small businesses, and approximately 100 residents. The World Trade Center plans involved evicting these business owners, some of whom fiercely protested the forced relocation. In June 1962, a group representing approximately 325 shops and 1,000 other affected small businesses filed an injunction, challenging the Port Authority's power of eminent domain. The dispute with local business owners worked its way through the court system, up to the New York State Court of Appeals, which in April 1963 upheld the Port Authority's right of eminent domain, saying that the project had a "public purpose." On 12 November 1963, the United States Supreme Court refused to accept the case. Under the state law, the Port Authority was required to assist business owners in relocating, though many business owners regarded what the Port Authority offered as inadequate. Questions continued while the World Trade Center was constructed, as to whether the Port Authority really ought to take on the project, described by some as a "mistaken social priority."

Private real estate developers and members of the Real Estate Board of New York also expressed concerns about this much "subsidized" office space going on the open market, competing with the private sector when there was already a glut of vacancies. An especially vocal critic was Lawrence A. Wien, owner of the Empire State Building, which would lose its title of tallest building in the world. Wien organized a group of builders into a group called the "Committee for a Reasonable World Trade Center" to demand that the project be scaled down.

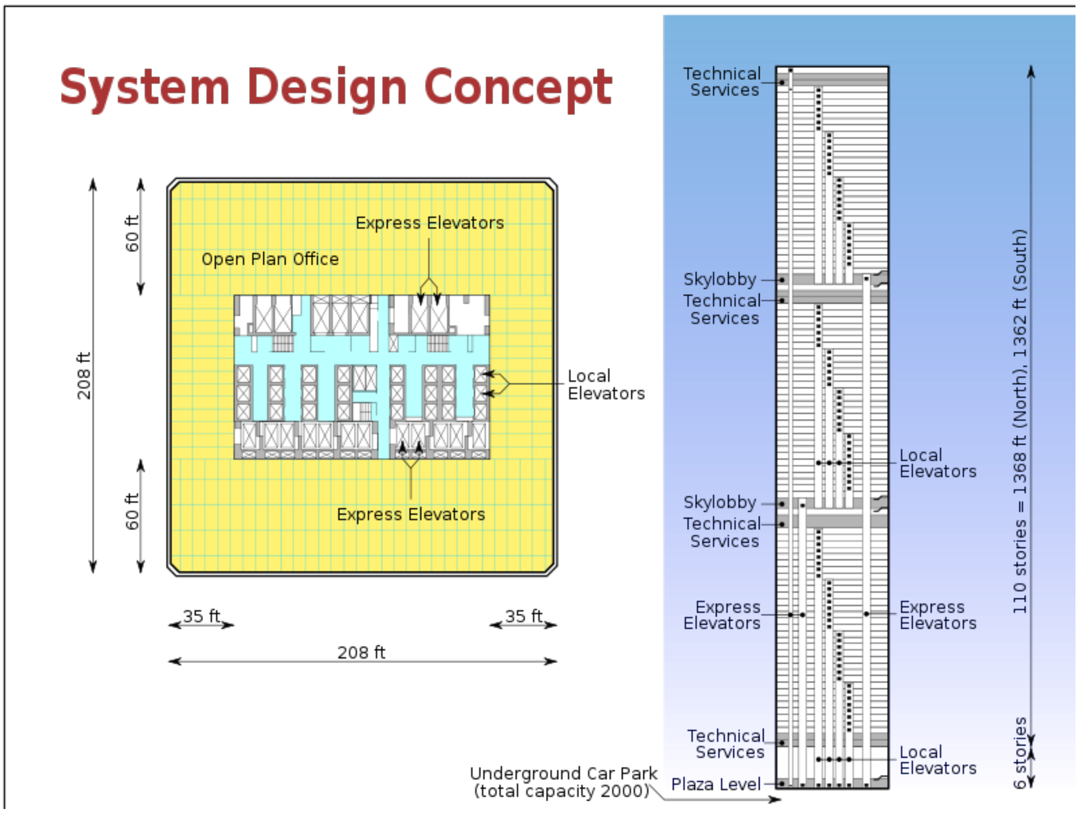
In January 1964, the Port Authority inked a deal with the State of New York to locate government offices at the World Trade Center. The Port Authority began signing commercial tenants in the spring and summer of 1964, including several banks. In 1965, the Port Authority signed the United States Customs Service as a tenant.

A final obstacle for the Port Authority was getting approval from New York City Mayor John Lindsay and the New York City Council, who raised concerns about the limited extent that the Port Authority involved the city in the negotiations and deliberations. Negotiations between The City of New York and the Port Authority were centered on tax issues. A final agreement was made on 3 August 1966, that the Port Authority would make annual payments to the City, in lieu of taxes, for the portion of the World Trade

Center leased to private tenants. In subsequent years, the payments would rise as the real estate tax rate increased.

Design

On 20 September 1962, the Port Authority announced the selection of Minoru Yamasaki as lead architect, and Emery Roth & Sons as associate architects. Originally, Yamasaki submitted to the Port Authority a concept incorporating twin towers, but with each building only 80 stories tall. Yamasaki remarked that the "obvious alternative, a group of several large buildings, would have looked like a housing project."



A typical floor layout and elevator arrangement of the WTC towers

To meet the Port Authority's requirement to build 10 million square feet (930,000 m²) of office space, the buildings would each need to be 110 stories tall. A major limiting factor in building heights is elevators; the taller the building, the more elevators are needed to service the building, requiring more space-consuming elevator banks. Yamasaki and the engineers decided to use a new system that included sky lobbies, which are floors where people can switch from a large-capacity express elevator, which goes only to the sky lobbies, to a local elevator that goes to each floor in a section (the local elevators can be stacked within the same elevator shaft). Located on the 44th and 78th floors of each tower, the sky lobbies enabled the elevators to be used efficiently, while also increasing the amount of usable space on each floor from 62 to 75 percent by reducing the number of required elevator shafts. The World Trade Center towers were the second supertall buildings to use sky lobbies, after the John Hancock Center in Chicago. This system was inspired by the New York City Subway system, whose lines include local stations where local trains stop and express stations where all trains stop.

Original architectural and engineering model

Yamasaki's design for the World Trade Center was unveiled to the public on 18 January 1964, with an eight-foot model. The towers had a square plan, approximately 207 feet (63 m) in dimension on each side. The buildings were designed with narrow office windows, only 18 inches (45 cm) wide, which reflected on Yamasaki's fear of heights and desire to make building occupants feel secure. Yamasaki's design called for the building facades to be sheathed in aluminum-alloy. In all, the World Trade Center complex contained six buildings within the 16-acre (65,000 m^2) superblock.

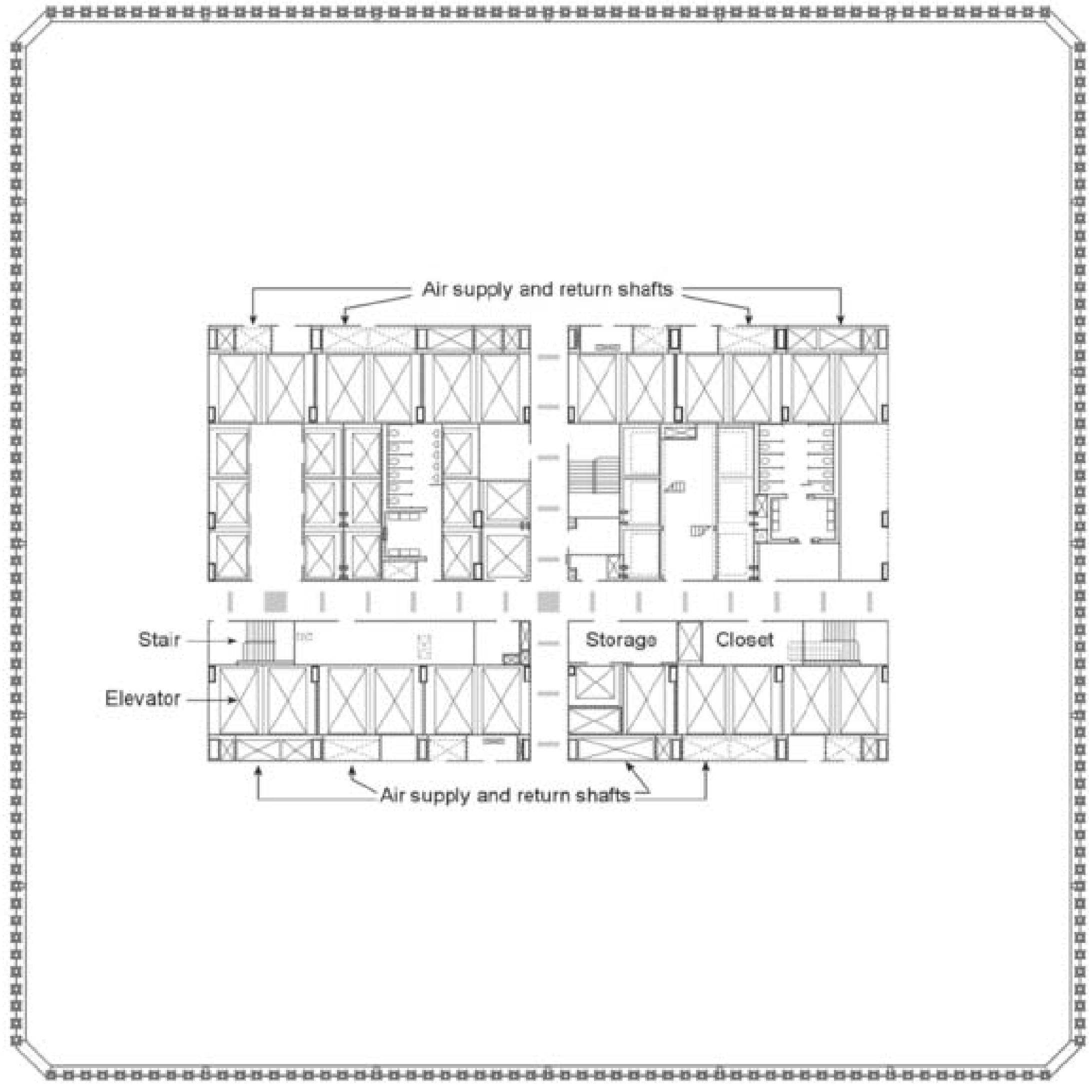
The World Trade Center design brought criticism of its aesthetics from the American Institute of Architects and other groups. Lewis Mumford, author of *The City in History* and other works on urban planning, criticized the project and described it and other new skyscrapers as "just glass-and-metal filing cabinets." Television broadcasters raised concerns that the World Trade Center twin towers would cause interference in television reception for viewers in the New York City area. In response to these concerns, the Port Authority offered to provide new television transmission facilities at the World Trade Center. The Linnaean Society of the American Museum of Natural History also opposed the Trade Center project, citing hazards the buildings would impose on migrating birds.

The structural engineering firm Worthington, Skilling, Helle & Jackson worked to implement Yamasaki's design, developing the tube-frame structural system used in the buildings. The Port Authority's Engineering Department served as foundation engineers, Joseph R. Loring & Associates as electrical engineers, and Jaros, Baum & Bolles as mechanical engineers. Tishman Realty & Construction Company was the general contractor on the World Trade Center project. Guy F. Tozzoli, director of the World Trade Department at the Port Authority, and the Port Authority's Chief Engineer, Rino M. Monti, oversaw the project.

Structural design

As an interstate agency, the Port Authority was not subject to local laws and regulations of the City of New York, including building codes. Nonetheless, the Port Authority required architects and structural engineers to follow the New York City building codes. At the time when the World Trade Center was planned, new building codes were being devised to replace the 1938 version that was still in place. The structural engineers ended up following draft versions of the new 1968 building codes, which incorporated "advanced techniques" in building design.

The World Trade Center towers included many structural engineering innovations in skyscraper design and construction, which allowed the buildings to reach new heights and become the tallest in the world. Traditionally, skyscrapers used a skeleton of columns distributed throughout the interior to support building loads, with interior columns disrupting the floor space. The tube-frame concept, earlier introduced by Fazlur Khan, was a major innovation, allowing open floor plans and more space to rent. The buildings used high-strength, load-bearing perimeter steel columns called Vierendeel trusses that were spaced closely together to form a strong, rigid wall structure. There were 59 perimeter columns, narrowly spaced, on each side of the buildings. In all, the perimeter walls of the towers were 210 feet (64 m) on each side, and the corners were beveled. The perimeter columns were designed to provide support for virtually all lateral loads (such as wind loads) and to share the gravity loads with the core columns. Structural analysis of major portions of the World Trade Center were computed on an IBM 1620.



Typical WTC architectural floor plan

The perimeter structure was constructed with extensive use of prefabricated modular pieces, which consisted of three columns, three stories tall, connected by spandrel plates. The perimeter columns had a square cross section, 14 inches (36 cm) on a side, and were constructed of welded steel plate. The thickness of the plates and grade of structural steel varied over the height of the tower, ranging from 36,000 to 100,000 pounds per square inch (260 to 670 MPa). The strength of the steel and thickness of the steel plates decreased with height because they were required to support lesser amounts of building mass on higher floors. The tube-frame design required 40 percent less structural steel than conventional building designs. From the 7th floor to the ground level, and down to the foundation, the columns were spaced 10 feet (3 m) apart. All columns were placed on bedrock, which, unlike that in Midtown Manhattan, where the bedrock is shallow, is at 65–85 feet (20–26 m) below the surface.

The spandrel plates were welded to the columns to create the modular pieces off-site at the fabrication shop. The modular pieces were typically 52 inches (1.3 m) deep, and extended for two full floors and half of two more floors. Adjacent modules were bolted together, with the splices occurring at mid-span of the columns and spandrels. The spandrel plates were located at each floor, transmitting shear stress between columns, allowing them to work together in resisting lateral loads. The joints between modules were staggered vertically, so the column splices between adjacent modules were not at the same floor.

The building's core housed the elevator and utility shafts, restrooms, three stairwells, and other support spaces. The core of each tower was a rectangular area 87 by 135 feet (27 by 41 m), and contained 47 steel columns running from the bedrock to the top of the tower. The columns tapered after the 66th floor, and consisted of welded box-sections at lower floors and rolled wide-flange sections at upper floors. The structural core in 1 WTC was oriented with the long axis east to west, while that of 2 WTC was oriented north to south. All elevators were located in the core. Each building had three stairwells, also in the core, except on the mechanical floors where they were located outside the core.

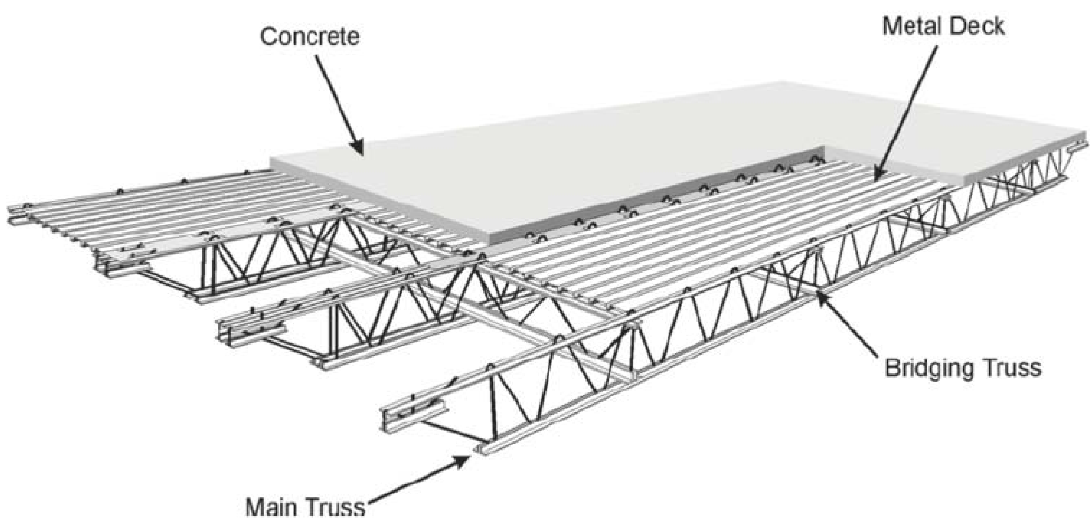


Figure 1–6. Schematic of composite floor truss system.

Schematic of composite floor truss system

The large, column-free space between the perimeter and core was bridged by prefabricated floor trusses. The floors supported their own weight, as well as live loads, provided lateral stability to the exterior walls, and distributed wind loads among the exterior walls. The floors consisted of 4-inch (10 cm) thick lightweight concrete slabs laid on a fluted steel deck with shear connections for composite action. A grid of lightweight bridging trusses and main trusses supported the floors. The trusses had a span of 60 feet (18 m) in the long-span areas and 35 feet (11 m) in the short span area. The trusses connected to the perimeter at alternate columns, and were on 6-foot-8-inch (2.03 m) centers. The top chords of the trusses were bolted to seats welded to the spandrels on the exterior side and a channel welded to the core columns on the interior side. The floors were connected to the perimeter spandrel plates with viscoelastic dampers, which helped reduce the amount of sway felt by building occupants.

Hat trusses (or "outrigger truss") located from the 107th floor to the top of the buildings were designed to support a tall communication antenna on top of each building. Only 1 WTC (north tower) actually had an antenna fitted, which was added in 1978. The truss system consisted of six trusses along the long axis of the core and four along the short axis. This truss system allowed some load redistribution between the perimeter and core columns and supported the transmission tower.

Wind effects

The tube frame design using steel core and perimeter columns protected with sprayed-on fire resistant material created a relatively lightweight structure that would sway more in response to the wind, compared to traditional structures such as the Empire State Building that have thick, heavy masonry for fireproofing of steel structural elements. During the design process, wind tunnel tests were done at Colorado State University and at the National Physical Laboratory in the United Kingdom to establish design wind pressures that the World Trade Center towers could be subjected to and structural response to those forces. Experiments were also done to evaluate how much sway occupants could tolerate. Subjects were recruited for "free eye exams," while the real purpose of the experiment was to subject them to simulated building sway and find out how much they could comfortably tolerate. Many subjects did not respond well, experiencing dizziness and other ill effects. One of the chief engineers Leslie Robertson worked with Canadian engineer Alan G. Davenport to develop viscoelastic dampers to absorb some of the sway. These viscoelastic dampers, used throughout the structures at the joints between floor trusses and perimeter columns, along with some other structural modifications reduced the building sway to an acceptable level.

Aircraft impact

The structural engineers on the project also considered the possibility that an aircraft could crash into the building. In July 1945, a B-25 bomber that was lost in the fog had crashed into the 79th floor of the Empire State Building. A year later, another airplane nearly crashed into the 40 Wall Street building, and there was another near-miss at the Empire State Building. In designing the World Trade Center, Leslie Robertson considered the scenario of the impact of a jet airliner, the Boeing 707, which might be lost in the fog, seeking to land at JFK or at Newark airports. The National Institute of Standards and Technology (NIST) found a three page white paper that mentioned another aircraft impact analysis, involving impact of a jet at 600 mph (970 km/h), was indeed considered, but the original documentation of the study was lost when Port Authority offices were destroyed in the collapse of the World Trade Center.

Fire protection

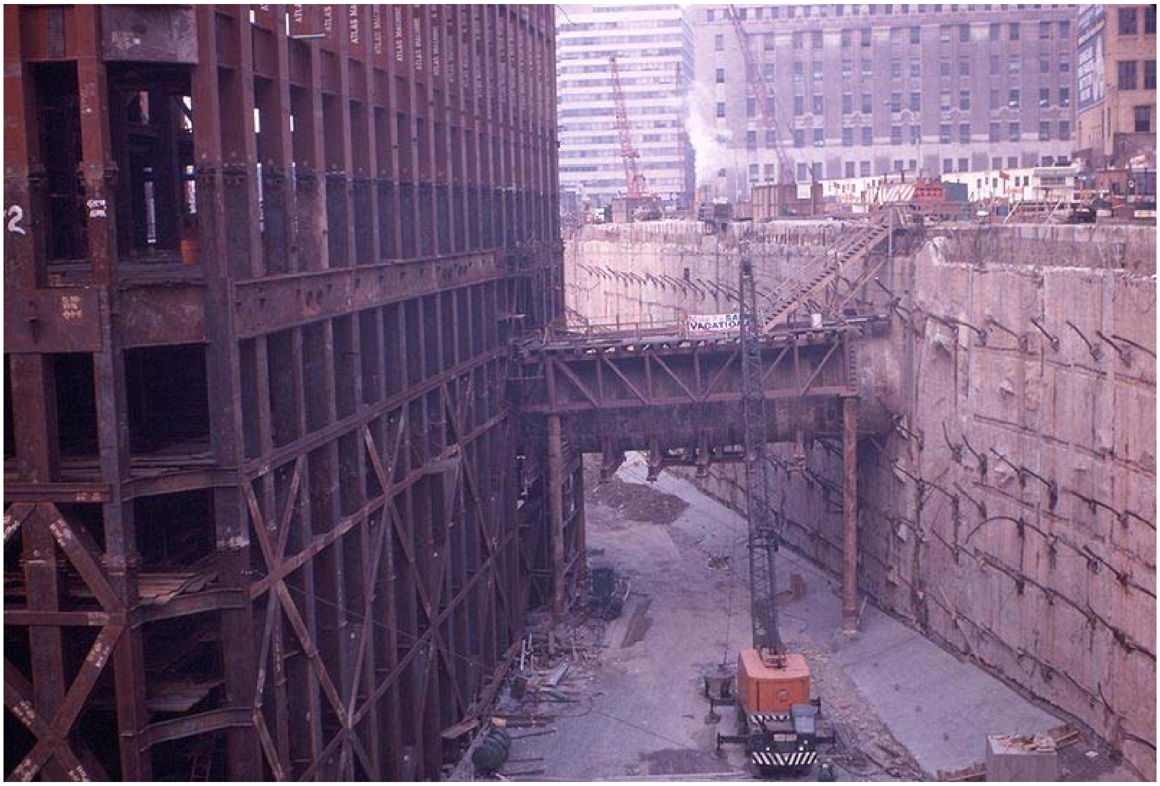
Sprayed-fire resistant materials (SFRMs) were used to protect some structural steel elements in the towers, including all floor trusses and beams. Gypsum wallboard in combination with SFRMs, or in some cases gypsum wallboard alone, was used to protect core columns. Vermiculite plaster was used on the interior-side and SFRMs on the other three sides of the perimeter columns for fire protection. The 1968 New York City building codes were more lenient in some aspects of fire protection, such as allowing three exit stairwells in the World Trade Center towers, instead of six as required under older building codes.

In April 1970, the New York City Department of Air Resources ordered contractors building the World Trade Center to stop the spraying of asbestos as an insulating material.

More fireproofing was added after a fire in February 1975 that spread to six floors before being extinguished. After the 1993 bombing, inspections found fireproofing to be deficient. The Port Authority was in the process of replacing it, but replacement had been completed on only 18 floors in WTC 1, including all the floors affected by the aircraft impact and fires on September 11, and on 13 floors in WTC 2, although only three of these floors (77,78, and 85) were directly affected by the aircraft impact.

The 1968 New York City building codes did not require sprinklers for high-rise buildings, except for underground spaces. In accordance with building codes, sprinklers were originally installed only in the underground parking structures of the World Trade Center. Following a major fire in February 1975, the Port Authority decided to start installing sprinklers throughout the buildings. By 1993, nearly all of 2 WTC and 85 percent of 1 WTC had sprinklers installed, and the entire complex was retrofitted by 2001.

Construction

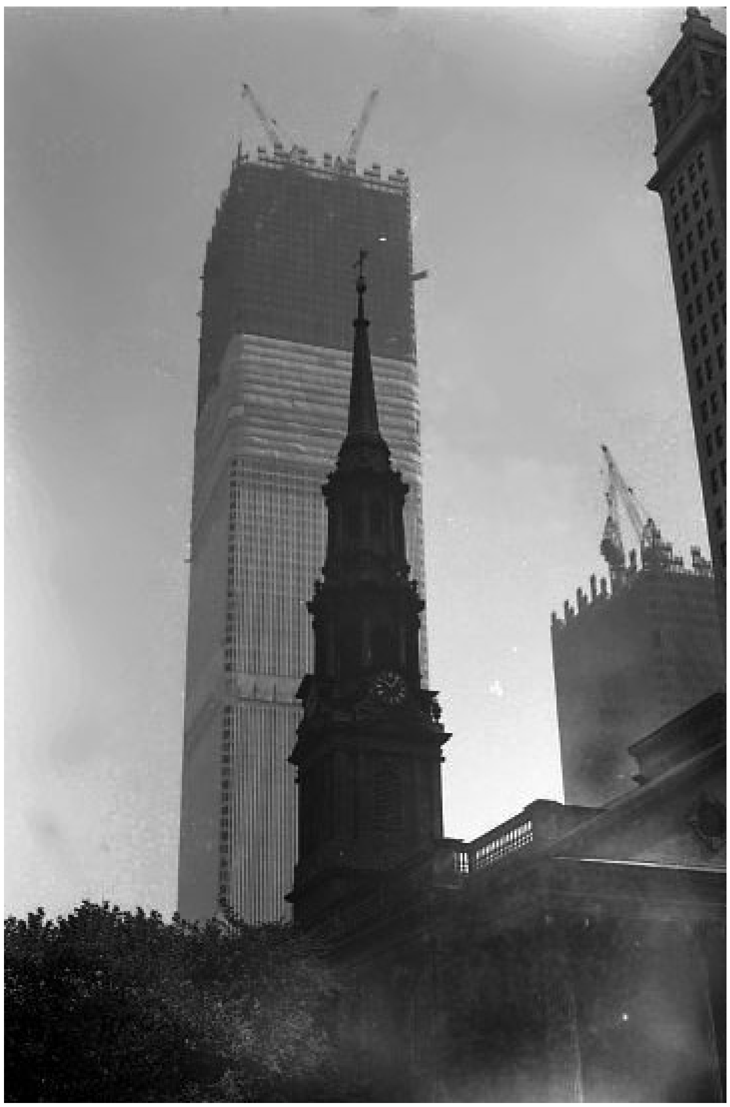


South Tower and slurry wall "bathtub" under construction in 1969

In March 1965, the Port Authority began acquiring property at the World Trade Center site. The Ajax Wrecking and Lumber Corporation was hired for the demolition work, which began on 12 March 1966 to clear the site for construction of the World Trade Center.

Groundbreaking was on 5 August 1966, marking the beginning of construction of the World Trade Center's foundations. The site of the World Trade Center was located on landfill, with the bedrock located 65 feet (20 m) below grade. In order to construct the World Trade Center, it was necessary to build the "bathtub", with the slurry wall along the West Street side of the site, to keep water from the Hudson River out. This method was used in place of conventional dewatering methods because lowering the groundwater table would cause large settlements of nearby buildings not built on deep foundations. The slurry method involves digging a trench, and as excavation proceeds, filling the space with a "slurry" mixture, composed of bentonite which plugs holes and keeps water out. When the trench was dug out, a steel cage was inserted, with concrete poured in, forcing the "slurry" out. The "slurry" method was devised by Port Authority chief engineer John M. Kyle, Jr. Towards the end of 1966, work began on building the slurry wall, led by Montreal-based Icanda, a subsidiary of an Italian engineering firm, Impresa Costruzioni Opere Specializzate (I.C.O.S.). It took fourteen months for the slurry wall to be completed, which was necessary before excavation of material from the interior of the site could begin. The original Hudson Tubes, which carried PATH trains into Hudson Terminal, remained in service as elevated tunnels until 1971 when a new PATH station was built.

Construction work began on the North Tower in August 1968 with construction beginning on the South Tower by January 1969. In January 1967, $74 million in contracts were awarded to the Pacific Car and Foundry Company, Laclede Steel Company, Granite City Steel Company, and Karl Koch Erecting Company to supply steel for the project. The Port Authority chose to use many different steel suppliers, bidding on smaller portions of steel, rather than buy larger amounts from a single source such as Bethlehem Steel or U.S. Steel as a cost-saving measure. Karl Koch was also hired to do all the work of erecting the steel, and a contract for work on the aluminum facade was awarded to the Aluminum Company of America. Tishman Realty & Construction was hired in February 1967 to oversee construction of the project.



World Trade Center under construction in 1971

Extensive use of prefabricated parts for the perimeter framing and floor truss systems helped speed up the construction process and reduce costs, while providing greater quality control. Steel components were freighted into a Penn Central yard in Jersey City. From there, they were brought in early morning hours through the Holland Tunnel to the construction site, and lifted into place by a crane. Larger pieces were brought to the construction site by tugboats. A special type of crane, suitable for constructing such tall buildings, that used hydraulics to lift components and provided its own power was used in construction of the World Trade Center. The Favco Standard 2700 Crane, manufactured by Favelle Mort Ltd. of New South Wales, Australia was informally called a "kangaroo crane".

In 1970, tugboat workers went on strike, halting the transport of material to the construction site. The Port Authority attempted other means of transporting material, including via helicopter. When this method was tried, the helicopter lost its load of steel into the Kill Van Kull. Some other mishaps occurred during the construction process, including disruption of telephone service in Lower Manhattan when telephone cables were crushed by pile drivers. On 16 March 1970, an explosion injured six workers when a truck hit a propane tank. In all, 60 workers were killed in construction accidents while the World Trade Center was being built.

The topping out ceremony of 1 WTC (North Tower) took place on 23 December 1970, with 2 WTC's ceremony (South Tower) occurring later on 19 July 1971. The first tenants moved into the North Tower in December 1970, and into the South Tower in January 1972. The buildings were dedicated on 4 April 1973; Tobin, who had resigned the year before, was absent from the ceremonies.

Building the World Trade Center involved excavating 1,200,000 cubic yards (920,000 m^3) of material. Rather than transporting this material at great costs out to sea or to landfills in New Jersey, the fill material was used to expand the Manhattan shoreline across West Street. Work to demolish the piers began on 5 January 1967, including Pier 7 to Pier 11 which were all constructed around 1910. The demolition work moved forward, despite conflicts between David Rockefeller, Governor Nelson Rockefeller, and Mayor John Lindsay regarding plans for Battery Park City. Landfill material from the World Trade Center was used to add land, and a cellular cofferdam was constructed to retain the material. The result was a 700-foot (210 m) extension into the Hudson River, running six blocks or 1,484 feet (452 m). This land was a "gift" to New York City, allowing more tax-generating developments in Battery Park City.

The original estimates put forth by the Port Authority had the costs for construction of the World Trade Center at $350 million—an optimistic figure. In December 1966, the Port Authority announced increased cost estimates, bringing the estimated total to $575 million. This announcement brought criticism of the project from private real estate developers, *The New York Times*, and others in New York City. The critics charged that the Port Authority figure was an unrealistically low estimate, and they estimated the project would end up costing $750 million. When the World Trade Center twin towers were completed, the total costs to the Port Authority had reached $900 million. The project was financed through tax-exempt bonds issued by the Port Authority.

Other buildings

The World Trade Center complex included four other smaller buildings constructed during the 1970s. 3 World Trade Center was a 22-story building, which was home to the Marriott World Trade Center. It was designed by Skidmore, Owings and Merrill in 1978–79. 4 World Trade Center, 5 World Trade Center, and 6 World Trade Center were all 8–9 story buildings that were designed by the same team as the Twin Towers, including Minoru Yamasaki, Emery Roth & Sons, and Skilling, Helle, Christiansen, Robertson. 7 World Trade Center was built in the mid-1980s, just north of the main World Trade Center site. The 47-story building was designed by Emery, Roth & Sons, and constructed on top of a Con Edison power substation.

Modifications

Over time, numerous structural modifications were made to suit the needs of tenants in the Twin Towers. Modifications were made in accordance with the Port Authority's *Tenant Alteration Review Manual* and were reviewed by the Port Authority to ensure the changes did not compromise structural integrity of the buildings. In many instances, openings were cut in the floors to accommodate new stairways to connect tenant floors. Some steel beams in the core were reinforced and strengthened to accommodate heavy live loads, such as large amounts of heavy files that tenants had on their floors.

Repairs to structural elements on the lower levels of 1 WTC were made following the 1993 bombing. The greatest damage occurred on levels B1 and B2, with significant structural damage also on level B3. Primary structural columns were not damaged, but secondary steel members experienced some damage. Floors that were blown out needed to be repaired to restore the structural support they provided to columns. The slurry wall was in peril following the bombing and loss of the floor slabs which provided lateral support to counteract pressure from Hudson River water on the other side. The refrigeration plant on sublevel B5, which provided air conditioning to the entire World Trade Center complex, was heavily damaged and replaced with a temporary system for the summer of 1993. The fire alarm system for the entire complex needed to be replaced, after critical wiring and signaling in the original system was destroyed in the 1993 bombing. Installation of the new system took years to complete, and replacement of some components was still underway at the time of the September 11, 2001 attacks.

Chapter- 7

Commercial Buildings

Casino

Slot machines are commonplace in casinos

A **casino** is a facility that houses and accommodates certain types of gambling activities. Casinos are most commonly built near or combined with hotels, restaurants, retail shopping, cruise ships and other tourist attractions. Some casinos are known for hosting live entertainment events, such as stand-up comedy, concerts, and sporting events. Earl Grinols a distinguished professor in Economics, shows that between 37 and 52 percent of casino revenues come from pathological or problem gamblers, and count for the larger part of their profits.

Coffeehouse

DISCUSSING THE WAR IN A PARIS CAFE.

"Discussing the War in a Paris Café", *The Illustrated London News* 17 September 1870

A **coffeehouse** or **coffee shop** is an establishment which primarily serves prepared coffee or other hot beverages. It shares some of the characteristics of a bar, and some of the characteristics of a restaurant, but it is different from a cafeteria. As the name suggests, coffeehouses focus on providing coffee and tea as well as light snacks. Many coffee houses in the Middle East, and in West Asian immigrant districts in the Western world, offer *shisha* (*nargile* in Turkish and Greek), flavored tobacco smoked through a hookah.

From a cultural standpoint, coffeehouses largely serve as centers of social interaction: the coffeehouse provides social members with a place to congregate, talk, write, read, entertain one another, or pass the time, whether individually or in small groups of 2 or 3.

In the United States, the French word for coffeehouse (**café**) means an informal restaurant, offering a range of hot meals.

Convention center

Bangabandhu Convention Centre, Dhaka, Bangladesh

A **convention center** (American English, **conference centre** British English) is a large building that is designed to hold a convention, where individuals and groups gather to promote and share common interests. Convention centers typically offer sufficient floor area to accommodate several thousand attendees. Very large venues, suitable for major trade shows, are known as 'exhibition centres'. Convention centers typically have at least one auditorium and may also contain concert halls, lecture halls, meeting rooms, and conference rooms. Some large resort area hotels include a convention center.

Skyscraper

A **skyscraper** is a tall, continuously habitable building. There is no official definition or height above which a building may clearly be classified as a skyscraper. Most cities define the term empirically; even a building of 80 meters (262 feet) may be considered a skyscraper if it protrudes above its built environment and changes the overall skyline.

Definition

The Burj Khalifa in Dubai, UAE is currently the tallest skyscraper in the world.

The word "skyscraper" originally was a nautical term referring to a small triangular sail set above the skysail on a sailing ship. The term was first applied to buildings in the late 19th century as a result of public amazement at the tall buildings being built in Chicago and New York City. The first skyscraper was for many years thought to be the Home Insurance Building built in Chicago, Illinois in 1885. More recent arguments point to New York's seven floor Equitable Life Assurance Building built in 1870 and it was arguably the first office building built using a kind of skeletal frame but it depends on what factors are chosen and even the scholars making the argument find it academic.

The structural definition of the word *skyscraper* was refined later by architectural historians, based on engineering developments of the 1880s that had enabled construction of tall multi-storey buildings. This definition was based on the steel skeleton—-as opposed to constructions of load-bearing masonry, which passed their practical limit in 1891 with Chicago's Monadnock Building. Philadelphia's City Hall, completed in 1901, still holds claim as the world's tallest load-bearing masonry structure at 167 m (548 ft). The steel frame developed in stages of increasing self-sufficiency, with several buildings in Chicago and New York advancing the technology that allowed the steel frame to carry a building on its own. Today, however, many of the tallest skyscrapers are built almost entirely with reinforced concrete. Pumps and storage tanks maintain water pressure at the top of skyscrapers.

Skyscraper and supertall

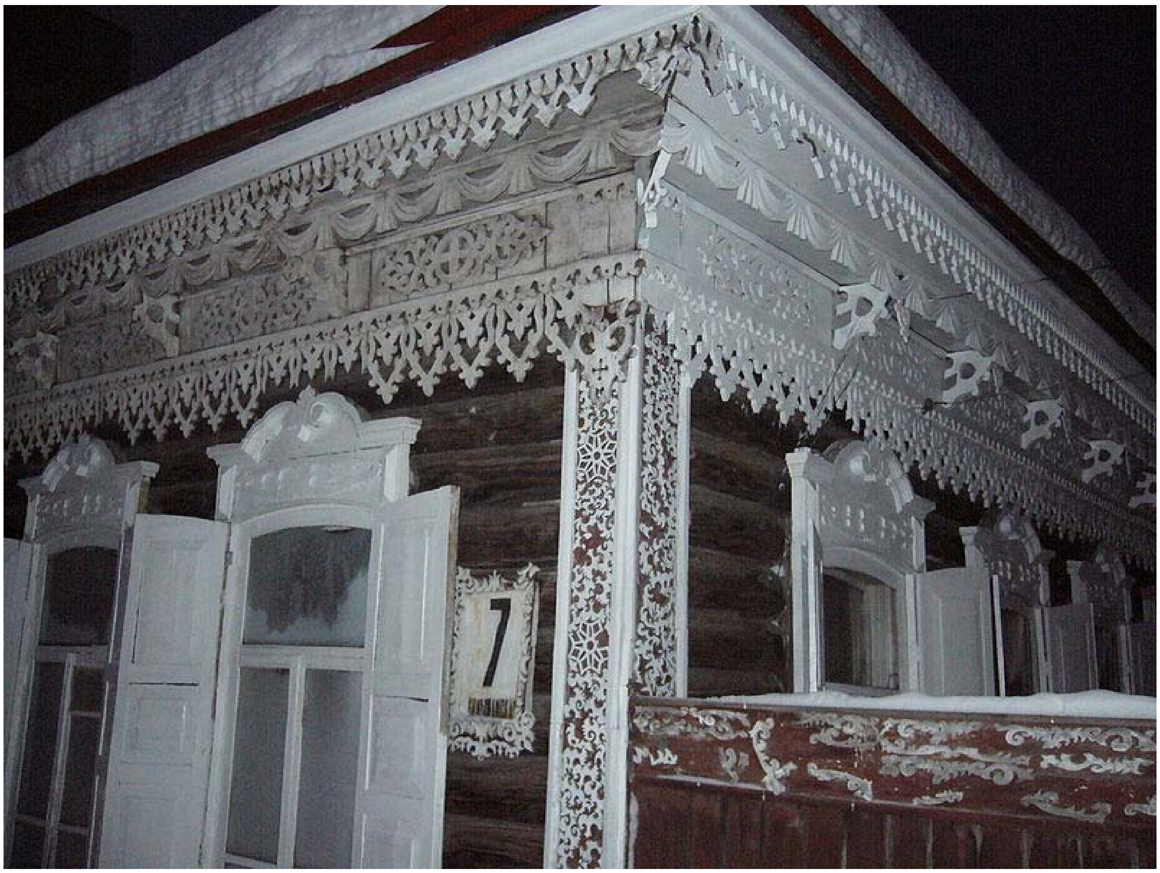
A loose convention in the United States and Europe now draws the lower limit of a skyscraper at 150 meters (~500 ft). A skyscraper taller than 300 meters (~1000 ft) may be referred to as *supertall*. Shorter buildings are still sometimes referred to as skyscrapers if they appear to dominate their surroundings.

The somewhat arbitrary term *skyscraper* should not be confused with the also ill-defined term *high-rise*. The Emporis Standards Committee defines a high-rise building as "a multi-story structure between 35-100 meters tall, or a building of unknown height from 12-39 floors" and a skyscraper as "a multi-story building whose architectural height is at least 100 meters." Some structural engineers define a highrise as any vertical construction for which wind is a more significant load factor than earthquake or weight. Note that this criterion fits not only high rises but some other tall structures, such as towers.

The word *skyscraper* often carries a connotation of pride and achievement. The skyscraper, in name and social function, is a modern expression of the age-old symbol of the world center or *axis mundi*: a pillar that connects earth to heaven and the four compass directions to one another.

Chapter- 8

House



A traditional house in Novosibirsk, Siberia, Russia

A ranch style house in Salinas, California, United States

"Terem" - Traditional house in European Russia.

A Yurt near the Gurvan Saikhan Mountains (in the background); part of Gobi Gurvansaikhan National Park.

A **house** is a home, building or structure that is a dwelling or place for habitation by human beings. The term house includes many kinds of dwellings ranging from rudimentary huts of nomadic tribes to free standing individual structures. In some contexts, "house" may mean the same as dwelling, residence, home, abode, lodging, accommodation, or housing, among other meanings. The social unit that lives in a house is known as a household. Most commonly, a household is a family unit of some kind, though households can be other social groups, such as single persons, or groups of unrelated individuals. Settled agrarian and industrial societies are composed of household units living permanently in housing of various types, according to a variety of forms of land tenure. English-speaking people generally call any building they routinely occupy "home". Many people leave their houses during the day for work and recreation, and return to them to sleep and for other activities.

Inside the house

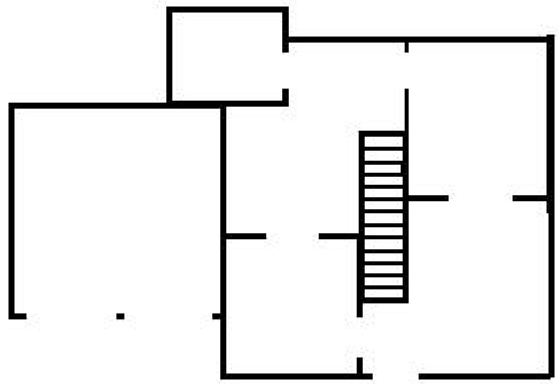
Layout

Example of an early Victorian "Gingerbread House" in Connecticut, United States, built in 1855

Ideally, architects of houses design rooms to meet the needs of the people who will live in the house. Such designing, known as "interior design", has become a popular subject in universities. Feng shui, originally a Chinese method of moving houses according to such factors as rain and micro-climates, has recently expanded its scope to address the design of interior spaces with a view to promoting harmonious effects on the people living inside the house. Feng shui can also mean the "aura" in or around a dwelling. Compare the real-estate sales concept of "indoor-outdoor flow".

The square footage of a house in the United States reports the area of "living space", excluding the garage and other non-living spaces. The "square meters" figure of a house in Europe reports the area of the walls enclosing the home, and thus includes any attached garage and non-living spaces.

Parts



Floor plan of a "foursquare" house

Many houses have several rooms with specialized functions. These may include a living/eating area, a sleeping area, and (if suitable facilities and services exist) washing and lavatory areas. Additionally, spa room, indoor pool, indoor basketball goal, and so forth. In traditional agriculture-oriented societies, domestic animals such as chickens or larger livestock (like cattle) often share part of the house with human beings. Most conventional modern houses will at least contain a bedroom, bathroom, kitchen (or kitchen area), and a living room. A typical "foursquare house" (as pictured) occurred commonly in the early history of the United States of America where they were mainly built, with a staircase in the center of the house, surrounded by four rooms, and connected to other sections of the house (including in more recent eras a garage).

The names of parts of a house often echo the names of parts of other buildings, but could typically include:

- Atrium
- Attic
- Alcove
- Basement/cellar
- Bathroom (in various senses of the word)
    - Bath/shower
    - Toilet
- Bedroom (or nursery, for infants or small children)
- Box-room / storage room
- Conservatory
- Dining room
- Hearth – often an important symbolic focus of family togetherness
- Kitchen
- Larder
- Laundry room
- Library
- Living room
- Loft
- Nook
- Window
- Office or study
- Pantry
- Parlour
- Pew/porch

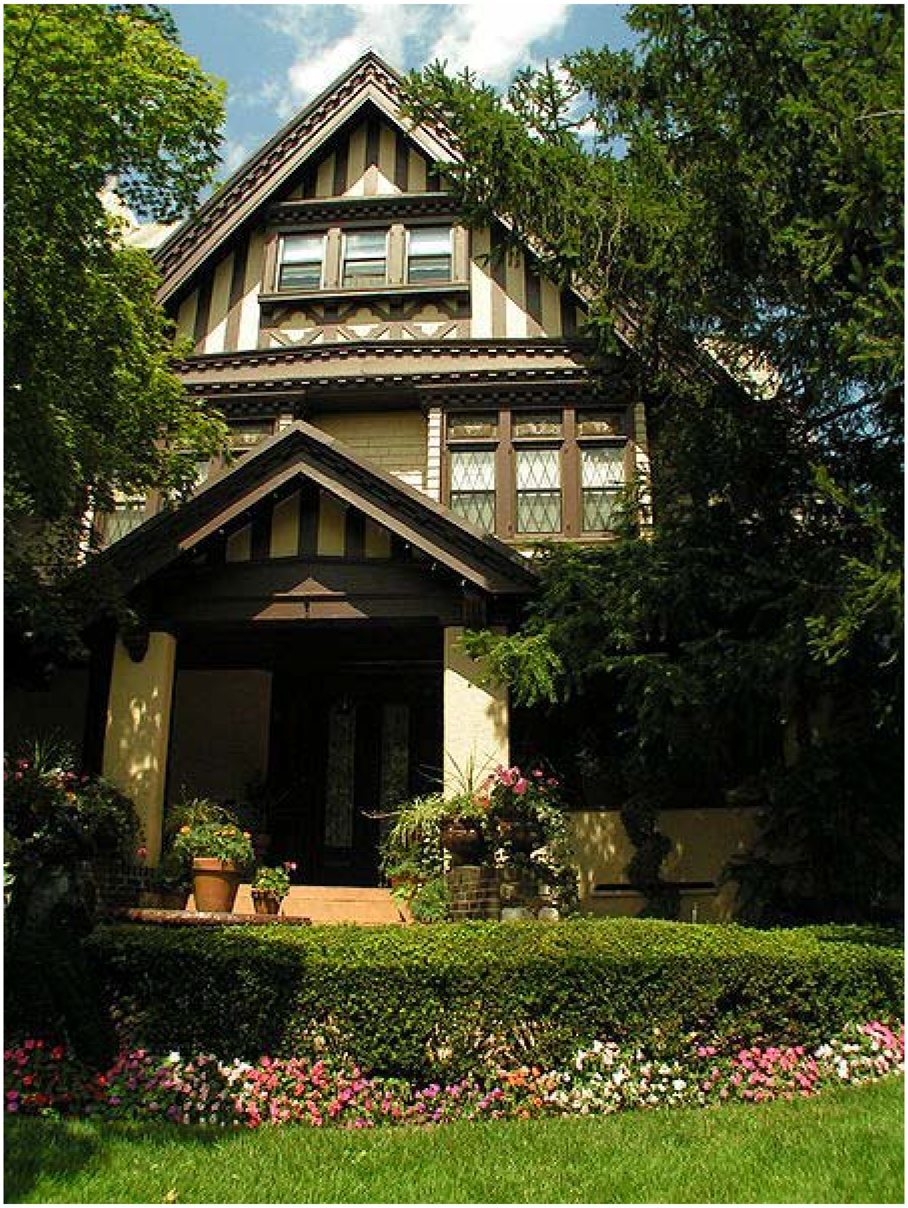
- Family room or den
    - Fireplace (for warmth during winter; generally not found in warmer climates)
- Foyer
- Front room (in various senses of the phrase)
- Garage
- Hallway / passage / Vestibule
- Recreation room / rumpus room / television room
- Shrines to serve the religious functions associated with a family
- Stairwell
- Sunroom
- Workshop

Some houses have a pool in the background, or a trampoline, or a playground.

Construction

The structure of the house (under demolition). This house is constructed from bricks and wood and was later covered by insulating panels. The roof construction is also seen.

In the United States, modern house-construction techniques include light-frame construction (in areas with access to supplies of wood) and adobe or sometimes rammed-earth construction (in arid regions with scarce wood-resources). Some areas use brick almost exclusively, and quarried stone has long provided walling. To some extent, aluminum and steel have displaced some traditional building materials. Increasingly popular alternative construction materials include insulating concrete forms (foam forms filled with concrete), structural insulated panels (foam panels faced with oriented strand board or fiber cement), and light-gauge steel framing and heavy-gauge steel framing.



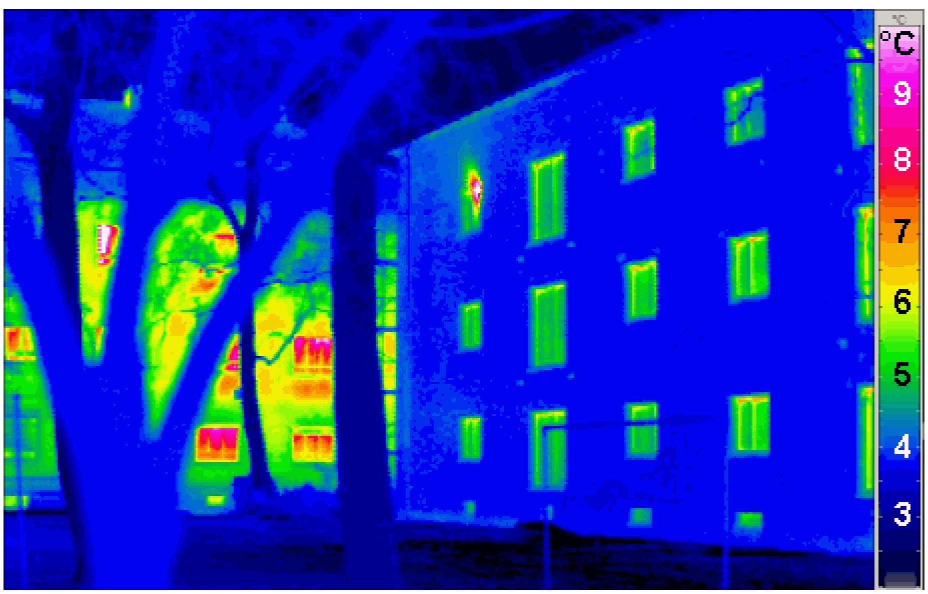
The Saitta House, Dyker Heights, Brooklyn, New York, United States built in 1899 is made of and decorated in wood.

More generally, people often build houses out of the nearest available material, and often tradition and/or culture govern construction-materials, so whole towns, areas, counties or even states/countries may be built out of one main type of material. For example, a large fraction of American houses use wood, while most British and many European houses utilize stone or brick.

In the 1900s, some house designers started using prefabrication. Sears, Roebuck & Co. first marketed their Sears Catalog Homes to the general public in 1908. Prefab techniques became popular after World War II. First small inside rooms framing, then later, whole walls were prefabricated and carried to the construction site. The original impetus was to use the labor force inside a shelter during inclement weather. More recently builders have begun to collaborate with structural engineers who use computers and finite element analysis to design prefabricated steel-framed homes with known resistance to high wind-loads and seismic forces. These newer products provide labor savings, more consistent quality, and possibly accelerated construction processes.

Lesser-used construction methods have gained (or regained) popularity in recent years. Though not in wide use, these methods frequently appeal to homeowners who may become actively involved in the construction process. They include:

- Cannabrick construction
- Cordwood construction
- Geodesic domes
- Straw-bale construction
- Wattle and daub



Thermographic comparison of traditional (left) and "passivhaus" (right) buildings

Energy-efficiency

In the developed world, energy-conservation has grown in importance in house-design. Housing produces a major proportion of carbon emissions (30% of the total in the UK, for example).

Development of a number of low-energy building types and techniques continues. They include the zero-energy house, the passive solar house, the autonomous buildings, the superinsulated and houses built to the *Passivhaus* standard.

Earthquake protection

One tool of earthquake engineering is base isolation which is increasingly used for earthquake protection. Base isolation is a collection of structural elements of a building that should substantially decouple it from the shaking ground thus protecting the building's integrity and enhancing its seismic performance. This technology, which is a kind of seismic vibration control, can be applied both to a newly designed building and to seismic upgrading of existing structures.

Normally, excavations are made around the building and the building is separated from the foundations. Steel or reinforced concrete beams replace the connections to the foundations, while under these, the isolating pads, or *base isolators*, replace the material removed. While the *base isolation* tends to restrict transmission of the ground motion to the building, it also keeps the building positioned properly over the foundation. Careful attention to detail is required where the building interfaces with the ground, especially at entrances, stairways and ramps, to ensure sufficient relative motion of those structural elements.

Legal issues

Buildings with historical importance have restrictions.

United Kingdom

New houses in the UK are not covered by the Sale of Goods Act. When purchasing a new house the buyer has less legal protection than when buying a new car. New houses in the UK may be covered by a NHBC guarantee but some people feel that it would be more useful to put new houses on the same legal footing as other products.

United States and Canada

In the US and Canada, many new houses are built in housing tracts, which provide homeowners a sense of "belonging" and the feeling they have "made the best use" of their money. However, these houses are sometimes built as cheaply and quickly as possible by large builders seeking to maximize profits. Many environmental health issues may be ignored or minimized in the construction of these structures. In one case in Benicia, California, a housing tract was built over an old landfill. Home buyers were never told, and only found out when some began having reactions to high levels of lead and chromium.

Identifying houses

With the growth of dense settlement, humans designed ways of identifying houses and/or parcels of land. Individual houses sometimes acquire proper names; and those names may acquire in their turn considerable emotional connotations: for example the house of *Howards End* or the castle of *Brideshead Revisited*. A more systematic and general approach to identifying houses may use various methods of house numbering.

Animal houses

Humans often build "houses" for domestic or wild animals, often resembling smaller versions of human domiciles. Familiar animal houses built by humans include bird-houses, hen-houses/chicken-coops and doghouses (kennels); while housed agricultural animals more often live in barns and stables. However, human interest in building houses for animals does not stop at the domestic pet. People build bat-houses, nesting-sites for wild ducks and other birds, bee houses, giraffe houses, kangaroo houses, worm houses, hermit crab houses, as well as shelters for many other animals.

Shelter

A modern style house in Canberra, Australia

Forms of (relatively) simple shelter may include:

- Bus stop
- Camper

- Chalet
- Cottage
- Izba
- Dugout
- Gazebo
- Hangar
- Houseboat
- Hut
- Lean-to
- Log Cabin
- Nuclear Bunkers
- Shack
- Tent (camp)
- Caravan
- Umbrella
- Yaodong

Houses and symbolism

Houses may express the circumstances or opinions of their builders or their inhabitants. Thus a vast and elaborate house may serve as a sign of conspicuous wealth, whereas a low-profile house built of recycled materials may indicate support of energy conservation.

Houses of particular historical significance (former residences of the famous, for example, or even just very old houses) may gain a protected status in town planning as examples of built heritage and/or of streetscape values. Commemorative plaques may mark such structures.

Home ownership provides a common measure of prosperity in economics. Contrast the importance of house-destruction, tent dwelling and house rebuilding in the wake of many natural disasters.

Peter Olshavsky's House for the Dance of Death provides a 'pataphysical variation on the house.

Chapter- 9

Bungalow, Bay-and-Gable & Deck

Bungalow

Modern Indian multi-storied bungalow in affluent area near Bangalore, India

A typical side-gabled bungalow in Louisville's Deer Park Neighborhood, United States.

Bungalows in Atlanta's Inman Park neighborhood, United States.

Bungalows in the Belmont-Hillsboro neighborhood of Nashville, United States.

A **bungalow** is a type of house, with varying meanings across the world. Common features to many (but not all) of these definitions include being detached, low-rise (single, or one-and-a-half storeys), and the use of verandahs. The term originated in India, deriving from the Gujarati *baṅgalo*, which in turn derives from the Hindustani *baṅglā*, meaning "Bengali" and used elliptically for a "house in the Bengal style". Such houses were traditionally small, only one story and thatched, and had a wide veranda.

The term is first found in English from 1696, where it was used to describe "bungales or hovells" in India for English sailors of the East India Company, which do not sound like very grand lodgings. Later it became used for the spacious homes or official lodgings of officials of the British Raj, and was so known in Britain and later America, where it initially had high status and exotic connotations, and began to be used in the late 19th century for large country or suburban houses built in an Arts and Crafts or other Western vernacular style - essentially as large cottages, a term also sometimes used. Later developers began to use the term for smaller houses. In Australia, the California bungalow was popular after the First World War. In Britain and North America a bungalow today is a residential house, normally detached, which is either single story, or has a second story built into a sloping roof, usually with dormer windows ("one and a half storeys"). Full vertical walls are therefore only seen on one story, at least on the front and rear elevations. Usually the houses are relatively small, especially from recent decades, though early examples may be large, in which case the term bungalow tends not to be used today.

Design considerations

Bungalows are very convenient for the homeowner in that all living areas are on a single storey and there are no stairs between living areas. A bungalow is well suited to persons with impaired mobility, such as the elderly or those in wheelchairs.

Neighborhoods of only bungalows offer more privacy than similar neighborhoods with two-storey houses. With bungalows, strategically planted trees and shrubs are usually sufficient to block the view of neighbors. With two-storey houses, the extra height requires much taller trees to accomplish the same, and it may not be practical to place such tall trees close to the house to obscure the view from the second floor of the next door neighbor. They are a very cost effective way of living. On the other hand, even closely spaced bungalows make for quite low density neighborhoods, contributing to urban sprawl. In Australia, bungalows have broad verandahs and as a result are often excessively dark inside, requiring artificial light even in daytime.

Cost and space considerations

One-story bungalow with painted trim, earth-tone shingles.

On a per unit area basis (e.g. per square foot or per square metre), bungalows are more expensive to construct than two story houses because a larger foundation and roof area is required for the same living area. The larger foundation will often translate into larger lot size requirements as well. This is why bungalows are typically fully detached from other houses and do not share a common foundation nor party wall: if the homeowner can afford the extra expense of a bungalow relative to a two-story house, they can typically afford to be fully detached as well.

The smaller size however may be desirable for elderly people (perhaps with grown children) as it requires less cleaning, etc.

Though the 'footprint' of a bungalow is often a simple rectangle, any foundation is possible. For bungalows with brick walls, the windows are often positioned high and are right to the roof. This avoids the need for special arches or lintels to support the brick wall above the windows. In two-storey houses, there is no choice but to continue the brick wall above the window (and the second storey windows may be positioned high and right to the roof.) .

Bay-and-gable

A pair of semi-detached bay-and-gable houses in Little Italy

Bay-and-gable houses in The Annex

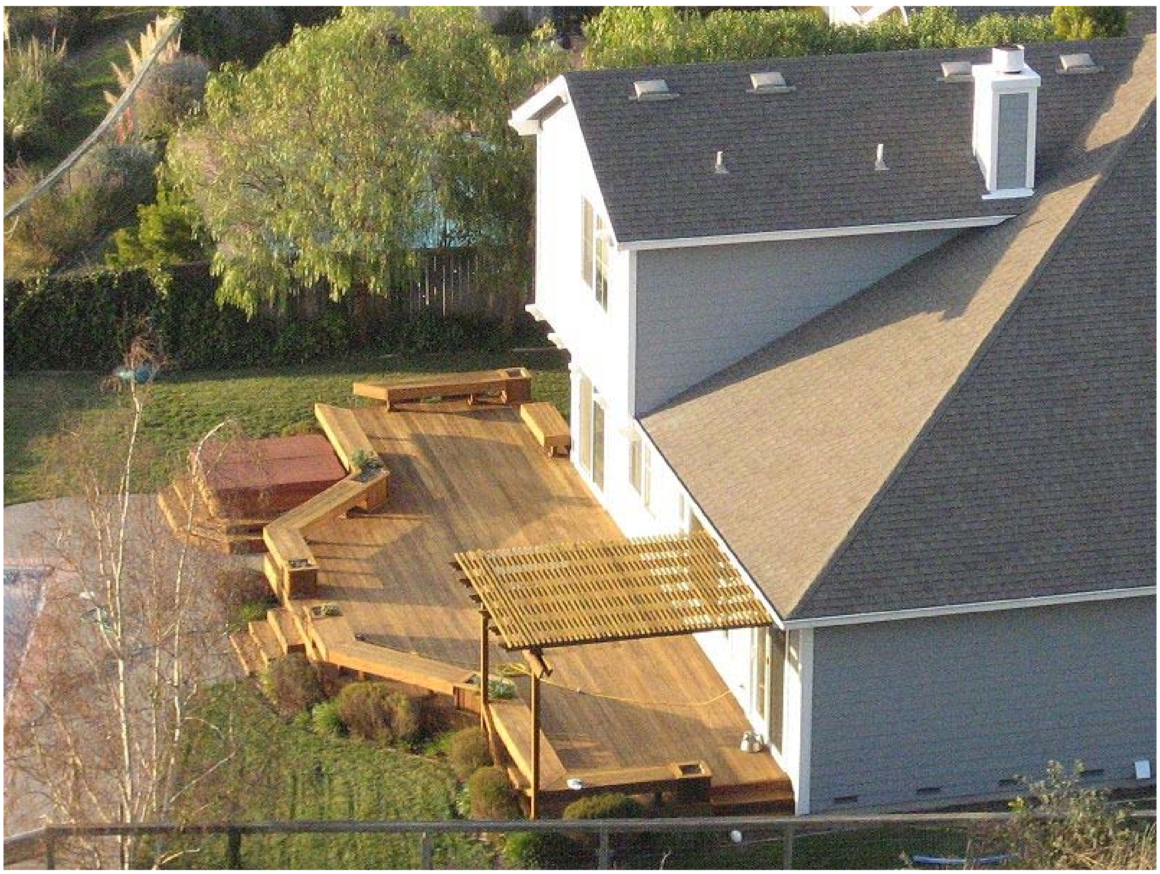
A **bay-and-gable** is a distinct architectural style of house that is ubiquitous in the older parts of Toronto, Canada. The most prominent features is the large bay window that usually covers more than half of the front of the house, surmounted by a gable roof. The classic bay and gable is a red brick semi-detached structure that is two and a half storeys tall, though many variations also exist. It was one of the most common forms of house built in late nineteenth and early twentieth century Toronto. The older parts of the city such as Cabbagetown and Little Italy are still home to many hundreds of examples.

The style was well suited to the layout of the city and the tastes of Torontonians. Old Toronto was laid out with very long and narrow lots, usually only 13 to 20 feet (6.1 m) wide. The tall narrow bay-and-gable house was ideally suited to this environment. High ceilings and large windows allowed light to still reach the depths of the house. Toronto architectural tastes in this era were dominated by the various Victorian Revival styles, especially Gothic Revival. The steep roofs and sharp vertical lines of the bay-and-gable imitated the Gothic style in a way that was affordable to middle class homeowners. For homeowners who wanted more ornament the gables and large windows both provided areas that could be elaborately decorated. Stained glass windows are common in bay-and-gables, as are bargeboards running along the gables and terracotta tiles with ornamental motifs and designs. To save money, often only the front of the house would be given a brick façade, with the back and sides done in wood, or later in imitation Insulbrick.

The style was also very flexible. The typical bay-and-gable house was made out of brick, but ones made completely out of wood were also easily produced. Bay-and-gable houses were most often built as semi-detached buildings, but the basic design could also easily be modified into a stand alone or row house format and many examples of both exist in Toronto. There are many variations on the bay-and-gable found in Toronto. One of the most common simplifications on the style is to replace the bay window with a flat wall.

The style faded as modernism was embraced in the years after the Second World War. It still remains popular among Toronto residents. In older areas of the city several new infill projects have been built in the bay-and-gable style. In the northeastern suburb of Markham, there are subdivisions filled with bay-and-gable houses modified to incorporate a two car garage.

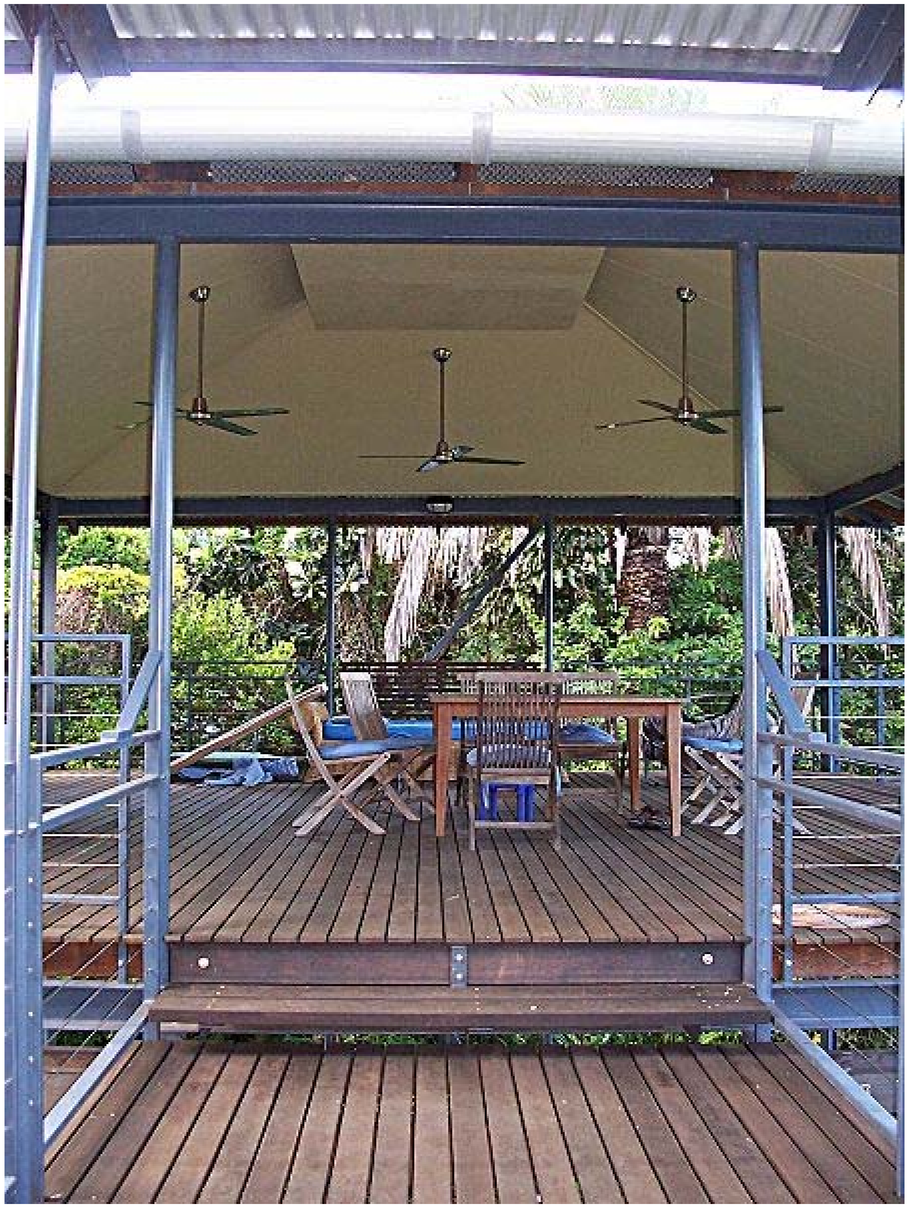
Deck (building)



A deck in the backyard of a suburban house.

Kuwait Towers' observation deck.

A high level corridor deck in the backyard of a suburban house, in Australia



A high level deck in the backyard of a suburban house, in Australia. The decking is a Malaysian timber, *Selangan Batu*

In architecture, a **deck** is a flat surface capable of supporting weight, similar to a floor, but typically constructed outdoors, often elevated from the ground, and usually connected to a building. The term is a generalization of decks as found on ships.

Functions and materials

Wood or timber "decking" can be used in a number of ways - as part of garden landscaping, to extend living areas of houses, and as an alternative to stone based features such as patios. Decks are made from treated lumber, composite material, Aluminum, Western red cedar, teak, mahogany, ipê and other hardwoods and recycled planks made from high-density polyethylene (HDPE), polystyrene (PS) and PET plastic as well as mixed plastics and wood fiber (often called "composite" lumber). Artificial decking products are often called "wood-plastic composites".

Historically, the softwoods used for decking were logged from old growth forests. These include Atlantic white cedar, redwood and Western red cedar (redcedar). Atlantic City built the first coastal boardwalk in the United States, originally constructed of Atlantic white cedar. However, it was not long before the commercial logging of this tree and clearing of cedar swamps in New Jersey caused a decline in the availability of decking. Atlantic City and New York City both switched to Western red cedar. By the 1960s, Western red cedar from the US was declining due to over-logging. More expensive Western red cedar was available from western Canada (British Columbia) but by then, pressure treated pine had become available.

But even with chemical treatments (such as chromated copper arsenate or CCA), pine decking is not as durable as cedars in an outdoor environment. Thus, many municipalities and homeowners are turning to hardwoods. Decks are often built from pressure treated wood. Pressure treated wood is long lasting and holds up to wet and icey weather conditions. Pressure treated wood however is treated with chemicals which have been known to be toxic. Slivers received from pressure treated wood most generally become infected. Pressure treated saw dust also contains toxins such as strychnine, also often used as rat poison. These toxins, when inhaled, can require hospitalization for both acute and chronic exposures.

Generally, hardwoods used for decking come from tropical forests. Much of the logging taking place to produce these woods, especially teak, mahogany and ipê, is occurring illegally, as outlined in numerous reports by environmental organizations such as Greenpeace, Friends of the Earth and Rainforest Relief. US tropical wood imports are rising, partly due to the demand for decking.

Due to environmental concerns, composite decking (a mixture of two materials, typically wood pulp and recycled material such as plastic bottles or plastic bags) have appeared on the market. Proponents of composite decking have touted this as a much needed development as this helps to curb logging of trees for new decks. However composite decking has been found to contain harmful chemicals, cannot be refurbished, and despite claims from decking companies, the composite deck still attracts molding.

Construction

The deck of a house is generally a wooden platform built above the ground and connected to the main building. It is generally enclosed by a railing for safety. Access may be from the house through doors and from the ground via a stairway. Residential decks can be constructed over steep areas or rough ground that is otherwise unusable. Decks can also be covered by a canopy or pergola to control sunlight. Deck designs can be found in numerous books, do-it-yourself magazines and web sites, and from the USDA.

Larger buildings may also have decks on the upper floors of the building which may be open to the public as **observation decks** or a Skyrise greenery.

A deck is also the surface used to construct a boardwalk over sand on barrier islands.

Laying deck or throwing deck refers to the act of placing and bolting down cold-formed steel beneath roofing and concrete floors. This is usually done by an ironworker, sometimes in conjunction with a cement mason or carpenter. It regarded as one of the most physically demanding jobs in the iron working industry.

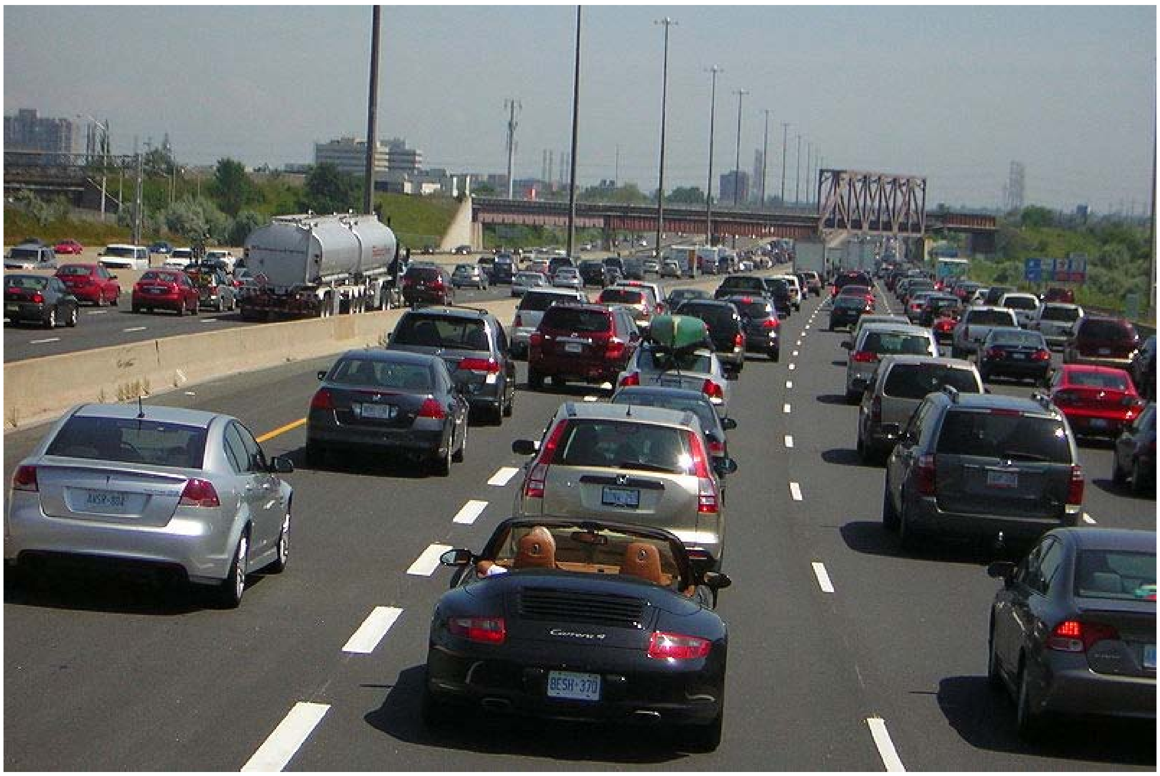
In the UK the 2007 ban on smoking in public buildings was expected lead to an increase in the use of timber decking for outdoor spaces where smokers can gather.

Roof deck

The roof deck is the roofing material layer between the primary structural components (trusses & joists) and either insulative layers or weatherproofing layers in a typical roof system. Usually the roof deck acts as a unifying structural diaphragm by tying all the structural components together. There are many types of roof deck: plywood or OSB sheathing, wood tongue and groove, corrugated metal, grancrete encapsulated polystyrene, reinforced concrete, and double tee.

Chapter- 10

Infrastructure



Highway 401, the busiest highway in North America.

Infrastructure is the basic physical and organizational structures needed for the operation of a society or enterprise, or the services and facilities necessary for an economy to function. The term typically refers to the technical structures that support a society, such as roads, water supply, sewers, power grids, telecommunications, and so forth. Viewed functionally, infrastructure *facilitates* the production of goods and services; for example, roads enable the transport of raw materials to a factory, and also for the distribution of finished products to markets. In some contexts, the term may also include basic social services such as schools and hospitals. In military parlance, the term refers to the buildings and permanent installations necessary for the support, redeployment, and operation of military forces.

History of the term

According to etymology online, the word infrastructure has been used in English since at least 1927 and meant: The installations that form the basis for any operation or system. Other sources, such as the Oxford English Dictionary, trace the word's origins to earlier usage, originally applied in a military sense. The word was imported from French, where it means *subgrade*, the native material underneath a constructed pavement or railway. The word is a combination of the Latin prefix "infra", meaning "below" and "structure". The military use of the term achieved currency in the United States after the formation of NATO in the 1940s, and was then adopted by urban planners in its modern civilian sense by 1970.

The term came to prominence in the United States in the 1980s following the publication of *America in Ruins* (Choate and Walter, 1981) , which initiated a public-policy discussion of the nation’s "infrastructure crisis", purported to be caused by decades of inadequate investment and poor maintenance of public works.

That public-policy discussion was hampered by lack of a precise definition for infrastructure. A U.S. National Research Council panel sought to clarify the situation by adopting the term "public works infrastructure", referring to:

"...both specific functional modes - highways, streets, roads, and bridges; mass transit; airports and airways; water supply and water resources; wastewater management; solid-waste treatment and disposal; electric power generation and transmission; telecommunications; and hazardous waste management - and the combined system these modal elements comprise. A comprehension of infrastructure spans not only these public works facilities, but also the operating procedures, management practices, and development policies that interact together with societal demand and the physical world to facilitate the transport of people and goods, provision of water for drinking and a variety of other uses, safe disposal of society's waste products, provision of energy where it is needed, and transmission of information within and between communities."

In Keynesian economics, the word *infrastructure* was exclusively used to describe public assets that facilitate production, but not private assets of the same purpose. In post-Keynesian times, however, the word has grown in popularity. It has been applied with increasing generality to suggest the internal framework discernible in any technology system or business organization.

"Hard" versus "soft" infrastructure

Here, "hard" infrastructure refers to the large physical networks necessary for the functioning of a modern industrial nation, whereas "soft" infrastructure refers to all the institutions which are required to maintain the economic, health and cultural/social standards of a country, such as the financial system, the education system, the health care system, the system of government and law enforcement, as well as emergency services.

Types of "hard" infrastructure

Chicago Transit Authority control tower 18 guides elevated Chicago 'L' north and southbound Purple and Brown lines intersecting with east and westbound Pink and Green lines and the looping Orange line above the Wells and Lake street intersection in the loop.

The following list is limited to capital assets that serve the function of conveyance or channelling of people, vehicles, fluids, energy or information, and which take the form either of a network or of a critical node used by vehicles, or used for the transmission of electro-magnetic waves. Infrastructure systems include both the fixed assets and the control systems and software required to operate, manage and monitor the systems, as well as any accessory buildings, plants or vehicles that are an essential part of the system. Also included are fleets of vehicles operating according to schedules such as public transit busses and garbage collection, as well as basic energy or communications facilities that are not usually part of a physical network (oil refineries, radio and TV broadcasting facilities).

Transportation infrastructure

- Road and highway networks, including structures (bridges, tunnels, culverts, retaining walls), signage and markings, electrical systems (street lighting and traffic lights), edge treatments (curbs, sidewalks, landscaping) and specialized facilities such as road maintenance depots and rest areas
- Railways, including structures, terminal facilities (rail yards, train stations), level crossings, signalizing and communications systems
- Canals and navigable waterways requiring continuous maintenance (dredging, etc.)
- Seaports and lighthouses
- Airports, including air navigational systems
- Mass transit systems (Commuter rail systems, subways, tramways, trolleys and bus transportation)
- Bicycle paths and pedestrian walkways;
- Ferries.

Energy infrastructure

- Electrical power network, including generation plants, electric grid, substations and local distribution;
- Natural gas pipelines, storage and distribution terminals, as well as the local distribution network. Some definitions may include the gas wells, as well as the fleets of ships and trucks transporting liquified gas;
- Petroleum pipelines, including associated storage and distribution terminals. Some definitions may include the oil wells, refineries, as well as the fleets of tanker ships and trucks;
- Coal mines, as well as specialized facilities for washing , storing and transporting coal;
- Steam or hot water production and distribution networks for district heating systems.
- Electric vehicle networks for charging electric vehicles

Water management infrastructure

- Drinking water supply, including the system of pipes, storage reservoirs, pumps, valves, filtration and treatment equipment and meters, including buildings and structures to house the equipment, used for the collection, treatment and distribution of drinking water
- Sewage collection and disposal of waste water
- Drainage systems (storm sewers, ditches, etc..)
- Major irrigation systems (reservoirs, irrigation canals)
- Major flood control systems (dikes, levees, major pumping stations and floodgates)
- Large-scale snow removal, including fleets of salt spreaders, snow plows, snowblowers, dedicated dumptrucks, sidewalk plows, the dispatching and routing

systems for these fleets, as well as fixed assets such as snow dumps, snow chutes, snow melters.

Communications infrastructure

- Postal service, including sorting facilities.
- Telephone networks (land lines) including switching systems
- Mobile phone networks
- Television and radio transmission stations, including the regulations and standards governing broadcasting;
- Cable television physical networks including receiving stations and cable distribution networks. (Does not include content providers or "networks" when used in the sense of a specialized channel such as CNN or MTV).
- The Internet, including the internet backbone, core routers and server farms, local internet service providers as well as the protocols and other basic software required for the system to function. (Does not include specific websites, although may include some widely-used web-based services, such as Social network services and web search engines).
- Communications satellites
- Undersea cables
- Major private, government or dedicated telecommunications networks, such as those used for internal communication and monitoring by major infrastructure companies, by governments, by the military or by emergency services, as well as national research and education networks.
- Pneumatic tube mail distribution networks

Solid waste management

- Municipal garbage and recyclables collection;
- Solid waste landfills
- Solid waste incinerators and plasma gasification facilities
- Materials recovery facilities
- Hazardous waste disposal facilities;

Earth monitoring and measurement networks

- Meteorological monitoring networks
- Tidal monitoring networks
- Stream Gauge or fluviometric monitoring networks
- Seismometer networks
- Earth observation satellites
- Geodetic benchmarks
- Global Positioning System
- Spatial Data Infrastructure

Types of "soft" infrastructure

"Soft" infrastructure includes both physical assets such as highly specialized buildings and equipment, as well as non-physical "systems" such as the body of rules and regulations governing the various systems, the financing of these systems, as well as the systems and organizations by which highly skilled and specialized professionals are trained, advance in their careers by acquiring experience, and are disciplined (if required) by professional associations (professional training, accreditation and discipline).

Institutional infrastructure

- The financial system, including the banking system, financial institutions, the payment system, exchanges, the money supply, financial regulations as well as accounting standards and regulations;
- The system of government and law enforcement, including the political, legislative, law enforcement, justice and penal systems, as well as specialized facilities (government offices, courthouses, prisons, etc.) and specialized systems for collecting, storing and disseminating data, laws and regulation;
- Emergency services, such as police, fire protection, ambulances, etc., including specialized vehicles, buildings, communications and dispatching systems.

Industrial infrastructure

- Manufacturing infrastructure, including industrial parks and special economic zones, mines and processing plants for basic materials used as inputs in industry, specialized energy, transportation and water infrastructure used by industry, plus the public safety, zoning and environmental laws and regulations that govern and limit industrial activity, and standards organizations;
- Agricultural, forestry and fisheries infrastructure, including specialized food and livestock transportation and storage facilities, major feedlots, agricultural price support systems (including agricultural insurance), agricultural health standards, food inspection, experimental farms and agricultural research centers and schools, the system of licencing and quota management, enforcement systems against poaching, forest wardens and fire fighting.

Social infrastructure

- The health care system, including hospitals, the financing of health care, including health insurance, the systems for regulation and testing of medications and medical procedures, the system for training, inspection and professional discipline of doctors and other medical professionals, public health monitoring and regulations, as well as coordination of measures taken during public health emergencies such as epidemics;

- The educational and research system, including elementary and secondary schools, universities, specialised colleges, research institutions, the systems for financing and accrediting educational institutions;
- Social welfare systems, including both government support and private charity for the poor, for people in distress or victims of abuse.

Cultural, sports and recreational infrastructure

- Sports and recreational infrastructure, such as parks, sports facilities, the system of sports leagues and associations;
- Cultural infrastructure, such as concert halls, museums. libraries, theatres, studios, and specialized training facilities;
- Business travel and tourism infrastructure, including both man-made and natural attractions, convention centers, hotels, restaurants and other services that cater mainly to tourists and business travellers, as well as the systems for informing and attracting tourists, travel insurance, etc.

Uses of the term

Engineering and construction

Engineers generally limit the use of the term *infrastructure* to describe fixed assets that are in the form of a large network, in other words, "hard" infrastructure. Recent efforts to devise more generic definitions of infrastructure have typically referred to the network aspects of most of the structures and to the accumulated value of investments in the networks as assets. One such effort defines infrastructure as the network of assets "where the system as a whole is intended to be maintained indefinitely at a specified standard of service by the continuing replacement and refurbishment of its components."

Civil defense and economic development

Civil defense planners and developmental economists generally refer to both "hard" and "soft" infrastructure, including public services such as schools and hospitals, emergency services such as police and fire fighting, and basic financial services.

Military

Military strategists use the term *infrastructure* to refer to all building and permanent installations necessary for the support of military forces, whether they are stationed in bases, being deployed or engaged in operations, such as barracks, headquarters, airfields, communications facilities, stores of military equipment, port installations, and maintenance stations.

Critical infrastructure

The term *critical infrastructure* has been widely adopted to distinguish those infrastructure elements (both hard and soft) that, if significantly damaged or destroyed, would cause serious disruption of the dependent system or organization. Storm, flood, or earthquake damage leading to loss of certain transportation routes in a city (for example, bridges crossing a river), could make it impossible for people to evacuate and for emergency services to operate; these routes would be deemed critical infrastructure. Similarly, an on-line booking system might be critical infrastructure for an airline.

Urban infrastructure

Urban or *municipal infrastructure* refers to "hard" infrastructure systems generally owned and operated by municipalities, such as streets, water distribution, sewers, etc. It may also include some of the facilities associated with "soft" infrastructure, such as parks, public pools and libraries.

Green infrastructure

Green Infrastructure is a concept that highlights the importance of the natural environment in decisions about land use planning. In particular there is an emphasis on the "life support" functions provided by a network of natural ecosystems, with an emphasis on interconnectivity to support long-term sustainability. Examples include clean water and healthy soils, as well as the more anthropocentric functions such as recreation and providing shade and shelter in and around towns and cities. The concept can be extended to apply to the management of stormwater runoff at the local level through the use of natural systems, or engineered systems that mimic natural systems, to treat polluted runoff.

Marxism

In Marxism, the term "infrastructure" is sometimes used as a synonym for *base* in the dialectic synthetic pair *base and superstructure*. However the Marxist notion of base is broader than the non-Marxist use of the term "infrastructure", and some "soft" infrastructure, such as laws, governance, regulations and standards, would be considered by Marxists to be part of the "superstructure", not the "base".

Other uses

In other applications, the term *infrastructure* may refer to information technology, informal and formal channels of communication, software development tools, political and social networks, or beliefs held by members of particular groups. Still underlying these more conceptual uses is the idea that infrastructure provides organizing structure and support for the system or organization it serves, whether it is a city, a nation, a corporation, or a collection of people with common interests. Examples: *IT infrastructure*, *research infrastructure*, *terrorist infrastructure*, *tourism infrastructure*.

Related concepts

The term *infrastructure* is often confused with the following overlapping or related concepts:

Land improvement and land development

The terms *land improvement* and *land development* are general terms that in some contexts may include infrastructure, but in the context of a discussion of infrastructure would refer only to smaller scale systems or works that are not included in infrastructure because they are typically limited to a single parcel of land, and are owned and operated by the land owner. For example, an irrigation canal that serves a region or district would be included with infrastructure, but the private irrigation systems on individual land parcels would be considered *land improvements*, not infrastructure. Service connections to municipal service and public utility networks would also be considered land improvements, not infrastructure.

Public works and public services

The term *public works* includes government owned and operated infrastructure as well as public buildings such as schools and court houses. The term *public works* generally refers to physical assets needed to deliver *public services*.

Public services include both infrastructure and services generally provided by government.

Typical attributes

"Hard" infrastructure generally has the following attributes:

Capital assets that provide services

- They are physical assets that provide services;
- The people employed in the "hard" infrastructure sector generally maintain, monitor and operate the assets, but do not offer services to the clients or users of the infrastructure. Interactions between workers and clients are generally limited to administrative tasks concerning ordering, scheduling or billing of services.

Large networks

- They are large networks constructed over generations, and are not often replaced as a whole system.
- The network provides services to a geographically defined area.
- The system or network has a long life because its service capacity is maintained by continual refurbishment or replacement of components as they wear out.

Historicity and interdependence

- The system or network tends to evolve over time as it is continuously modified, improved, enlarged, and as various components are re-built, decommissioned or adapted to other uses.
- The system components are interdependent and not usually capable of subdivision or separate disposal, and consequently are not readily disposable within the commercial marketplace.
- The system interdependency may limit a component life to a lesser period than the expected life of the component itself.

Natural monopoly

- The systems tend to be natural monopolies, insofar that economies of scale means that multiple agencies providing a service are less efficient than would be the case if a single agency provided the service.
- The assets have a high initial cost and a value that is difficult to determine.
- Once most of the system is built, the marginal cost of servicing additional clients or users tends to be relatively inexpensive, and may be negligible if there is no need to increase the peak capacity or the geographical extent of the network.

Economics, management, engineering and impacts

The following concerns mainly "hard" infrastructure and the specialized facilities used for "soft" infrastructure.

Ownership and financing

Infrastructure may be owned and managed by governments or by private companies, such as public utility or railway companies. Generally, most roads, major ports and airports, water distribution systems and sewage networks are publicly owned, whereas most energy and telecommunications networks are privately owned. Publicly owned infrastructure may be paid for from taxes, tolls or metered user fees, whereas private infrastructure is generally paid for by metered user fees. Major investment projects are generally financed by the issuance of long-term bonds.

Note that government owned and operated infrastructure may be developed and operated in the private sector or in public-private partnership in addition to in the public sector.

In the United States, public spending on infrastructure has varied between 2.3% and 3.6% of GDP since 1950.

Many financial institutions invest in infrastructure.

National Infrastructure Bank Act of 2007

In 2007, Senator Christopher Dodd of Connecticut and Senator Charles Hagel of Nebraska introduced the National Infrastructure Bank Act of 2007. This bill would provide for a national fund to help pay for large infrastructure projects in the United States.

Planning and management

The method of 'Infrastructure Asset Management' is based upon the definition of a Standard of Service (SoS) that describes how an asset will perform in objective and measurable terms. The SoS includes the definition of a minimum condition grade, which is established by considering the consequences of a failure of the infrastructure asset.

The key components of 'Infrastructure Asset Management' are:

- Definition of a Standard of Service
    - Establishment of measurable specifications of how the asset should perform
    - Establishment of a minimum condition grade
- Establishment of a whole-life cost approach to managing the asset
- Elaboration of an Asset Management Plan

The 2009 report card produced by the American Society of Civil Engineers gives America's Infrastructure a grade of **"D"**.

Engineering

Most infrastructure is designed by engineers, urbanists or architects. Generally road and rail transport networks, as well as water and waste management infrastructure are designed by civil engineers; electrical power and lighting networks are designed by power engineers and electrical engineers; and telecommunications, computing and monitoring networks are designed by systems engineers. In the case of urban infrastructure, the general layout of roads, sidewalks and public places may sometimes be designed by urbanists or architects, although the detailed design will still be performed by civil engineers. If a building is required, it is designed by an architect, and if an industrial or processing plant is required, it may be designed by industrial engineer or a process engineer.

In terms of engineering tasks, the design and construction management process usually follows these steps:

- **Preliminary Studies**:
    - Determine existing and future traffic loads, determine existing capacity, and estimate the existing and future standards of service;

  - Conduct a preliminary survey and obtain information from existing air photos, maps, plans, etc.
  - Identify possible conflicts with other assets or topographical features;
  - Perform environmental impact studies:
    - Evaluate the impact on the human environment (Noise pollution, odors, electromagnetic interference, etc. ..);
    - Evaluate the impact on the natural environment (disturbance of natural ecosystems);
    - Evaluate possible presence of contaminated soils;
  - Given various time horizons, standards of service, environmental impacts and conflicts with existing structures or terrain, propose various preliminary designs;
  - Estimate the costs of the various designs, and make recommendations;
- **Detailed Survey**:
  - Perform a detailed survey of the construction site;
  - Obtain *As Built* drawings of existing infrastructure;
  - Dig exploratory pits where required to survey underground infrastructure;
  - Perform a geotechnical survey to determine the bearing capacity of soils and rock;
  - Perform soil sampling and testing to estimate nature, degree and extent of soil contamination;
- **Detailed Engineering**:
  - Prepare detailed plans and technical specifications;
  - Prepare a detailed bill of materials;
  - Prepare a detailed cost estimate;
  - Establish a general work schedule;
- **Authorization**:
  - Obtain authorization from environmental and other regulatory agencies;
  - Obtain authorization from any owners or operators of assets affected by the work;
  - Inform emergency services, and prepare contingency plans in case of emergencies;
- **Tendering**:
  - Prepare administrative clauses and other tendering documents;
  - Organize and announce a Call for Tenders;
  - Answer contractor questions and issue addenda during the tendering process;
  - Receive and analyse tenders, and make a recommendation to the owner;
- **Construction Supervision**:
  - Once the construction contract has been signed between the owner and the general contractor, once all authorisations have been obtained, and once all pre-construction submittals have been received from the general contractor, the construction supervisor issues an Order to Begin Construction;
  - Regularly schedule meetings and obtain contact information for the general contractor (GC) and all interested parties;

- Obtain a detailed work schedule and list of subcontractors from the GC.
- Obtain detailed traffic diversion and emergency plans from the GC;
- Obtain proof of certification, insurance and bonds;
- Examine shop drawings submitted by the GC;
- Receive reports from the materials quality control lab;
- When required, review Change request s from the GC, and issue Construction Directives and Change Orders;
- Follow work progress and authorize partial payments;
- When substantially completed, inspect the work and prepare a list of deficiencies;
- Supervise testing and commissioning;
- Verify that all operating and maintenance manuals, as well as warranties, are complete;
- Prepare "As Built" drawings;
- Make a final inspection, issue a certificate of final completion and authorize the final payment.

Impact on economic development

Investment in infrastructure is part of the capital accumulation required for economic development.

Use as economic stimulus

During the Great Depression of the 1930s, many governments undertook public works projects in order to create jobs and stimulate the economy. The economist John Maynard Keynes provided a theoretical justification for this policy in The General Theory of Employment, Interest and Money, published in 1936. Following the global financial crisis of 2008–2009, some are again proposing investing in infrastructure as a means of stimulating the economy.

Environmental impacts

(This is a stub, the following statement needs elaboration:) "Infrastuctures have had harmful, long-term, and potentially irrepable effects on ecostructure."

History

The following concerns mainly "hard" infrastructure.

Before 1700

Infrastructure before 1700 consisted mainly of roads and canals. Canals were used for transportation or for irrigation. Sea navigation was aided by ports and lighthouses. A few advanced cities had aqueducts that serviced public fountains and baths, and even fewer had sewers.

Roads:

The first roads were tracks that often followed game trails, such as the Natchez Trace.

The first paved streets appear to have been built in Ur in 4000 BCE. Corduroy roads were built in Glastonbury, England in 3300 BCE and brick-paved roads were built in the Indus Valley Civilization on the Indian subcontinent from around the same time. In 500 BCE, Darius I the Great started an extensive road system for Persia (Iran), including the Royal Road.

With the advent of the Roman Empire, the Romans built roads using deep roadbeds of crushed stone as an underlying layer to ensure that they kept dry. On the more heavily traveled routes, there were additional layers that included six sided capstones, or pavers, that reduced the dust and reduced the drag from wheels.

In the medieval Islamic world, many roads were built throughout the Arab Empire. The most sophisticated roads were those of the Baghdad, Iraq, which were paved with tar in the 8th century.

Canals and irrigation systems: The oldest known canals were built in Mesopotamia circa 4000 BCE, in what is now modern day Iraq and Syria. The Indus Valley Civilization in India and Pakistan (from circa 3300 BCE) had a sophisticated canal irrigation system. In Egypt, canals date back to at least 2300 BCE, when a canal was built to bypass the cataract on the Nile near Aswan.

In ancient China, large canals for river transport were established as far back as the Warring States (481-221 BCE). By far the longest canal was the Grand Canal of China, still the longest canal in the world today at 1,794 kilometres (1,115 mi) long, and completed in 609.

In Europe, canal building began in the Middle Ages because of commercial expansion from the 12th century CE. Notable canals were the Stecknitz Canal in Germany in 1398, the Briare Canal connecting the Loire and Seine in France (1642) followed by the Canal du Midi (1683) connecting the Atlantic to the Mediterranean. Canal building progressed steadily in Germany in the 17th and 18th centuries with three great rivers, the Elbe, Oder and Weser being linked by canals.

1700 to 1870

Roads: As traffic levels increased in England and roads deteriorated, toll roads were built by *Turnpike Trusts*, especially between 1730–1770. Turnpikes were also later built in the United States. They were usually built by private companies under a government franchise.

Water transport on rivers and canals carried many farm goods from the frontier U.S. (between the Appalachian mountains and Mississippi River) in the early 19th century, but the shorter route over the mountains had advantages.

In France, Pierre-Marie-Jérôme Trésaguet is widely credited with establishing the first scientific approach to road building about the year 1764. It involved a layer of large rocks, covered by a layer of smaller gravel. John Loudon McAdam (1756–1836) designed the first modern highways, and developed an inexpensive paving material of soil and stone aggregate (known as macadam).

Canals: In Europe, particularly Britain and Ireland, and then in the young United States and the Canadian colonies, inland canals preceded the development of railroads during the earliest phase of the Industrial Revolution. In Britain between 1760 and 1820 over one hundred canals were built.

In the United States, navigable canals reached into isolated areas and brought them in touch with the world beyond. By 1825 the Erie Canal, 363 miles (584 km) long with 82 locks, opened up a connection from the populated Northeast to the fertile Great Plains. During the 19th century, the length of canals grew from 100 miles (160 km) to over 4,000, with a complex network making the Great Lakes navigable, in conjunction with Canada, although some canals were later drained and used as railroad rights-of-way.

Railways: The earliest railways were used in mines or to bypass waterfalls, and were pulled by horses or by people. In 1811 John Blenkinsop designed the first successful and practical railway locomotive, and a line was built connecting the Middleton Colliery to Leeds. The Liverpool and Manchester Railway, considered to be the world's first "Inter City" line, opened in 1826. In the following years, railways spread throughout the United Kingdom and the world, and became the dominant means of land transport for nearly a century.

In the United States, the 1826 Granite Railway in Massachusetts was the first commercial railroad to evolve through continuous operations into a common carrier. The Baltimore and Ohio, opened in 1830, was the first to evolve into a major system. In 1869, the symbolically important transcontinental railroad was completed in the United States with the driving of a golden spike at Promontory, Utah.

Telegraph service: The first *commercial* electrical telegraph was first successfully demonstrated on 25 July 1837 between Euston and Camden Town in London. It entered commercial use on the Great Western Railway over the 13 miles (21 km) from Paddington station to West Drayton on 9 April 1839.

In the United States, the telegraph was developed by Samuel Morse and Alfred Vail. On 24 May 1844, Morse made the first public demonstration of his telegraph by sending a message from the Supreme Court Chamber in the U.S. Capitol in Washington, D.C. to the B&O Railroad "outer depot" (now the B&O Railroad Museum) in Baltimore. The

Morse/Vail telegraph was quickly deployed in the following two decades. On 24 October 1861, the first transcontinental telegraph system was established.

The first successful transatlantic telegraph cable was completed on 27 July 1866, allowing transatlantic telegraph communications for the first time. Within 29 years of its first installation at Euston Station, the telegraph network crossed the oceans to every continent but Antarctica, making instant global communication possible for the first time.

1870 to 1920

Roads: Tar-bound macadam (tarmac) was applied to macadam roads towards the end of the 19th century in cities such as Paris. In the early 20th century tarmac and concrete paving were extended into the countryside.

Canals: Many notable sea canals were completed in this period: the Suez Canal (1869); the Kiel Canal (1897) - which carries tonnage many times that of most other canals; and the Panama Canal, opened in 1914.

Telephone service: In 1876, Alexander Graham Bell achieved the first successful telephone transmission of clear speech. The first telephones had no network but were in private use, wired together in pairs. Users who wanted to talk to different people had as many telephones as necessary for the purpose. A user who wished to speak, whistled into the transmitter until the other party heard. Soon, however, a bell was added for signalling, and then a switchhook, and telephones took advantage of the exchange principle already employed in telegraph networks. Each telephone was wired to a local telephone exchange, and the exchanges were wired together with trunks. Networks were connected together in a hierarchical manner until they spanned cities, countries, continents and oceans.

Electricity: At the Paris Exposition of 1878, electric arc lighting had been installed along the Avenue de l'Opera and the Place de l'Opera, using electric Yablochkov arc lamps, powered by Zénobe Gramme alternating current dynamos. Yablochkov candles required high voltage, and it was not long before experimenters reported that the arc lights could be powered on a 7-mile circuit. Within a decade scores of cities would have lighting systems using a central power plant that provided electricity to multiple customers via electrical transmission lines. These systems were in direct competition with the dominant gaslight utilities of the period.

The first electricity system supplying incandescent lights was built by Edison Illuminating Company in lower Manhattan eventually serving one square mile with 6 "jumbo dynamos" housed at Pearl Street Station.

The first transmission of three-phase alternating current using high voltage took place in 1891 during the international electricity exhibition in Frankfurt. A 25 kV transmission line, approximately 175 kilometers long, connected Lauffen on the Neckar and Frankfurt. Voltages used for electric power transmission increased throughout the 20th century. By

1914 fifty-five transmission systems operating at more than 70,000 V were in service, the highest voltage then used was 150,000 volts.

Water distribution and sewers: In the 19th century major treatment works were built in London in response to cholera threats. The Metropolis Water Act 1852 was enacted. "Under the Act, it became unlawful for any water company to extract water for domestic use from the tidal reaches of the Thames after 31 August 1855, and from 31 December 1855 all such water was required to be "effectually filtered". The Metropolitan Commission of Sewers was formed, water filtration was made compulsory, and new water intakes on the Thames were established above Teddington Lock. The technique of purification of drinking water by use of compressed liquefied chlorine gas was developed in 1910 by U.S. Army Major (later Brig. Gen.) Carl Rogers Darnall (1867–1941), Professor of Chemistry at the Army Medical School. Darnall's work became the basis for present day systems of municipal water '***purification'***.

Subways: In 1863 the London Underground was created; in 1890, it first started using electric traction and deep-level tunnels. Soon afterward Budapest and many other cities started using subway systems including New York. By 1940, 19 subway systems were in use.

Since 1920

Roads: In 1925, Italy was the first country to build a freeway-like road, which linked Milan to Lake Como. It is known in Italy as the Autostrada dei Laghi. In Germany, the autobahns formed the first limited-access, high-speed road network in the world, with the first section from Frankfurt am Main to Darmstadt opening in 1935. The first long-distance rural freeway in the United States is generally considered to be the Pennsylvania Turnpike, which opened on October 1, 1940. In the United States, the Interstate Highway System was authorized by the Federal-Aid Highway Act of 1956. Most of the system was completed between 1960 and 1990.

A multi lane, multi carriageway freeway.

Chapter- 11

Road and Highway

Road

Road in the United Arab Emirates

Via Roma, a street in Florence, Italy

St. Gotthard Pass with hairpin turns in the Swiss Alps, Switzerland

A **road** is a thoroughfare, route, or way between two places, which typically has been improved to allow travel by some conveyance, including a horse, cart, or motorized vehicle. Modern roads are normally smoothed, paved, or otherwise prepared to allow easy travel although historically many roads were simply recognizable routes without any formal construction or maintenance.

A road is made up of one or more roadways (British: Carriageway) each with one or more lanes and optionally also sidewalks (British:pavement) and tree lawns (British: verge).

Definitions

For purposes of international statistical comparison, the OECD defines a road as "*a line of communication (travelled way) using a stabilized base other than rails or air strips open to public traffic, primarily for the use of road motor vehicles running on their own wheels*" which should include "*bridges, tunnels, supporting structures, junctions, crossings, interchanges and toll roads but not cycle paths*". In urban areas roads may diverge through a city or village and be named as streets, serving a dual function as urban space easement and route.

United States

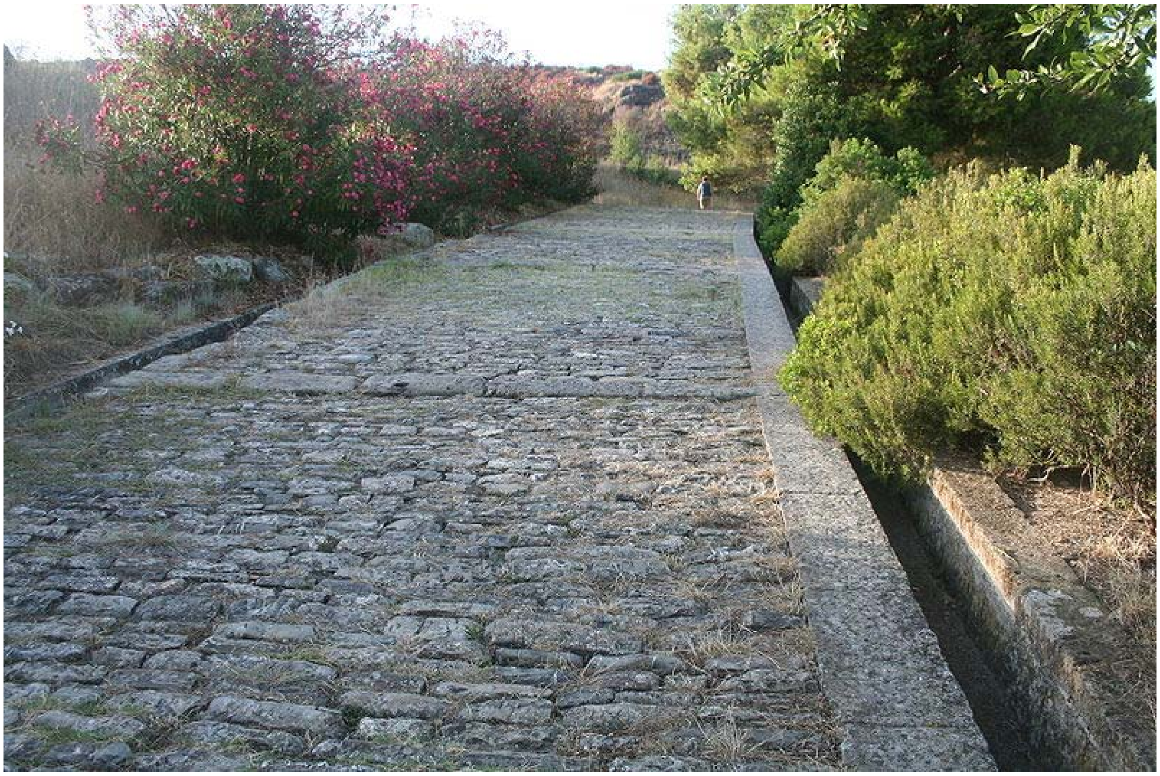
In the United States, laws make distinctions between "public roads," which are open to public use, and "private roads," the use of which are privately controlled.

United Kingdom

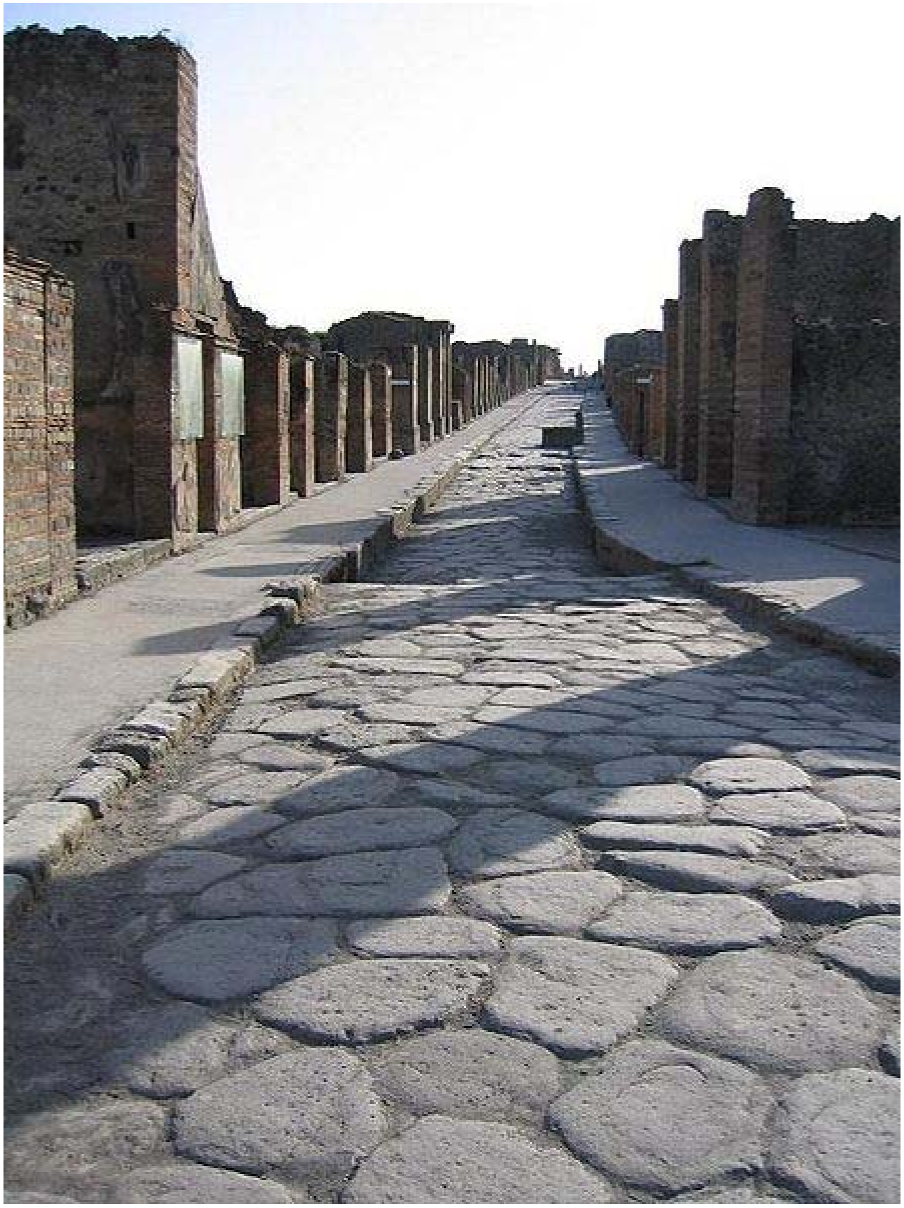
In the United Kingdom there is some ambiguity between the terms highway and road. The Highway code details rules for 'road users'. For the purposes of the English law Highways Act 1980, which covers England and Wales (but not Scotland or Northern Ireland), the term "road" is defined to be *any length of highway or of any other road to which the public has access, and includes bridges over which a road passes*. This includes footpaths, bridleways and cycle tracks, and also road and driveways on private land and many car parks. Vehicle Excise Duty (a road use tax) is payable on some vehicles used on the public road.

The definition of a road depends on the definition of a highway, however there is no formal definition for a highway in the relevant Act. A 1984 ruling said *The land over which a public right of way exists is known as a highway; and although most highways have been made up into roads, and most easements of way exist over footpaths, the presence or absence of a made road has nothing to do with the distinction*. Another legal view is that whereas a highway historically included footpaths, bridleways, driftways etc it can now be used to mean those ways which allow the movement of motor-vehicles, and the term rights of way can be used to cover the wider usage.

Historical road construction



The Porta Rosa is a Greek street dating from the 3rd to 4th century BC in Velia, Italy with a paved surface and gutters.



A paved Roman road in Pompeii, Italy

That the first pathways were the trails made by animals has not been universally accepted, arguing that animals do not follow constant paths. Others believe that some roads originated from following animal trails. The Icknield Way is given as an example of this type of road origination, where man and animal both selected the same natural line. By about 10,000 BC, rough pathways were used by human travelers.

- Stone-paved streets are found in the city of Ur in the Middle East dating back to 4000 BC.

- Corduroy roads (log roads) are found dating to 4000 BC in Glastonbury, England.

- The timber trackway; Sweet Track causeway in England, is one of the oldest engineered roads discovered and the oldest timber trackway discovered in Northern Europe. Built in winter 3807 BC or spring 3806 BC, tree-ring dating (Dendrochronology) enabled very precise dating. It has been claimed to be the oldest road in the world.

- Brick-paved streets were used in India as early as 3000 BC.

- In 500 BC, Darius I the Great started an extensive road system for Persia (Iran), including the famous Royal Road which was one of the finest highways of its time. The road remained in use after Roman times.

- In ancient times, transport by river was far easier and faster than transport by road, especially considering the cost of road construction and the difference in carrying capacity between carts and river barges. A hybrid of road transport and ship transport beginning in about 1740 is the horse-drawn boat in which the horse follows a cleared path along the river bank.

- From about 312 BC, the Roman Empire built straight strong stone Roman roads throughout Europe and North Africa, in support of its military campaigns. At its peak the Roman Empire was connected by 29 major roads moving out from Rome and covering 78,000 kilometers or 52,964 Roman miles of paved roads.

- In the 8th century AD, many roads were built throughout the Arab Empire. The most sophisticated roads were those of the Baghdad, Iraq, which were paved with tar in the 8th century. Tar was derived from petroleum, accessed from oil fields in the region, through the chemical process of destructive distillation.

- The Highways Act 1555 in Britain required local parishes to maintain their roads. This resulted in a poor and variable state of roads. To remedy this, the first of the "Turnpike trusts" was established around 1706, to build good roads and collect tolls from passing vehicles. Eventually there were approximately 1,100 trusts in Britain and some 36,800 km of engineered roads. The Rebecca Riots in Carmarthenshire and Rhayader from 1839 to 1844 contributed to a Royal Commission leading to the demise of the system in 1844 which also coincided with the development of the UK railway system.

Construction

A road being torn up.

Surveyor at work with a leveling instrument.

Asphalt layer and roller

Sub-base layer composed of cement-based material being applied during construction of the M8 motorway in Ireland.

Road construction requires the creation of a continuous right-of-way, overcoming geographic obstacles and having grades low enough to permit vehicle or foot travel. and may be required to meet standards set by law or official guidelines. The process is often begun with the removal of earth and rock by digging or blasting, construction of embankments, bridges and tunnels, and removal of vegetation (this may involve deforestation) and followed by the laying of pavement material. A variety of road building equipment is employed in road building.

After design, approval, planning, legal and environmental considerations have been addressed alignment of the road is set out by a surveyor. The Radii and gradient are designed and staked out to best suit the natural ground levels and minimize the amount of cut and fill. Great care is taken to preserve reference Benchmarks

Roadways are designed and built for primary use by vehicular and pedestrian traffic. Storm drainage and environmental considerations are a major concern. Erosion and sediment controls are constructed to prevent detrimental effects. Drainage lines are laid with sealed joints in the road easement with runoff coefficients and characteristics adequate for the land zoning and storm water system. Drainage systems must be capable of carrying the ultimate design flow from the upstream catchment with approval for the outfall from the appropriate authority to a watercourse, creek, river or the sea for drainage discharge.

A borrow pit (source for obtaining fill, gravel, and rock) and a water source should be located near or in reasonable distance to the road construction site. Approval from local authorities may be required to draw water or for working (crushing and screening) of materials for construction needs. The top soil and vegetation is removed from the borrow pit and stockpiled for subsequent rehabilitation of the extraction area. Side slopes in the excavation area not steeper than one vertical to two horizontal for safety reasons.

Road construction on Marquette Avenue in Minneapolis, Minnesota, United States

Old road surfaces, fences, and buildings may need to be removed before construction can begin. Trees in the road construction area may be marked for retention. These protected trees should not have the topsoil within the area of the tree's drip line removed and the area should be kept clear of construction material and equipment. Compensation or replacement may be required if a protected tree is damaged. Much of the vegetation may be mulched and put aside for use during reinstatement. The topsoil is usually stripped and stockpiled nearby for rehabilitation of newly constructed embankments along the road. Stumps and roots are removed and holes filled as required before the earthwork begins. Final rehabilitation after road construction is completed will include seeding, planting, watering and other activities to reinstate the area to be consistent with the untouched surrounding areas.

Processes during earthwork include excavation, removal of material to spoil, filling, compacting, construction and trimming. If rock or other unsuitable material is discovered it is removed, moisture content is managed and replaced with standard fill compacted to 90% relative compaction. Generally blasting of rock is discouraged in the road bed. When a depression must be filled to come up to the road grade the native bed is compacted after the topsoil has been removed. The fill is made by the "compacted layer method" where a layer of fill is spread then compacted to specifications, the process is repeated until the desired grade is reached.

Typical pavement strata for a heavily traveled road

General fill material should be free of organics, meet minimum California bearing ratio (CBR) results and have a low plasticity index. The lower fill generally comprises sand or a sand-rich mixture with fine gravel, which acts as an inhibitor to the growth of plants or other vegetable matter. The compacted fill also serves as lower-stratum drainage. Select second fill (sieved) should be composed of gravel, decomposed rock or broken rock below a specified Particle size and be free of large lumps of clay. Sand clay fill may also be used. The road bed must be "proof rolled" after each layer of fill is compacted. If a roller passes over an area without creating visible deformation or spring the section is deemed to comply.

The completed road way is finished by paving or left with a gravel or other natural surface. The type of road surface is dependent on economic factors and expected usage. Safety improvements like Traffic signs, Crash barriers, Raised pavement markers, and other forms of Road surface marking are installed.

According to a May 2009 report by the American Association of State Highway and Transportation Officials (AASHTO) and TRIP—a national transportation research organization—driving on rough roads costs the average American motorist approximately $400 a year in extra vehicle operating costs. Drivers living in urban areas with populations more than 250,000 are paying upwards of $750 more annually because of accelerated vehicle deterioration, increased maintenance, additional fuel consumption, and tire wear caused by poor road conditions.

When a single carriageway road is converted into dual carriageway by building a second separate carriageway alongside the first, it is usually referred to as *duplication*, *twinning* or *doubling*. The original carriageway is changed from two-way to become one-way, while the new carriageway is one-way in the opposite direction. In the same way as converting railway lines from single track to double track, the new carriageway is not always constructed directly alongside the existing carriageway.

Maintenance

Like all structures, roads deteriorate over time. Deterioration is primarily due to accumulated damage from vehicles, however environmental effects such as frost heaves, thermal cracking and oxidation often contribute. According to a series of experiments carried out in the late 1950s, called the AASHO Road Test, it was empirically determined that the effective damage done to the road is roughly proportional to the 4th power of axle weight. A typical tractor-trailer weighing 80,000 pounds (36.287 t) with 8,000 pounds (3.6287 t) on the steer axle and 36,000 pounds (16.329 t) on both of the tandem axle groups is expected to do 7,800 times more damage than a passenger vehicle with 2,000 pounds (0.907 t) on each axle. Potholes on roads are caused by rain damage and vehicle braking or related construction works.

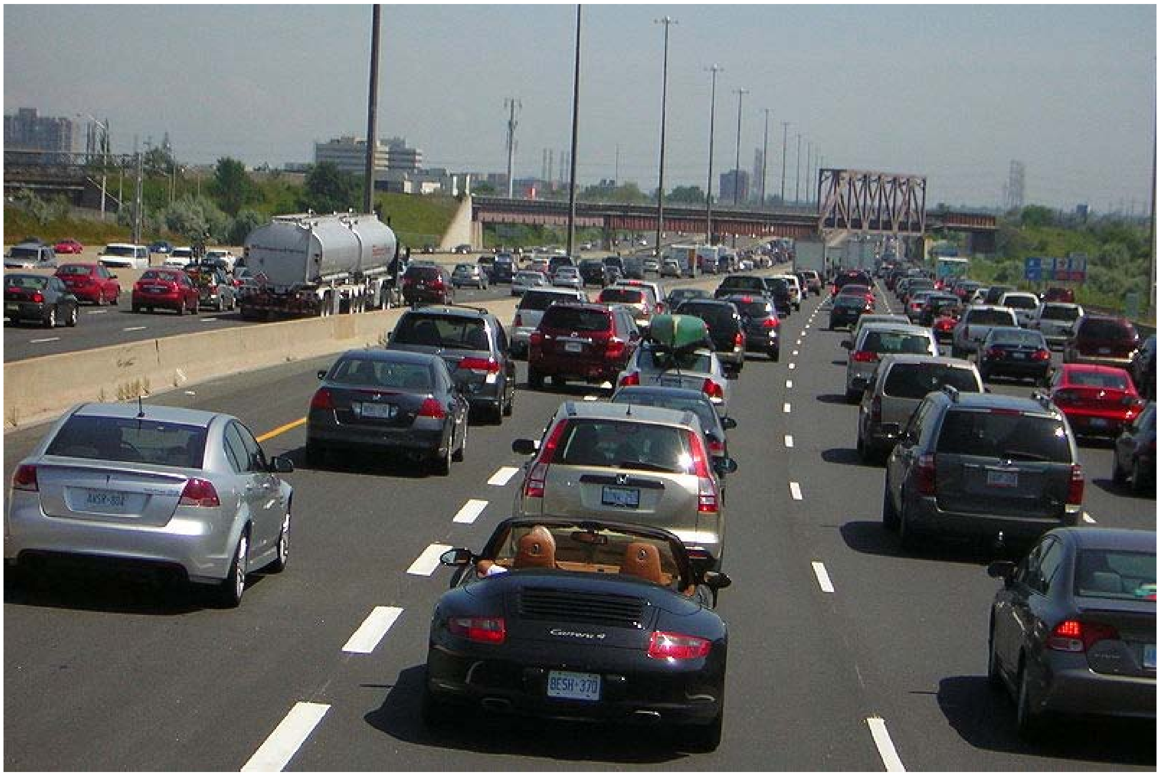
Pavements are designed for an expected service life or design life. In some UK countries the standard design life is 40 years for new bitumen and concrete pavement. Maintenance is considered in the whole life cost of the road with service at 10, 20 and 30 year milestones. Roads can be and are designed for a variety of lives (8-, 15-, 30-, and 60-year designs). When pavement lasts longer than its intended life, it may have been overbuilt, and the original costs may have been too high. When a pavement fails before its intended design life, the owner may have excessive repair and rehabilitation costs. Many concrete pavements built since the 1950s have significantly outlived their intended design lives. Some roads like Chicago, Illinois's "Wacker Drive", a major two-level viaduct in downtown area are being rebuilt with a designed service life of 100 years.

Virtually all roads require some form of maintenance before they come to the end of their service life. Pro-active agencies continually monitor road conditions and apply preventive maintenance treatments as needed to prolong the lifespan of their roads. Technically advanced agencies monitior the road network surface condition with sophisticated equipment such as laser/inertial Profilometers. These measurements include road curvature, cross slope, asperity, roughness, rutting and texture (roads). This data is fed into a pavement management system, which recommends the best maintenance or construction treatment to correct the damage that has occurred.

Maintenance treatments for asphalt concrete generally include crack sealing, surface rejuvenating, fog sealing, micro-milling and surface treatments. Thin surfacing preserves, protects and improves the functional condition of the road while reducing the need for routing maintenance, leading to extended service life without increasing structural capacity.

Failure to maintain roads properly can create significant costs to society, in a 2009 report released by the American Association of State Highway and Transportation Officials (USA) about 50% of the roads in the USA are in bad condition with urban areas worse. The report estimates that urban drivers pay an average of $746/year on vehicle repairs while the average US motorist pays about $335/year. In contrast, the average motorist pays about $171/year in road maintenance taxes (based on 600 gallons/year and $0.285/gallon tax).

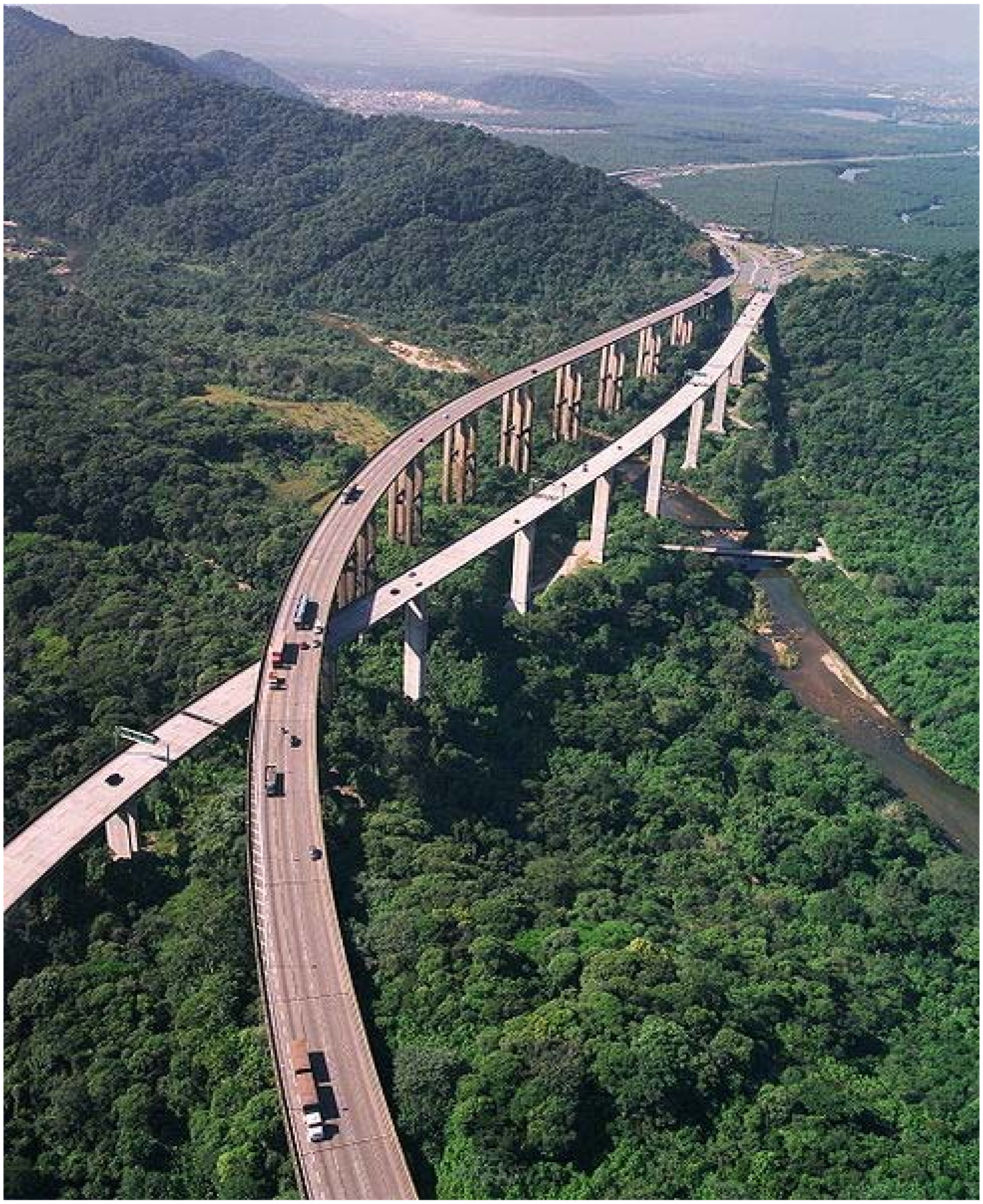
Highway



Highway 401, the busiest highway in North America.

A German Autobahn in Lehrte.

The Makran Coastal Highway was an ancient road within Pakistan. Now it's a major road leading to the city of Gwadar



The SP-160, known as Rodovia dos Imigrantes, in southeastern Brazil.

A **highway** is a public road, especially a major road connecting two or more destinations. Any interconnected set of highways can be variously referred to as a "highway system", a "highway network", or a "highway transportation system". Each country has its own national highway system. Major highways are often named and numbered by the governments that typically develop and maintain them. Australia's Highway 1 is the longest national highway in the world at over 14,500 km (9,000 miles) and runs almost the entire way around the continent. The United States has the world's largest network of highways, including both the Interstate Highway System and the U.S. Highway System. At least one of these networks is present in every state and they interconnect most major cities. Some highways, like the Pan-American Highway or the European routes, span multiple countries. Some major highway routes include ferry services, such as U.S. Route 10, which crosses Lake Michigan.

Germany is world famous to have one of the oldest and best constructed highway networks in the world. Also it's one the few public roads in the world without blanket speed limits for cars and motorcycles wich makes driving on the German 'autobahn' a unique experience but sometimes dangerous if you're not used to this way of driving.

Traditionally highways were used by people on foot or on horses. Later they also accommodated carriages, bicycles and eventually motor cars, facilitated by advancements in road construction. In the 1920s and 1930s many nations began investing heavily in progressively more modern highway systems to spur commerce and bolster national defense. Major modern highways that connect cities in populous developed and developing countries usually incorporate features intended to enhance the road's capacity, efficiency, and safety to various degrees. Such features include a reduction in the number of locations for user access, the use of dual carriageways with two or more lanes on each carriageway, and grade-separated junctions with other roads and modes of transport. These features are typically present on highways built as *motorways* (*freeways*).

Terminology

In English law, parliament and more formal situations the term is used to denote *any* public road used which include streets and lanes as well as main roads, trunk roads and motorways. Acts of parliament have used the term throughout history from the Highways Act 1555 through to the Highways Act 1980. The rules of the road are outlined in the Highway Code.

In England and Wales, a "Public Highway" is a road or footpath over which the public has the right of access, i.e. the opposite of a "private road".

In American law, the word "highway" is sometimes used to denote any public way used for travel, whether major highway, freeway, turnpike, street, lane, alley, pathway, dirt track, footpaths, and trails, and navigable waterways; however, in practical and useful meaning, a "highway" is a major and significant, well-constructed road that is capable of carrying reasonably-heavy to extremely-heavy traffic. Highways generally have a route number designated by the state and federal road comptroller offices.

California Vehicle Code, Sections 360, 590, define a "highway" as only a way open for use of motor vehicles, but the California Supreme Court has held that "the definition of 'highway' in the Vehicle Code is used for special purposes of that act," and that canals in the town of Venice, California, are "highways" that are entitled to be maintained with state highway funds.

Smaller roads may be termed byways.