



Components of Technology, Science and Infrastructure

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WWT

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WORLD TECHNOLOGIES

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Chapter- 1

Engineering



The Watt steam engine, a major driver in the Industrial Revolution, underscores the importance of engineering in modern history. This model is on display at the main building of the ETSIIM in Madrid, Spain

Engineering is the discipline, art, and profession of acquiring and applying scientific, mathematical, economic, social, and practical knowledge to design and build structures, machines, devices, systems, materials and processes that safely realize solutions to the needs of society.

The American Engineers' Council for Professional Development (ECPD, the predecessor of ABET) has defined "engineering" as:

[T]he creative application of scientific principles to design or develop structures, machines, apparatus, or manufacturing processes, or works utilizing them singly or in combination; or to construct or operate the same with full cognizance of their design; or

to forecast their behavior under specific operating conditions; all as respects an intended function, economics of operation and safety to life and property.

One who practices engineering is called an engineer, and those licensed to do so may have more formal designations such as Professional Engineer, Chartered Engineer, Incorporated Engineer, Ingenieur or European Engineer. The broad discipline of engineering encompasses a range of more specialized subdisciplines, each with a more specific emphasis on certain fields of application and particular areas of technology.

History

The *concept* of engineering has existed since ancient times as humans devised fundamental inventions such as the pulley, lever, and wheel. Each of these inventions is consistent with the modern definition of engineering, exploiting basic mechanical principles to develop useful tools and objects.

The term *engineering* itself has a much more recent etymology, deriving from the word *engineer*, which itself dates back to 1325, when an *engine'er* (literally, one who operates an *engine*) originally referred to “a constructor of military engines.” In this context, now obsolete, an “engine” referred to a military machine, *i.e.*, a mechanical contraption used in war (for example, a catapult). Notable exceptions of the obsolete usage which have survived to the present day are military engineering corps, *e.g.*, the U.S. Army Corps of Engineers.

The word “engine” itself is of even older origin, ultimately deriving from the Latin *ingenium* (c. 1250), meaning “innate quality, especially mental power, hence a clever invention.”

Later, as the design of civilian structures such as bridges and buildings matured as a technical discipline, the term civil engineering entered the lexicon as a way to distinguish between those specializing in the construction of such non-military projects and those involved in the older discipline of military engineering.

Ancient era

The Pharos of Alexandria, the pyramids in Egypt, the Hanging Gardens of Babylon, the Acropolis and the Parthenon in Greece, the Roman aqueducts, Via Appia and the Colosseum, Teotihuacán and the cities and pyramids of the Mayan, Inca and Aztec Empires, the Great Wall of China, among many others, stand as a testament to the ingenuity and skill of the ancient civil and military engineers.

The earliest civil engineer known by name is Imhotep. As one of the officials of the Pharaoh, Djoser, he probably designed and supervised the construction of the Pyramid of Djoser (the Step Pyramid) at Saqqara in Egypt around 2630-2611 BC. He may also have been responsible for the first known use of columns in architecture.

Ancient Greece developed machines in both the civilian and military domains. The Antikythera mechanism, the first known mechanical computer, and the mechanical inventions of Archimedes are examples of early mechanical engineering. Some of Archimedes' inventions as well as the Antikythera mechanism required sophisticated knowledge of differential gearing or epicyclic gearing, two key principles in machine theory that helped design the gear trains of the Industrial revolution, and are still widely used today in diverse fields such as robotics and automotive engineering.

Chinese, Greek and Roman armies employed complex military machines and inventions such as artillery which was developed by the Greeks around the 4th century B.C., the trireme, the ballista and the catapult. In the Middle Ages, the Trebuchet was developed.

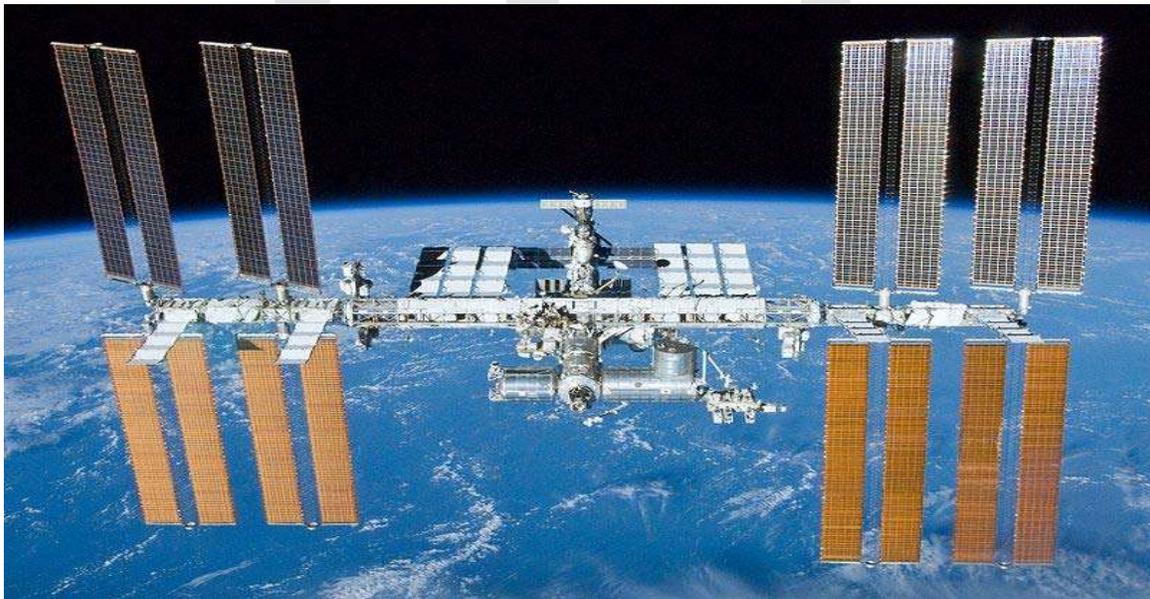
Renaissance era

The first electrical engineer is considered to be William Gilbert, with his 1600 publication of *De Magnete*, who was the originator of the term "electricity".

The first steam engine was built in 1698 by mechanical engineer Thomas Savery. The development of this device gave rise to the industrial revolution in the coming decades, allowing for the beginnings of mass production.

With the rise of engineering as a profession in the eighteenth century, the term became more narrowly applied to fields in which mathematics and science were applied to these ends. Similarly, in addition to military and civil engineering the fields then known as the mechanic arts became incorporated into engineering.

Modern era



The International Space Station represents a modern engineering challenge from many disciplines.

Electrical engineering can trace its origins in the experiments of Alessandro Volta in the 1800s, the experiments of Michael Faraday, Georg Ohm and others and the invention of the electric motor in 1872. The work of James Maxwell and Heinrich Hertz in the late 19th century gave rise to the field of Electronics. The later inventions of the vacuum tube and the transistor further accelerated the development of electronics to such an extent that electrical and electronics engineers currently outnumber their colleagues of any other Engineering specialty.

The inventions of Thomas Savery and the Scottish engineer James Watt gave rise to modern Mechanical Engineering. The development of specialized machines and their maintenance tools during the industrial revolution led to the rapid growth of Mechanical Engineering both in its birthplace Britain and abroad.

Chemical Engineering, like its counterpart Mechanical Engineering, developed in the nineteenth century during the Industrial Revolution. Industrial scale manufacturing demanded new materials and new processes and by 1880 the need for large scale production of chemicals was such that a new industry was created, dedicated to the development and large scale manufacturing of chemicals in new industrial plants. The role of the chemical engineer was the design of these chemical plants and processes.

Aeronautical Engineering deals with aircraft design while Aerospace Engineering is a more modern term that expands the reach envelope of the discipline by including spacecraft design. Its origins can be traced back to the aviation pioneers around the turn of the century from the 19th century to the 20th although the work of Sir George Cayley has recently been dated as being from the last decade of the 18th century. Early knowledge of aeronautical engineering was largely empirical with some concepts and skills imported from other branches of engineering.

The first PhD in engineering (technically, *applied science and engineering*) awarded in the United States went to Willard Gibbs at Yale University in 1863; it was also the second PhD awarded in science in the U.S.

Only a decade after the successful flights by the Wright brothers, the 1920s saw extensive development of aeronautical engineering through development of World War I military aircraft. Meanwhile, research to provide fundamental background science continued by combining theoretical physics with experiments.

In 1990, with the rise of computer technology, the first search engine was built by computer engineer Alan Emtage.

Main branches of engineering

Engineering, much like other science, is a broad discipline which is often broken down into several sub-disciplines. These disciplines concern themselves with differing areas of engineering work. Although initially an engineer will usually be trained in a specific discipline, throughout an engineer's career the engineer may become multi-disciplined,

having worked in several of the outlined areas. Engineering is often characterized as having four main branches:

- Chemical engineering – The exploitation of chemical principles in order to carry out large scale chemical process, as well as designing new specialty materials and fuels.
- Civil engineering – The design and construction of public and private works, such as infrastructure (roads, railways, water supply and treatment etc.), bridges and buildings.
- Electrical engineering – a very broad area that may encompass the design and study of various electrical & electronic systems, such as electrical circuits, generators, motors, electromagnetic/electromechanical devices, electronic devices, electronic circuits, optical fibers, optoelectronic devices, computer systems, telecommunications and electronics.
- Mechanical engineering – The design of physical or mechanical systems, such as power and energy systems, aerospace/aircraft products, weapon systems, transportation products engines, compressors, powertrains, kinematic chains, vacuum technology, and vibration isolation equipment.

Beyond these four, sources vary on other main branches. Historically, naval engineering and mining engineering were major branches. Modern fields sometimes included as major branches include industrial, aerospace, architectural, and nuclear engineering.

New specialties sometimes combine with the traditional fields and form new branches. A new or emerging area of application will commonly be defined temporarily as a permutation or subset of existing disciplines; there is often gray area as to when a given sub-field becomes large and/or prominent enough to warrant classification as a new "branch." One key indicator of such emergence is when major universities start establishing departments and programs in the new field.

For each of these fields there exists considerable overlap, especially in the areas of the application of sciences to their disciplines such as physics, chemistry and mathematics.

If multiple options exist, engineers weigh different design choices on their merits and choose the solution that best matches the requirements. The crucial and unique task of the engineer is to identify, understand, and interpret the constraints on a design in order to produce a successful result. It is usually not enough to build a technically successful product; it must also meet further requirements.

Constraints may include available resources, physical, imaginative or technical limitations, flexibility for future modifications and additions, and other factors, such as requirements for cost, safety, marketability, productibility, and serviceability. By understanding the constraints, engineers derive specifications for the limits within which a viable object or system may be produced and operated.

Problem solving

Engineers use their knowledge of science, mathematics, logic, economics, and appropriate experience or tacit knowledge to find suitable solutions to a problem. Creating an appropriate mathematical model of a problem allows them to analyze it (sometimes definitively), and to test potential solutions.

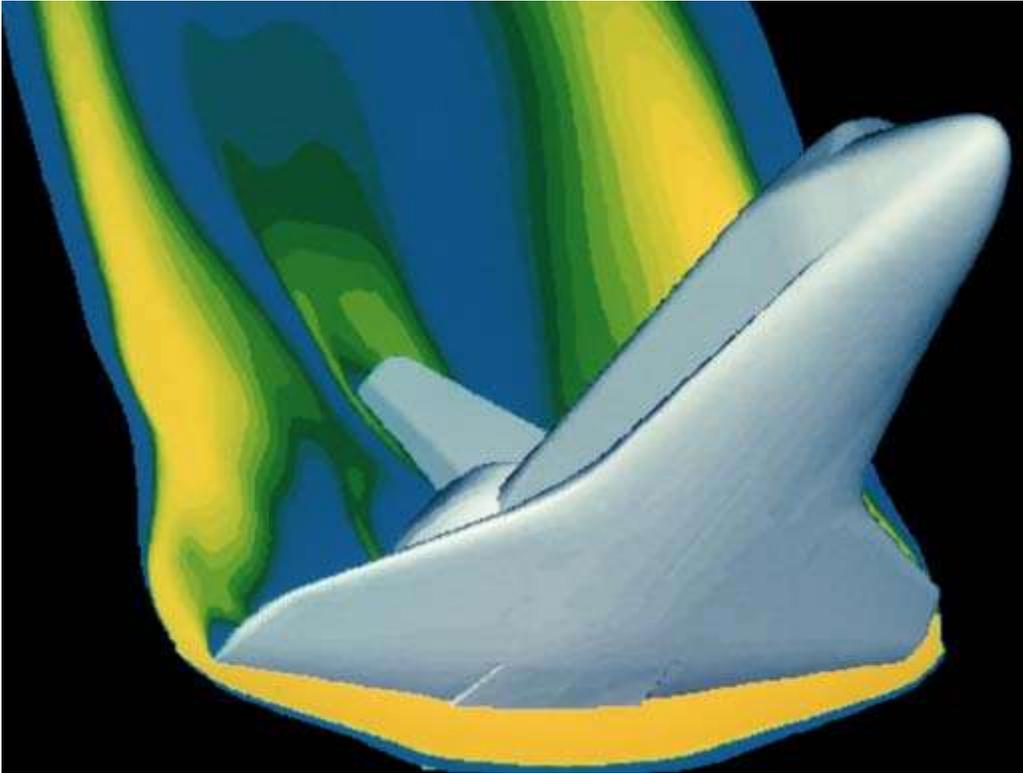
Usually multiple reasonable solutions exist, so engineers must evaluate the different design choices on their merits and choose the solution that best meets their requirements. Genrich Altshuller, after gathering statistics on a large number of patents, suggested that compromises are at the heart of "low-level" engineering designs, while at a higher level the best design is one which eliminates the core contradiction causing the problem.

Engineers typically attempt to predict how well their designs will perform to their specifications prior to full-scale production. They use, among other things: prototypes, scale models, simulations, destructive tests, nondestructive tests, and stress tests. Testing ensures that products will perform as expected.

Engineers as professionals take seriously their responsibility to produce designs that will perform as expected and will not cause unintended harm to the public at large. Engineers typically include a factor of safety in their designs to reduce the risk of unexpected failure. However, the greater the safety factor, the less efficient the design may be.

The study of failed products is known as forensic engineering, and can help the product designer in evaluating his or her design in the light of real conditions. The discipline is of greatest value after disasters, such as bridge collapses, when careful analysis is needed to establish the cause or causes of the failure.

Computer use



High velocity air flow around the Space Shuttle during re-entry. Solutions to the flow require modelling of the combined effects of the fluid flow and heat equations.

As with all modern scientific and technological endeavors, computers and software play an increasingly important role. As well as the typical business application software there are a number of computer aided applications (Computer-aided technologies) specifically for engineering. Computers can be used to generate models of fundamental physical processes, which can be solved using numerical methods.

One of the most widely used tools in the profession is computer-aided design (CAD) software which enables engineers to create 3D models, 2D drawings, and schematics of their designs. CAD together with Digital mockup (DMU) and CAE software such as finite element method analysis or analytic element method allows engineers to create models of designs that can be analyzed without having to make expensive and time-consuming physical prototypes.

These allow products and components to be checked for flaws; assess fit and assembly; study ergonomics; and to analyze static and dynamic characteristics of systems such as stresses, temperatures, electromagnetic emissions, electrical currents and voltages, digital logic levels, fluid flows, and kinematics. Access and distribution of all this information is generally organized with the use of Product Data Management software.

There are also many tools to support specific engineering tasks such as Computer-aided manufacture (CAM) software to generate CNC machining instructions; Manufacturing Process Management software for production engineering; EDA for printed circuit board (PCB) and circuit schematics for electronic engineers; MRO applications for maintenance management; and AEC software for civil engineering.

In recent years the use of computer software to aid the development of goods has collectively come to be known as Product Lifecycle Management (PLM).

Social context

Engineering is a subject that ranges from large collaborations to small individual projects. Almost all engineering projects are beholden to some sort of financing agency: a company, a set of investors, or a government. The few types of engineering that are minimally constrained by such issues are pro bono engineering and open design engineering.

By its very nature engineering is bound up with society and human behavior. Every product or construction used by modern society will have been influenced by engineering design. Engineering design is a very powerful tool to make changes to environment, society and economies, and its application brings with it a great responsibility. Many engineering societies have established codes of practice and codes of ethics to guide members and inform the public at large.

Engineering projects can be subject to controversy. Examples from different engineering disciplines include the development of nuclear weapons, the Three Gorges Dam, the design and use of Sport utility vehicles and the extraction of oil. In response, some western engineering companies have enacted serious corporate and social responsibility policies.

Engineering is a key driver of human development. Sub-Saharan Africa in particular has a very small engineering capacity which results in many African nations being unable to develop crucial infrastructure without outside aid. The attainment of many of the Millennium Development Goals requires the achievement of sufficient engineering capacity to develop infrastructure and sustainable technological development.

All overseas development and relief NGOs make considerable use of engineers to apply solutions in disaster and development scenarios. A number of charitable organizations aim to use engineering directly for the good of mankind:

- Engineers Without Borders
- Engineers Against Poverty
- Registered Engineers for Disaster Relief
- Engineers for a Sustainable World

Relationships with other disciplines

Science

Scientists study the world as it is; engineers create the world that has never been.

—Theodore von Kármán



Bioreactors for producing proteins, NRC Biotechnology Research Institute, Montréal, Canada

There exists an overlap between the sciences and engineering practice; in engineering, one applies science. Both areas of endeavor rely on accurate observation of materials and phenomena. Both use mathematics and classification criteria to analyze and communicate observations.

Scientists are expected to interpret their observations and to make expert recommendations for practical action based on those interpretations. Scientists may also have to complete engineering tasks, such as designing experimental apparatus or building prototypes. Conversely, in the process of developing technology engineers sometimes find themselves exploring new phenomena, thus becoming, for the moment, scientists.

In the book *What Engineers Know and How They Know It*, Walter Vincenti asserts that engineering research has a character different from that of scientific research. First, it often deals with areas in which the basic physics and/or chemistry are well understood, but the problems themselves are too complex to solve in an exact manner.

Examples are the use of numerical approximations to the Navier-Stokes equations to describe aerodynamic flow over an aircraft, or the use of Miner's rule to calculate fatigue damage. Second, engineering research employs many semi-empirical methods that are foreign to pure scientific research, one example being the method of parameter variation.

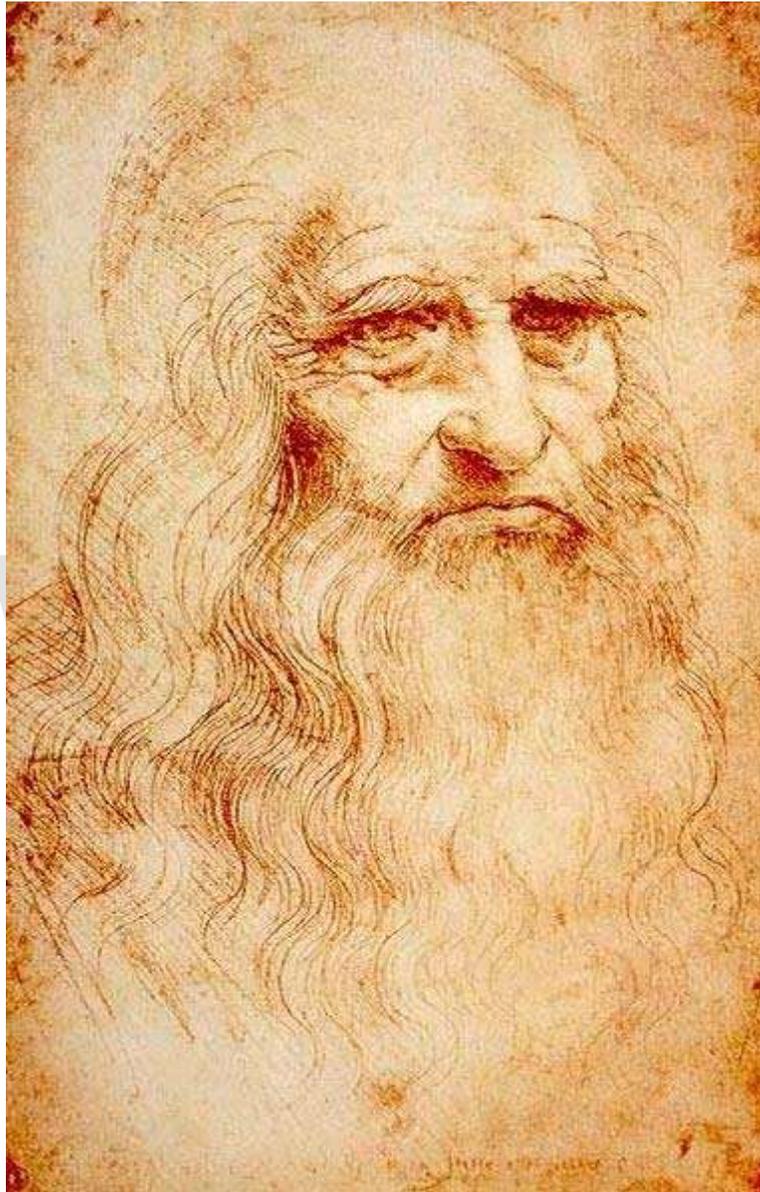
As stated by Fung et al. in the revision to the classic engineering text, *Foundations of Solid Mechanics*:

"Engineering is quite different from science. Scientists try to understand nature. Engineers try to make things that do not exist in nature. Engineers stress invention. To embody an invention the engineer must put his idea in concrete terms, and design something that people can use. That something can be a device, a gadget, a material, a method, a computing program, an innovative experiment, a new solution to a problem, or an improvement on what is existing. Since a design has to be concrete, it must have its geometry, dimensions, and characteristic numbers. Almost all engineers working on new designs find that they do not have all the needed information. Most often, they are limited by insufficient scientific knowledge. Thus they study mathematics, physics, chemistry, biology and mechanics. Often they have to add to the sciences relevant to their profession. Thus engineering sciences are born."

Although engineering solutions make use of scientific principles, engineers must also take into account safety, efficiency, economy, reliability and constructibility or ease of fabrication, as well as legal considerations such as patent infringement or liability in the case of failure of the solution.

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Medicine and biology



Leonardo da Vinci, seen here in a self-portrait, has been described as the epitome of the artist/engineer. He is also known for his studies on human anatomy and physiognomy

The study of the human body, albeit from different directions and for different purposes, is an important common link between medicine and some engineering disciplines. Medicine aims to sustain, enhance and even replace functions of the human body, if necessary, through the use of technology.

Modern medicine can replace several of the body's functions through the use of artificial organs and can significantly alter the function of the human body through artificial devices such as, for example, brain implants and pacemakers. The fields of Bionics and

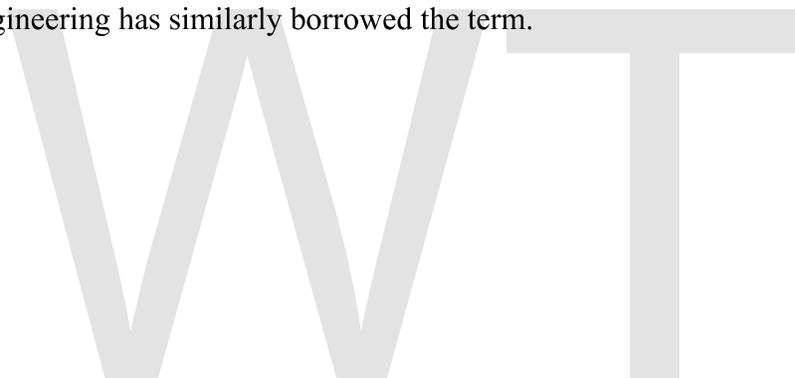
that these disciplines may sometimes be included in a University's Faculty of Engineering); and indirect in others.

The Art Institute of Chicago, for instance, held an exhibition about the art of NASA's aerospace design. Robert Maillart's bridge design is perceived by some to have been deliberately artistic. At the University of South Florida, an engineering professor, through a grant with the National Science Foundation, has developed a course that connects art and engineering.

Among famous historical figures Leonardo Da Vinci is a well known Renaissance artist and engineer, and a prime example of the nexus between art and engineering.

Other fields

In Political science the term *engineering* has been borrowed for the study of the subjects of Social engineering and Political engineering, which deal with forming political and social structures using engineering methodology coupled with political science principles. Financial engineering has similarly borrowed the term.



Chapter- 2

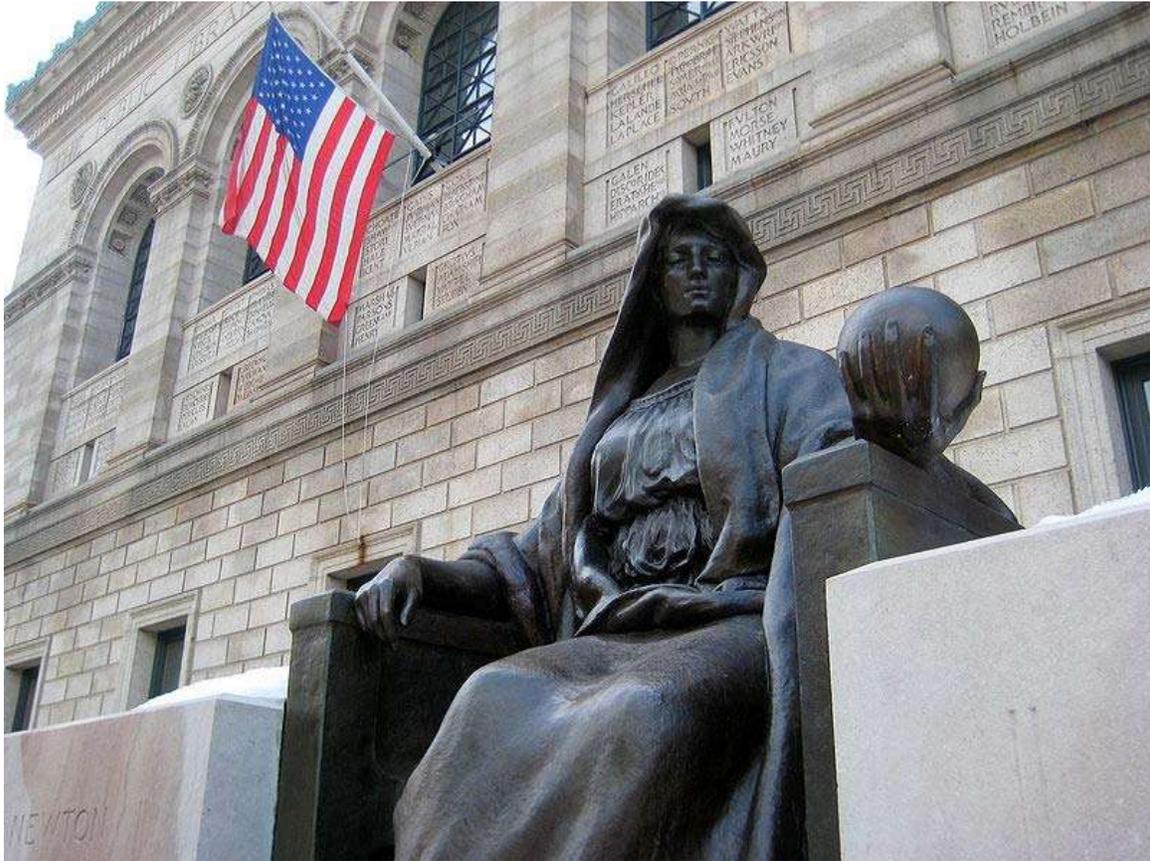
Science

Science (from the Latin *scientia*, meaning "knowledge") is an enterprise that builds and organizes knowledge in the form of testable explanations and predictions about the world. An older meaning still in use today is that of Aristotle, for whom scientific knowledge was a body of reliable knowledge that can be logically and rationally explained.

Since classical antiquity science as a type of knowledge was closely linked to philosophy. In early modern times the two words, "science" and "philosophy", were sometimes used interchangeably in the English language. By the 17th century, "natural philosophy" (which is today called "natural science") could be considered separately from "philosophy" in general. However, "science" continued to be used in a broad sense denoting reliable knowledge about a topic, in the same way it is still used in modern terms such as library science or political science.

Science is "[i]n modern use, often treated as synonymous with 'Natural and Physical Science', and thus restricted to those branches of study that relate to the phenomena of the material universe and their laws, sometimes with implied exclusion of pure mathematics. This is now the dominant sense in ordinary use." This narrower sense of "science" developed as a part of science became a distinct enterprise of defining "laws of nature", based on early examples such as Kepler's laws, Galileo's laws, and Newton's laws of motion. In this period it became more common to refer to natural philosophy as "natural science". Over the course of the 19th century, the word "science" became increasingly associated with the disciplined study of the natural world including physics, chemistry, geology and biology. This sometimes left the study of human thought and society in a linguistic limbo, which was resolved by classifying these areas of academic study as social science. Similarly, several other major areas of disciplined study and knowledge exist today under the general rubric of "science", such as formal science and applied science.

History and etymology



Personification of "Science" in front of the Boston Public Library

"It is widely accepted that 'modern science' arose in the Europe of the 17th century (towards the end of the Renaissance), introducing a new understanding of the natural world."

While descriptions of disciplined empirical investigations of the natural world exist from times at least as early as classical antiquity (for example, by Aristotle and Pliny the Elder), and scientific methods have been employed since the Middle Ages (for example, by Alhazen and Roger Bacon), the dawn of modern science is generally traced back to the early modern period during what is known as the Scientific Revolution of the 16th and 17th centuries. This period was marked by a new way of studying the natural world, by methodical experimentation aimed at defining "laws of nature" while avoiding concerns with metaphysical concerns such as Aristotle's theory of causation.

This modern science developed from an older and broader enterprise. The word "science" is from Old French, and in turn from Latin *scientia* which was one of several words for "knowledge" in that language. In philosophical contexts, *scientia* and "science" were used to translate the Greek word *epistemē*, which had acquired a specific definition in Greek

philosophy, especially Aristotle, as a type of reliable knowledge which is built up logically from strong premises, and can be communicated and taught. In contrast to modern science, Aristotle's influential emphasis was upon the "theoretical" steps of deducing universal rules from raw data, and did not treat the gathering of experience and raw data as part of science itself.

From the Middle Ages to the Enlightenment, science or *scientia* continued to be used in this broad sense, which was still common until the 20th century. "Science" therefore had the same sort of very broad meaning that *philosophy* had at that time. In other Latin influenced languages, including French, Spanish, Portuguese, and Italian, the word corresponding to *science* also carried this meaning.

Prior to the 18th century, the preferred term for the study of nature among English speakers was "natural philosophy", while other philosophical disciplines (e.g., logic, metaphysics, epistemology, ethics and aesthetics) were typically referred to as "moral philosophy". (Today, "moral philosophy" is more-or-less synonymous with "ethics".) Science only became more strongly associated with natural philosophy than other sciences gradually with the strong promotion of the importance of experimental scientific method, by people such as Francis Bacon. With Bacon, begins a more widespread and open criticism of Aristotle's influence which had emphasized theorizing and did not treat raw data collection as part of science itself. An opposed position became common: that what is critical to science at its best is methodical collecting of clear and useful raw data, something which is easier to do in some fields than others.

The word "science" in English was still however used in the 17th century to refer to the Aristotelian concept of knowledge which was secure enough to be used as a prescription for exactly how to accomplish a specific task. With respect to the transitional usage of the term "natural philosophy" in this period, the philosopher John Locke wrote in 1690 that "natural philosophy is not capable of being made a science". However, it may be that Locke was not using the word 'science' in the modern sense, but suggesting that 'natural philosophy' could not be deduced in the same way as mathematics and logic.

Locke's assertion notwithstanding, by the early 19th century natural philosophy had begun to separate from philosophy, though it often retained a very broad meaning. In many cases, *science* continued to stand for reliable knowledge about any topic, in the same way it is still used today in the broad sense in modern terms such as library science, political science, and computer science. In the more narrow sense of *science*, as natural philosophy became linked to an expanding set of well-defined laws (beginning with Galileo's laws, Kepler's laws, and Newton's laws for motion), it became more popular to refer to natural philosophy as natural science. Over the course of the 19th century, moreover, there was an increased tendency to associate science with study of the natural world (that is, the non-human world). This move sometimes left the study of human thought and society (what would come to be called social science) in a linguistic limbo by the end of the century and into the next.

Through the 19th century, many English speakers were increasingly differentiating science (i.e., the natural sciences) from all other forms of knowledge in a variety of ways. The now-familiar expression “scientific method,” which refers to the *prescriptive* part of how to make discoveries in natural philosophy, was almost unused until then, but became widespread after the 1870s, though there was rarely total agreement about just what it entailed. The word “scientist,” meant to refer to a systematically working natural philosopher, (as opposed to an intuitive or empirically minded one) was coined in 1833 by William Whewell. Discussion of scientists as a special group of people who did science, even if their attributes were up for debate, grew in the last half of the 19th century. Whatever people actually meant by these terms at first, they ultimately depicted science, in the narrow sense of the habitual use of the scientific method and the knowledge derived from it, as something deeply distinguished from all other realms of human endeavor.

By the 20th century, the modern notion of science as a special kind of knowledge about the world, practiced by a distinct group and pursued through a unique method, was essentially in place. It was used to give legitimacy to a variety of fields through such titles as “scientific” medicine, engineering, advertising, or motherhood. Over the 20th century, links between science and technology also grew increasingly strong. As Martin Rees explains, progress in scientific understanding and technology have been synergistic and vital to one another.

Richard Feynman described science in the following way for his students: “The principle of science, the definition, almost, is the following: *The test of all knowledge is experiment*. Experiment is the *sole judge* of scientific ‘truth’. But what is the source of knowledge? Where do the laws that are to be tested come from? Experiment, itself, helps to produce these laws, in the sense that it gives us hints. But also needed is imagination to create from these hints the great generalizations — to guess at the wonderful, simple, but very strange patterns beneath them all, and then to experiment to check again whether we have made the right guess.” Feynman also observed, “...there is an expanding frontier of ignorance...things must be learned only to be unlearned again or, more likely, to be corrected.”

Basic classifications

Scientific fields are commonly divided into two major groups: natural sciences, which study natural phenomena (including biological life), and social sciences, which study human behavior and societies. These groupings are empirical sciences, which means the knowledge must be based on observable phenomena and capable of being tested for its validity by other researchers working under the same conditions. There are also related disciplines that are grouped into interdisciplinary and applied sciences, such as engineering and medicine. Within these categories are specialized scientific fields that can include parts of other scientific disciplines but often possess their own terminology and expertise.

Mathematics, which is classified as a formal science, has both similarities and differences with the empirical sciences (the natural and social sciences). It is similar to empirical sciences in that it involves an objective, careful and systematic study of an area of knowledge; it is different because of its method of verifying its knowledge, using *a priori* rather than empirical methods. Formal science, which also includes statistics and logic, is vital to the empirical sciences. Major advances in formal science have often led to major advances in the empirical sciences. The formal sciences are essential in the formation of hypotheses, theories, and laws, both in discovering and describing how things work (natural sciences) and how people think and act (social sciences).

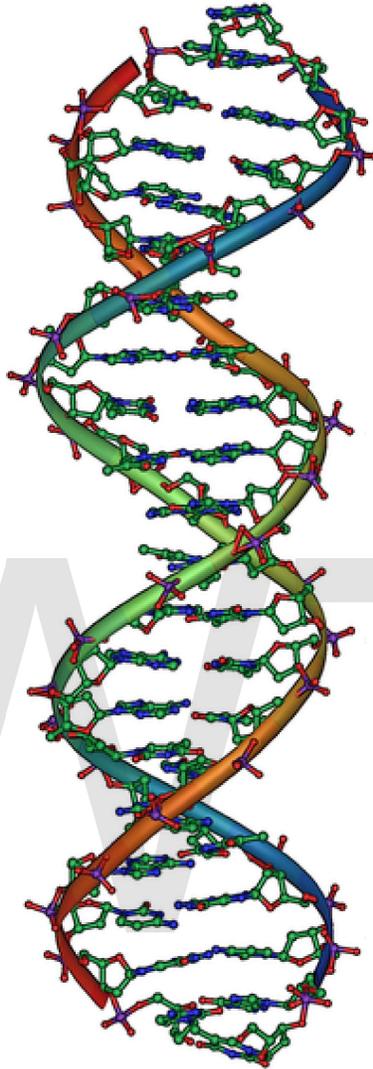
Scientific method

A scientific method seeks to explain the events of nature in a reproducible way, and to use these findings to make useful predictions. This is done partly through observation of natural phenomena, but also through experimentation that tries to simulate natural events under controlled conditions. Taken in its entirety, a scientific method allows for highly creative problem solving whilst minimizing any effects of subjective bias on the part of its users (namely the confirmation bias).

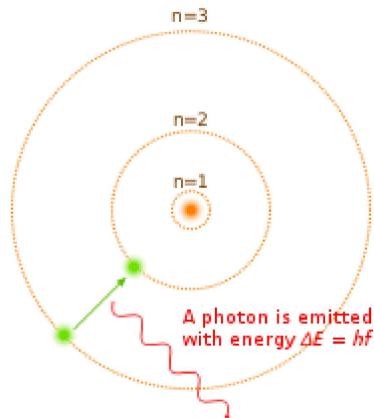
Basic and applied research

Although some scientific research is applied research into specific problems, a great deal of our understanding comes from the curiosity-driven undertaking of basic research. This leads to options for technological advance that were not planned or sometimes even imaginable. This point was made by Michael Faraday when, allegedly in response to the question "what is the *use* of basic research?" he responded "Sir, what is the use of a newborn child?". For example, research into the effects of red light on the human eye's rod cells did not seem to have any practical purpose; eventually, the discovery that our night vision is not troubled by red light would lead militaries to adopt red light in the cockpits of all jet fighters. In a nutshell: Basic research is the search for knowledge. Applied research is the search for solutions to practical problems using this knowledge.

Experimentation and hypothesizing



DNA determines the genetic structure of all known life



The Bohr model of the atom, like many ideas in the history of science, was at first prompted by (and later partially disproved by) experimentation.

Based on observations of a phenomenon, scientists may generate a model. (The models need not be completely abstract: when modeling, the problems can be simplified — strings joining masses may be modeled as unstretchable, as in a metallic wire, or perhaps be modeled with noticeable mass, as in a dog chain. Once a mathematical solution is known, it can be re-used elsewhere in science.) This is an attempt to describe or depict the phenomenon in terms of a logical physical or mathematical representation. As empirical evidence is gathered, scientists can suggest a hypothesis to explain the phenomenon. Hypotheses may be formulated using principles such as parsimony (traditionally known as "Occam's Razor") and are generally expected to seek consilience - fitting well with other accepted facts related to the phenomena. This new explanation is used to make falsifiable predictions that are testable by experiment or observation. When a hypothesis proves unsatisfactory, it is either modified or discarded. Experimentation is especially important in science to help establish a causal relationship (to avoid the correlation fallacy). Operationalization also plays an important role in coordinating research in/across different fields.

Once a hypothesis has survived testing, it may become adopted into the framework of a scientific theory. This is a logically reasoned, self-consistent model or framework for describing the behavior of certain natural phenomena. A theory typically describes the behavior of much broader sets of phenomena than a hypothesis; commonly, a large number of hypotheses can be logically bound together by a single theory. Thus a theory is a hypothesis explaining various other hypotheses. In that vein, theories are formulated according to most of the same scientific principles as hypotheses.

While performing experiments, scientists may have a preference for one outcome over another, and so it is important to ensure that science as a whole can eliminate this bias. This can be achieved by careful experimental design, transparency, and a thorough peer review process of the experimental results as well as any conclusions. After the results of an experiment are announced or published, it is normal practice for independent researchers to double-check how the research was performed, and to follow up by performing similar experiments to determine how dependable the results might be.

Certainty and science

A scientific theory is empirical, and is always open to falsification if new evidence is presented. That is, no theory is ever considered strictly certain as science accepts the concept of fallibilism. The philosopher of science Karl Popper sharply distinguishes truth from certainty. He writes that scientific knowledge "consists in the search for truth", but it "is not the search for certainty ... All human knowledge is fallible and therefore uncertain."



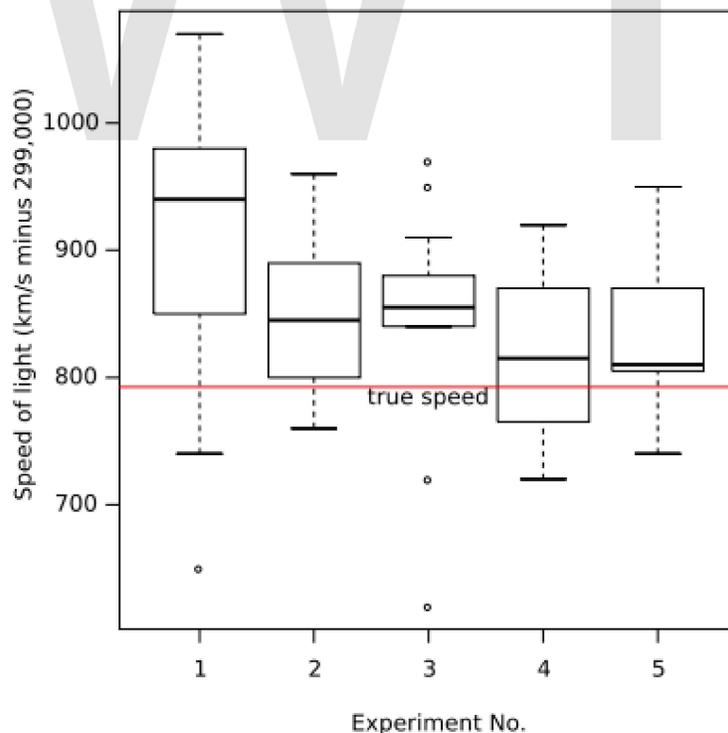
Although science values legitimate doubt, The Flat Earth Society is still widely regarded as an example of taking skepticism too far

Theories very rarely result in vast changes in our understanding. According to psychologist Keith Stanovich, it may be the media's overuse of words like "breakthrough" that leads the public to imagine that science is constantly proving everything it thought was true to be false. While there are such famous cases as the theory of relativity that required a complete reconceptualization, these are extreme exceptions. Knowledge in science is gained by a gradual synthesis of information from different experiments, by various researchers, across different domains of science; it is more like a climb than a leap. Theories vary in the extent to which they have been tested and verified, as well as their acceptance in the scientific community. For example, heliocentric theory, the theory of evolution, and germ theory still bear the name "theory" even though, in practice, they are considered factual.

Philosopher Barry Stroud adds that, although the best definition for "knowledge" is contested, being skeptical and entertaining the *possibility* that one is incorrect is compatible with being correct. Ironically then, the scientist adhering to proper scientific method will doubt themselves even once they possess the truth. The fallibilist C. S. Peirce argued that inquiry is the struggle to resolve actual doubt and that merely quarrelsome, verbal, or hyperbolic doubt is fruitless—but also that the inquirer should try to attain genuine doubt rather than resting uncritically on common sense. He held that the successful sciences trust, not to any single chain of inference (no stronger than its weakest link), but to the cable of multiple and various arguments intimately connected.

Stanovich also asserts that science avoids searching for a "magic bullet"; it avoids the single cause fallacy. This means a scientist would not ask merely "What is *the* cause of...", but rather "What *are* the most significant *causes* of...". This is especially the case in the more macroscopic fields of science (e.g. psychology, cosmology). Of course, research often analyzes few factors at once, but this always to add to the long list of factors that are most important to consider. For example: knowing the details of only a person's genetics, or their history and upbringing, or the current situation may not explain a behaviour, but a deep understanding of all these variables combined can be very predictive.

Mathematics



Data from the famous Michelson–Morley experiment

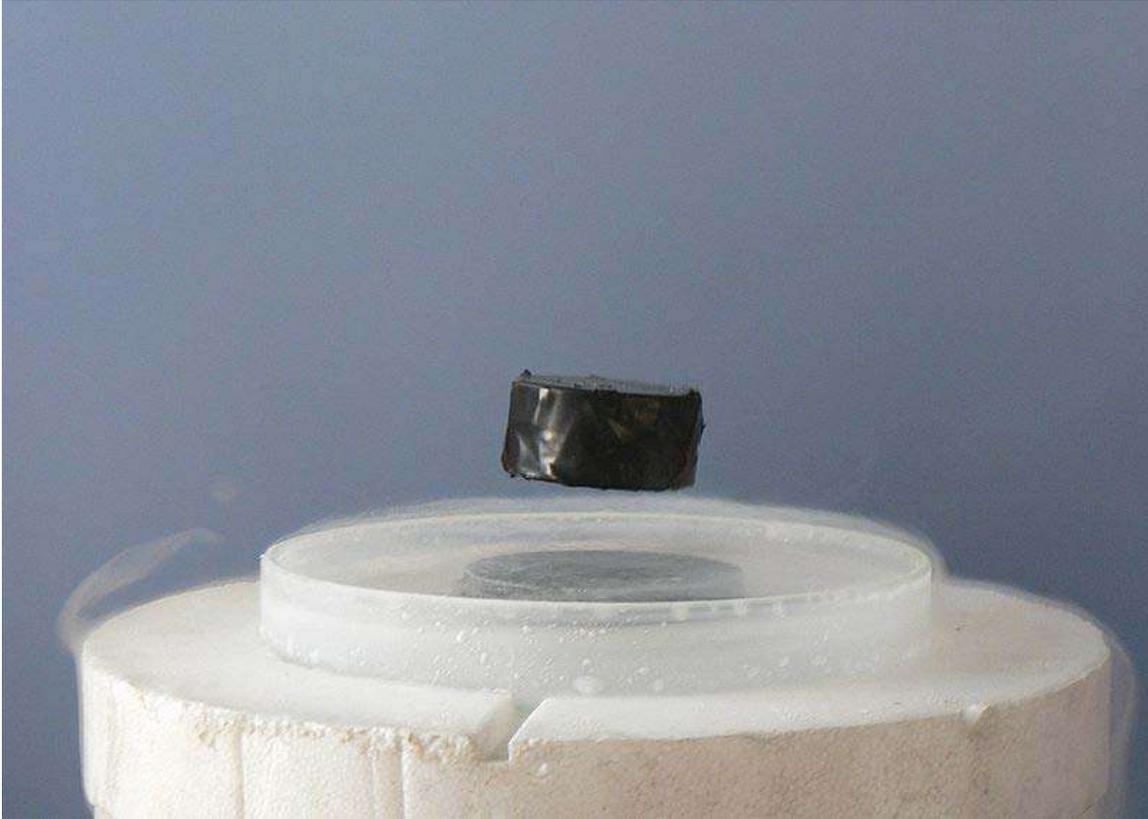
Mathematics is essential to the sciences. One important function of mathematics in science is the role it plays in the expression of scientific *models*. Observing and collecting measurements, as well as hypothesizing and predicting, often require extensive use of mathematics. Arithmetic, algebra, geometry, trigonometry and calculus, for example, are all essential to physics. Virtually every branch of mathematics has applications in science, including "pure" areas such as number theory and topology.

Statistical methods, which are mathematical techniques for summarizing and analyzing data, allow scientists to assess the level of reliability and the range of variation in experimental results. Statistical analysis plays a fundamental role in many areas of both the natural sciences and social sciences.

Computational science applies computing power to simulate real-world situations, enabling a better understanding of scientific problems than formal mathematics alone can achieve. According to the Society for Industrial and Applied Mathematics, computation is now as important as theory and experiment in advancing scientific knowledge.

Whether mathematics itself is properly classified as science has been a matter of some debate. Some thinkers see mathematicians as scientists, regarding physical experiments as inessential or mathematical proofs as equivalent to experiments. Others do not see mathematics as a science, since it does not require an experimental test of its theories and hypotheses. Mathematical theorems and formulas are obtained by logical derivations which presume axiomatic systems, rather than the combination of empirical observation and logical reasoning that has come to be known as scientific method. In general, mathematics is classified as formal science, while natural and social sciences are classified as empirical sciences.

Scientific community



The Meissner effect causes a magnet to levitate above a superconductor

The scientific community consists of the total body of scientists, its relationships and interactions. It is normally divided into "sub-communities" each working on a particular field within science.

Fields

Fields of science are widely recognized categories of specialized expertise, and typically embody their own terminology and nomenclature. Each field will commonly be represented by one or more scientific journal, where peer reviewed research will be published.

Institutions



Louis XIV visiting the Académie des sciences in 1671

Learned societies for the communication and promotion of scientific thought and experimentation have existed since the Renaissance period. The oldest surviving institution is the *Accademia dei Lincei* in Italy. The respective National Academies of Science are distinguished institutions that exist in a number of countries, beginning with the British Royal Society in 1660 and the French *Académie des Sciences* in 1666.

International scientific organizations, such as the International Council for Science, have since been formed to promote cooperation between the scientific communities of

different nations. More recently, influential government agencies have been created to support scientific research, including the National Science Foundation in the U.S.

Other prominent organizations include the National Scientific and Technical Research Council in Argentina, the academies of science of many nations, CSIRO in Australia, Centre national de la recherche scientifique in France, Max Planck Society and Deutsche Forschungsgemeinschaft in Germany, and in Spain, CSIC.

Literature

An enormous range of scientific literature is published. Scientific journals communicate and document the results of research carried out in universities and various other research institutions, serving as an archival record of science. The first scientific journals, *Journal des Sçavans* followed by the *Philosophical Transactions*, began publication in 1665. Since that time the total number of active periodicals has steadily increased. As of 1981, one estimate for the number of scientific and technical journals in publication was 11,500. Today Pubmed lists almost 40,000, related to the medical sciences only.

Most scientific journals cover a single scientific field and publish the research within that field; the research is normally expressed in the form of a scientific paper. Science has become so pervasive in modern societies that it is generally considered necessary to communicate the achievements, news, and ambitions of scientists to a wider populace.

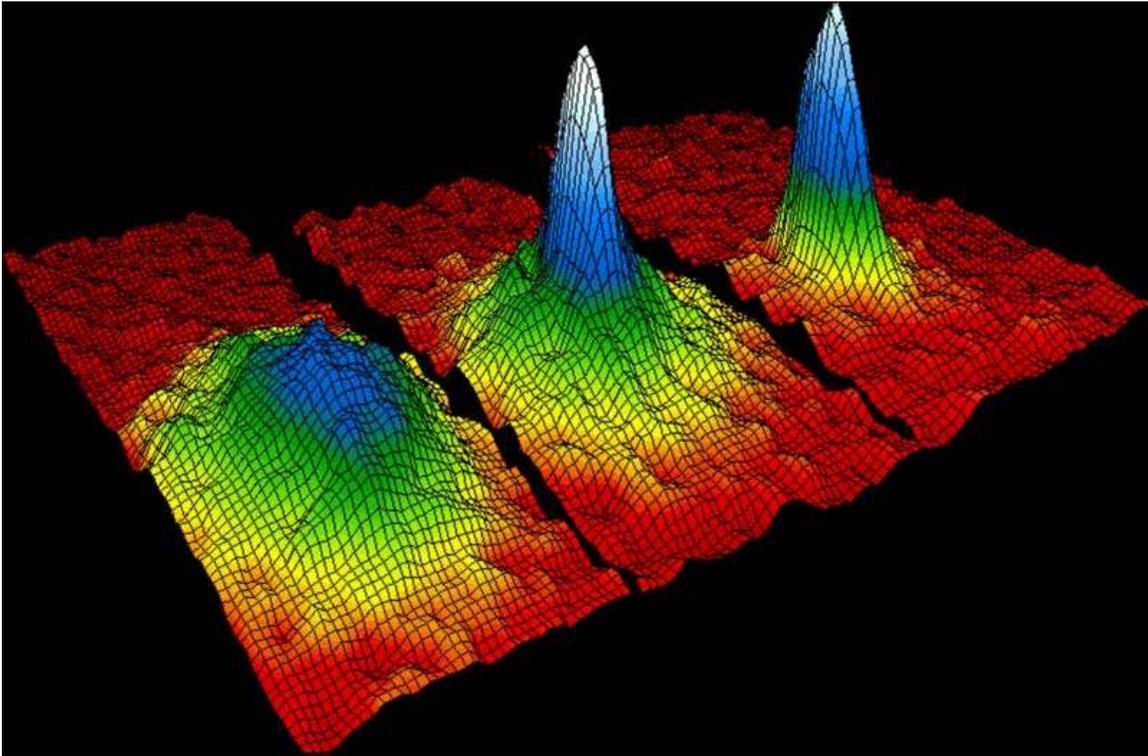
Science magazines such as *New Scientist*, *Science & Vie* and *Scientific American* cater to the needs of a much wider readership and provide a non-technical summary of popular areas of research, including notable discoveries and advances in certain fields of research. Science books engage the interest of many more people. Tangentially, the science fiction genre, primarily fantastic in nature, engages the public imagination and transmits the ideas, if not the methods, of science.

Recent efforts to intensify or develop links between science and non-scientific disciplines such as Literature or, more specifically, Poetry, include the *Creative Writing Science* resource developed through the Royal Literary Fund.

Women in science

Science is, in general, a male-dominated field. Evidence suggests that this is *not* because women are inferior scientists, but rather because of stereotypes (e.g. science as "manly") as well as self-fulfilling prophecies. A case in point: experiments have shown that parents challenge and explain more to boys than girls, asking them to reflect more deeply and logically. Physicist Evelyn Fox Keller adds that science may even suffer for its manly stereotypes when ego and competitiveness obstruct progress, since these tendencies prevent collaboration and the sharing of information.

Philosophy of science



Velocity-distribution data of a gas of rubidium atoms, confirming the discovery of a new phase of matter, the Bose–Einstein condensate

The philosophy of science seeks to understand the nature and justification of scientific knowledge. It has proven difficult to provide a definitive account of scientific method that can decisively serve to distinguish science from non-science. Thus there are legitimate arguments about exactly where the borders are, which is known as the problem of demarcation. There is nonetheless a set of core precepts that have broad consensus among published philosophers of science and within the scientific community at large. For example, it is generally agreed that scientific hypotheses and theories must be capable of being independently tested and verified by other scientists in order to become accepted by the scientific community.

There are different schools of thought in the philosophy of scientific method. The most popular position is empiricism, which claims that knowledge is created by a process involving observation and that hence scientific theories are the result of generalizations from observation. Empiricism generally encompasses inductivism, a position that tries to explain the way general theories can be justified by the finite number of observations humans can make and the hence finite amount of empirical evidence available to confirm scientific theories. This is necessary because the number of predictions those theories make is infinite, which means that they cannot be known from the finite amount of evidence using deductive logic only. It has been a long running matter of philosophical

debate whether such positions require metaphysical assumptions about the structure of the world that themselves cannot be justified in a scientific way, and whether that poses a problem for science or not. Biologist Stephen J. Gould, for example, maintained that 1) uniformity of law and 2) uniformity of processes across time and space must first be assumed by anyone who wants to do science as a scientist. Gould summarized this view as follows:

The assumption of spatial and temporal invariance of natural laws is by no means unique to geology since it amounts to a warrant for inductive inference which, as Bacon showed nearly four hundred years ago, is the basic mode of reasoning in empirical science. Without assuming this spatial and temporal invariance, we have no basis for extrapolating from the known to the unknown and, therefore, no way of reaching general conclusions from a finite number of observations. (Since the assumption is itself vindicated by induction, it can in no way “prove” the validity of induction - an endeavor virtually abandoned after Hume demonstrated its futility two centuries ago).

– *Gould, S. J. 1965. Is uniformitarianism necessary? American Journal of Science* 263:223–228.

Empiricism holds that the landmark of scientific theories is their verifiability by induction from evidence. Many versions of empiricism exist, with the predominant ones being bayesianism (using Bayes' rule to compute the inductive probability of theories from evidence) and the hypothetico-deductive method (inductive confirmation of theories taken as purely hypothetical at the point of invention).

Empiricism has stood in contrast to rationalism, the opposing position originally associated with the approach of Descartes as opposed to Bacon, which holds that knowledge is created by the human intellect, not by observation. A significant twentieth century version of rationalism is critical rationalism, first brought forward by Austrian-British philosopher Karl Popper. Popper acknowledged the fact that a connection exists between observation and theories, but rejected the way that empiricism describes the nature of this connection. More specifically, Popper claimed that theories are not generated by observation, but that observation is made in the light of theories—that observation is "theory-laden"—and that the only way a theory can be affected by observation is when it comes in conflict with it. Popper proposed falsifiability (the ability of theories to come in conflict with observation) as the landmark of empirical theories, and falsification (the search for observations that conflict with the theory) as the empirical method to replace verifiability and induction by purely deductive notions. Contrasting his views with inductivism, he went so far as to claim that the scientific method does not actually exist: "(1) There is no method of discovering a scientific theory (2) There is no method for ascertaining the truth of a scientific hypothesis, i.e., no method of verification; (3) There is no method for ascertaining whether a hypothesis is 'probable', or probably true" Instead, he claimed that there is really only one universal method, and that this method is not specific to science: The negative method of criticism, trial and error. It covers all products of the human mind, including science, mathematics, philosophy, art and so on, and even extends to the evolution of life. Popper especially

questioned the claim that there is a difference between the natural and the social sciences and criticized the prevalent philosophy of the social sciences as scientific, as a "slavish imitation of *what certain people mistake* for the method and language of science". He contributed to the so-called Positivism dispute with respect to this question, a philosophical dispute between Critical rationalism (Popper, Albert) and the Frankfurt School (Adorno, Habermas) about the methodology of the social sciences. Popper, together with students William W. Bartley and David Miller, also questioned the classical theory of rationality. This theory claims that rational knowledge in general, and scientific knowledge in particular, stands out as knowledge that can be justified in a way that other claims cannot be justified. Popper criticized the very concept of justification, held that science or rationality in general have no way of justifying or sanctioning ideas at all and argued that rationality is simply willingness to accept criticism and change one's views accordingly, and to criticize the views of others—not the ability to justify one's views, or the ability to criticize the lack of justification of the views of others. Popper, Bartley and Miller also argued against limits of rationality, especially against seeing falsifiability as a limit of rationality. Accordingly, they rejected the view that science has authority and instead considered it as inherently fallible.

Another approach, Instrumentalism, colloquially termed "shut up and calculate", emphasizes the utility of theories as instruments for explaining and predicting phenomena. It essentially claims that scientific theories are black boxes with only their input (initial conditions) and output (predictions) being relevant. Consequences, notions and logical structure of the theories are claimed to be something that should simply be ignored and that scientists shouldn't make a fuss about.

A position often cited in political debates of scientific skepticism against controversial movements like creationism, that purport to be scientific, but have controversial criticisms of mainstream science, is methodological naturalism. Its main point is that a difference between natural and supernatural explanations should be made, and that science should be restricted methodologically to natural explanations. That the restriction is merely methodological (rather than ontological) means that science should not consider supernatural explanations itself, but should not claim them to be wrong either. Instead, supernatural explanations should be left a matter of personal belief outside the scope of science. Methodological naturalism maintains that proper science requires strict adherence to empirical study and independent verification as a process for properly developing and evaluating explanations for observable phenomena. The absence of these standards, arguments from authority, biased observational studies and other common fallacies are frequently cited by supporters of methodological naturalism as criteria for the dubious claims they criticize not to be true science.

Science policy

Science policy is an area of public policy concerned with the policies that affect the conduct of the science and research enterprise, including research funding, often in pursuance of other national policy goals such as technological innovation to promote commercial product development, weapons development, health care and environmental

monitoring. Science policy also refers to the act of applying scientific knowledge and consensus to the development of public policies. Science policy thus deals with the entire domain of issues that involve the natural sciences. In accordance with public policy being concerned about the well-being of its citizens, science policy's goal is to consider how science and technology can best serve the public.

State policy has influenced the funding of public works and science for thousands of years, dating at least from the time of the Mohists, who inspired the study of logic during the period of the Hundred Schools of Thought, and the study of defensive fortifications during the Warring States Period in China. In Great Britain, governmental approval of the Royal Society in the seventeenth century recognized a scientific community which exists to this day. The professionalization of science, begun in the nineteenth century, was partly enabled by the creation of scientific organizations such as the National Academy of Sciences, the Kaiser Wilhelm Institute, and State funding of universities of their respective nations. Public policy can directly affect the funding of capital equipment, intellectual infrastructure for industrial research, by providing tax incentives to those organizations who fund research. Vannevar Bush, director of the office of scientific research and development for the United States government, the forerunner of the National Science Foundation, wrote in July 1945 that "Science is a proper concern of government"

Science and technology research is often funded through a competitive process, in which potential research projects are evaluated and only the most promising receive funding. Such processes, which are run by government, corporations or foundations, allocate scarce funds. Total research funding in most developed countries is between 1.5% and 3% of GDP. In the OECD, around two-thirds of research and development in scientific and technical fields is carried out by industry, and 20% and 10% respectively by universities and government. The government funding proportion in certain industries is higher, and it dominates research in social science and humanities. Similarly, with some exceptions (e.g. biotechnology) government provides the bulk of the funds for basic scientific research. In commercial research and development, all but the most research-oriented corporations focus more heavily on near-term commercialisation possibilities rather than "blue-sky" ideas or technologies (such as nuclear fusion).

Pseudoscience, fringe science, and junk science

An area of study or speculation that masquerades as science in an attempt to claim a legitimacy that it would not otherwise be able to achieve is sometimes referred to as pseudoscience, fringe science, or "alternative science". Another term, junk science, is often used to describe scientific hypotheses or conclusions which, while perhaps legitimate in themselves, are believed to be used to support a position that is seen as not legitimately justified by the totality of evidence. Physicist Richard Feynman coined the term "cargo cult science" in reference to pursuits that have the formal trappings of science but lack "a principle of scientific thought that corresponds to a kind of utter honesty" that allows their results to be rigorously evaluated. Various types of commercial advertising, ranging from hype to fraud, may fall into these categories.

There also can be an element of political or ideological bias on all sides of such debates. Sometimes, research may be characterized as "bad science", research that is well-intentioned but is seen as incorrect, obsolete, incomplete, or over-simplified expositions of scientific ideas. The term "scientific misconduct" refers to situations such as where researchers have intentionally misrepresented their published data or have purposely given credit for a discovery to the wrong person.

Critiques

Philosophical critiques

Historian Jacques Barzun termed science "a faith as fanatical as any in history" and warned against the use of scientific thought to suppress considerations of meaning as integral to human existence. Many recent thinkers, such as Carolyn Merchant, Theodor Adorno and E. F. Schumacher considered that the 17th century scientific revolution shifted science from a focus on understanding nature, or wisdom, to a focus on manipulating nature, i.e. power, and that science's emphasis on manipulating nature leads it inevitably to manipulate people, as well. Science's focus on quantitative measures has led to critiques that it is unable to recognize important qualitative aspects of the world.

Philosopher of science Paul K Feyerabend advanced the idea of epistemological anarchism, which holds that there are no useful and exception-free methodological rules governing the progress of science or the growth of knowledge, and that the idea that science can or should operate according to universal and fixed rules is unrealistic, pernicious and detrimental to science itself. Feyerabend advocates treating science as an ideology alongside others such as religion, magic and mythology, and considers the dominance of science in society authoritarian and unjustified. He also contended (along with Imre Lakatos) that the demarcation problem of distinguishing science from pseudoscience on objective grounds is not possible and thus fatal to the notion of science running according to fixed, universal rules.

Feyerabend also criticized Science for not having evidence for its own philosophical precepts. Particularly the notion of Uniformity of Law and the Uniformity of Process across time and space. "We have to realize that a unified theory of the physical world simply does not exist" says Feyerabend, "We have theories that work in restricted regions, we have purely formal attempts to condense them into a single formula, we have lots of unfounded claims (such as the claim that all of chemistry can be reduced to physics), phenomena that do not fit into the accepted framework are suppressed; in physics, which many scientists regard as the one really basic science, we have now at least three different points of view...without a promise of conceptual (and not only formal) unification".

Sociologist Stanley Aronowitz scrutinizes science for operating with the presumption that the only acceptable criticisms of science are those conducted within the methodological framework that science has set up for itself. That science insists that only those who have been inducted into its community, through means of training and credentials, are

qualified to make these criticisms. Aronowitz also alleges that while scientists consider it absurd that Fundamentalist Christianity uses biblical references to bolster their claim that the bible is true, scientists pull the same tactic by using the tools of science to settle disputes concerning its own validity.

Psychologist Carl Jung believed that though science attempted to understand all of nature, the experimental method imposed artificial and conditional questions that evoke equally artificial answers. Jung encouraged, instead of these 'artificial' methods, empirically testing the world in a holistic manner. David Parkin compared the epistemological stance of science to that of divination. He suggested that, to the degree that divination is an epistemologically specific means of gaining insight into a given question, science itself can be considered a form of divination that is framed from a Western view of the nature (and thus possible applications) of knowledge.

Several academics have offered critiques concerning ethics in science. In *Science and Ethics*, for example, the philosopher Bernard Rollin examines the relevance of ethics to science, and argues in favor of making education in ethics part and parcel of scientific training.

Media perspectives

The mass media face a number of pressures that can prevent them from accurately depicting competing scientific claims in terms of their credibility within the scientific community as a whole. Determining how much weight to give different sides in a scientific debate requires considerable expertise regarding the matter. Few journalists have real scientific knowledge, and even beat reporters who know a great deal about certain scientific issues may be ignorant about other scientific issues that they are suddenly asked to cover.

Politics and Public Perception of Science

Many issues damage the relationship of science to the media and the use of science and scientific arguments by politicians. As a very broad generalisation, many politicians seek certainties and *facts* whilst scientists typically offer probabilities and caveats. However, politicians' ability to be heard in the mass media frequently distorts the scientific understanding by the public. Examples in Britain include the controversy over the MMR inoculation, and the 1988 forced resignation of a Government Minister, Edwina Currie for revealing the high probability that battery eggs were contaminated with *Salmonella*.

Chapter- 3

Tool



A modern toolbox



Knives were some of the first tools developed by humans

A **tool** is a device that can be used to produce or achieve something, but that is not consumed in the process. Colloquially a tool can also be a procedure or process used for a specific purpose. Tools that are used in particular fields or activities may have different designations such as *Instrument*, *Utensil*, *Implement*, *Machine*, *Apparatus*.

Evolution of tool use

Anthropologists believe that the use of tools was an important step in the evolution of mankind. Humans evolved an opposable thumb — useful in holding tools — and increased dramatically in intelligence, which aided in the use of tools.

Tools are the most important items that the ancient humans used to climb to the top of the food chain; by inventing tools, they were able to accomplish tasks that human bodies could not, such as using a spear or bow and arrow to kill prey, since their teeth were not sharp enough to pierce many animals' skins.

A telephone is a communication tool that interfaces between two people engaged in conversation at one level. And between each user and the communication network at another. It is in the domain of media and communications technology that a counter-intuitive aspect of our relationships with our tools first began to gain popular recognition. Marshall McLuhan famously said "We shape our tools. And then our tools shape us." McLuhan was referring to the fact that our social practices co-evolve with our use of new tools and the refinements we make to existing tools.



Carpentry tools recovered from the wreck of a 16th century sailing ship, the Mary Rose.

Tool use by animals

Observation has confirmed that that multiple species can use tools, including monkeys, apes, several birds, and sea otters. Philosophers originally thought that only humans had the ability to *make* tools, until zoologists observed birds and monkeys making tools. Now humans' unique relationship to tools is considered to be that we are the only species that uses tools to make *other* tools.

Functions

The basic functions of tools are:

- Cutting tools, such as the knife, scythe or sickle, are wedge-shaped implements that produce a shearing force along a narrow face. Ideally, the edge of the tool needs to be harder than the material being cut or else the blade will become dulled with repeated use. But even resilient tools will require periodic sharpening, which

is the process of removing deformation wear from the edge. Also gouges and drill bits.

- Moving tools move huge and tiny things, e.g. concentrating force tools like the hammer moves a nail, the maul moves a stake, or a whip moves flesh on a horse. These operate by applying physical compression to a surface. In the case of the screwdriver, the force is rotational and called torque. Writing implements deliver a fluid to a surface via compression to activate the ink cartridge. Also grabbing and twisting nuts and bolts with pliers, a glove, a wrench, etc. All these tools move items by some kind of force. Also Trucks, Rockets and Planes move larger items and particle accelerators move very small items.
- Tools that enact chemical changes, including temperature and ignition, such as lighters and blowtorches.
- Guiding, measuring and perception tools include the ruler, glasses, set square, sensors, straightedge, theodolite, microscope, monitor, clock, phone, printer
- Shaping tools, such as moulds, jigs, trowels.
- Fastening tools, such as welders, rivet guns, nail guns, or glue guns.
- Information and data manipulation tools, such as computers, middleware, IDE, spreadsheets

Some tools may be combinations of other tools. An alarm-clock is for example a combination of a measuring tool (the clock) and a perception tool (the alarm). This enables the alarm-clock to be a tool that falls outside of all the categories mentioned above.

Protective gear items are not considered tools, because they do not directly help perform work, just protect the worker like ordinary clothing. Personal protective equipment includes such items as gloves, safety glasses, ear defenders and biohazard suits.

Tool substitution

Often, by design or coincidence, a tool may share key functional attributes with one or more other tools. In this case, some tools can substitute for other tools, either as a make-shift solution or as a matter of practical efficiency. "One tool does it all" is a motto of some importance for workers who cannot practically carry every specialized tool to the location of every work task. Tool substitution may be divided broadly into two classes: substitution "by-design", or "multi-purpose" use, and substitution as make-shift. In many cases, the designed secondary functions of tools are not widely known. As an example of the former, many wood-cutting hand saws integrate a carpenter's square by incorporating a specially shaped handle that allows 90° and 45° angles to be marked by aligning the appropriate part of the handle with an edge and scribing along the back edge of the saw. The latter is illustrated by the saying "All tools can be used as hammers." Nearly all tools can be used to function as a hammer, even though very few tools are intentionally designed for it and even fewer work as well as the original.

Multi-use tools

- A multitool is a hand tool that incorporates several tools into a single, portable device.
- Lineman's pliers incorporate a gripper and cutter, and are often used secondarily as a hammer.
- Hand saws often incorporate the functionality of the carpenter's square in the right-angle between the blade's dull edge and the saw's handle.

History



Prehistoric tools over 10,000 years old, found in Les Combarelles cave, France

Because tools are used extensively by both humans and wild chimpanzees, it is widely assumed that the first routine use of tools took place prior to the divergence between the two species. These early tools, however, were likely made of perishable materials such as sticks, or consisted of unmodified stones that cannot be distinguished from other stones as tools. The beginning of the Stone Age marks the era when hominins first began manufacturing stone tools, and evidence of these tools dates back at least 2.6 million years in Ethiopia. One of the earliest distinguishable stone tool forms is the hand axe.

The transition from stone to metal tools roughly coincided with the development of agriculture around the 4th millennium BC.

Mechanical devices experienced a major expansion in their use in the Middle Ages with the systematic employment of new energy sources: water (waterwheels) and wind (windmills).

Machine tools occasioned a surge in producing new tools in the industrial revolution. Advocates of nanotechnology expect a similar surge as tools become microscopic in size.

WWT

Chapter- 4

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 canvases 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- 5

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

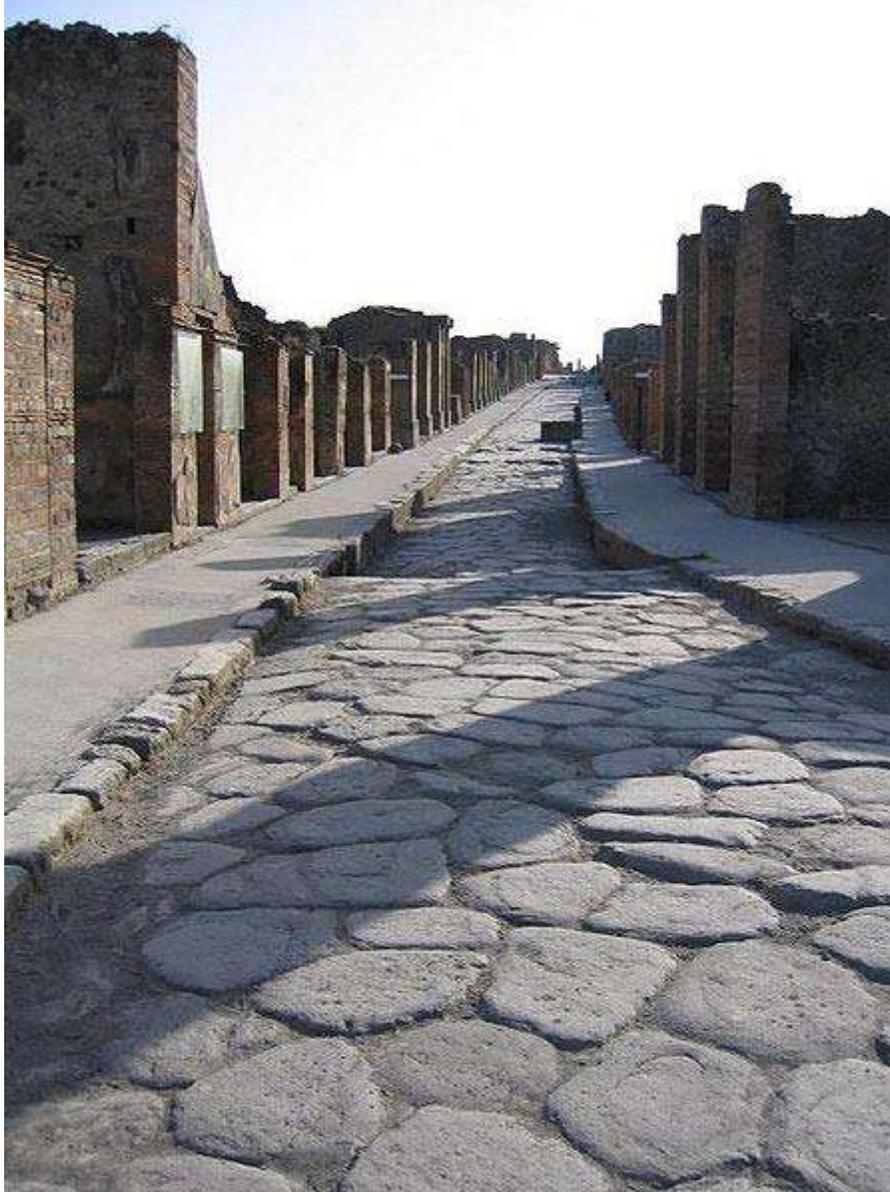
In the United Kingdom there is some ambiguity between the terms highway and road. The Highway code details rules for 'road users'. For the purposes of the English law Highways Act 1980, which covers England and Wales (but not Scotland or Northern Ireland), the term "road" is defined to be *any length 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.

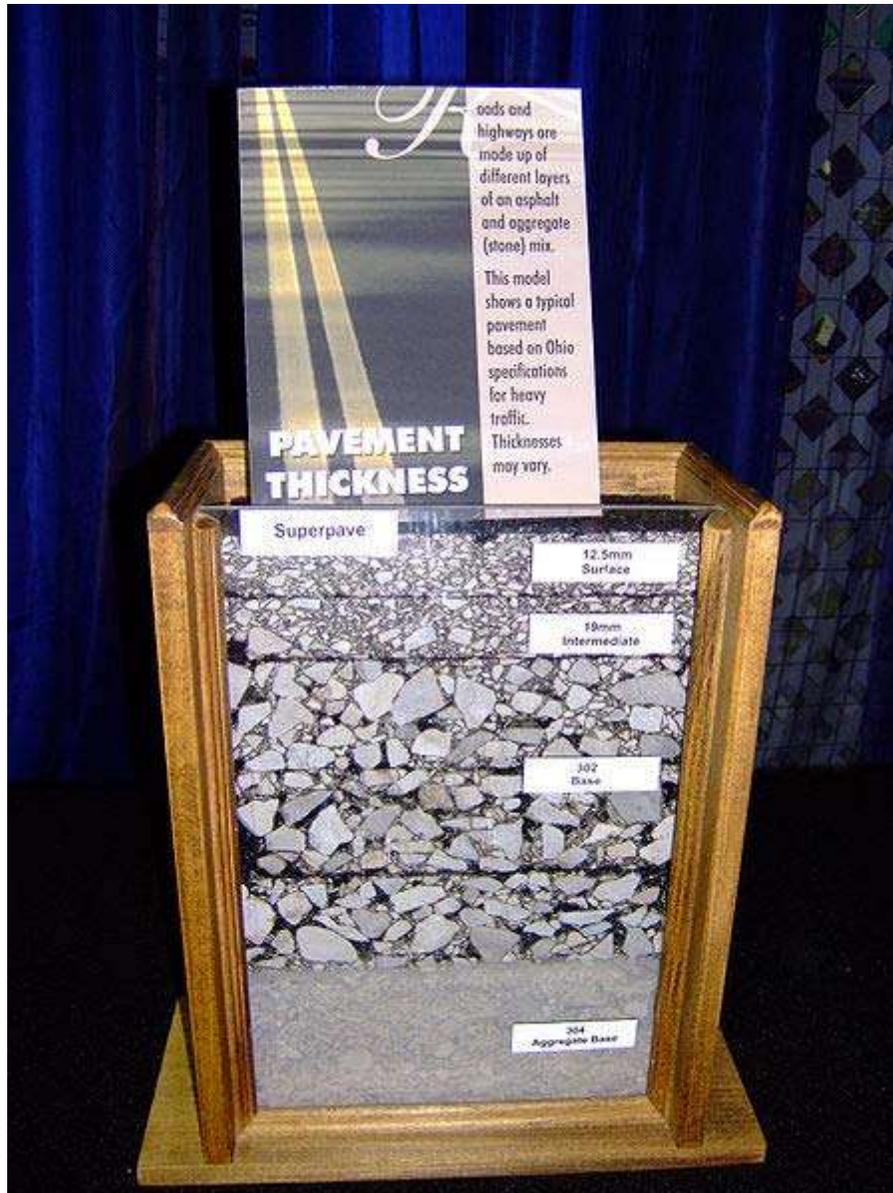
A borrow pit (source for obtaining fill, gravel, and rock) and a water source should be located near or in reasonable distance to the road construction site. Approval from local authorities may be required to draw water or for working (crushing and screening) of materials for construction needs. The 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



UK roadworks sign. In other European countries, the signs are similar.

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 monitor 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).

Slab Stabilization

Distress and serviceability loss on concrete roads can be caused by loss of support due to voids beneath the concrete pavement slabs. The voids usually occur near cracks or joints due to surface water infiltration. The most common causes of voids are pumping, consolidation, subgrade failure and bridge approach failure. Slab stabilization is a non-destructive method of solving this problem and is usually employed with other Concrete Pavement Restoration (CPR) methods including patching and diamond grinding. The technique restores support to concrete slabs by filling small voids that develop underneath the concrete slab at joints, cracks or the pavement edge. The process consists of pumping a cementitious grout or polyurethane mixture through holes drilled through the slab. The grout can fill small voids beneath the slab and/or sub-base. The grout also displaces free water and helps keep water from saturating and weakening support under the joints and slab edge after stabilization is complete. The three steps for this method after finding the voids are locating and drilling holes, grout injection and post-testing the stabilized slabs.

Slab stabilization does not correct depressions, increase the design structural capacity, stop erosion or eliminate faulting. It does, however, restore the slab support, therefore, decreasing deflections under the load. Stabilization should only be performed at joints and cracks where loss of support exists. Visual inspection is the simplest manner to find voids. Signs that repair is needed are transverse joint faulting, corner breaks and shoulder drop off and lines at or near joints and cracks. Deflection testing is another common procedure utilized to locate voids. It is recommended to do this testing at night as during cooler temperatures, joints open, aggregate interlock diminishes and load deflections are at their highest.

Another testing method is ground penetrating radar. It pulses electromagnetic wave technology into the pavement and then ceases the transmission during which the transmitter-receiver detects signals that are deflected from the pavement. Yet another method is the epoxy/core test, which confirms void presence by visual and mechanical methods. It consists of drilling a 25 to 50 millimeter hole through the pavement and into the sub-base with a dry-bit roto-hammer. Next, a two-part epoxy is poured into the hole that is dyed for visual clarity. Once the epoxy is hardened, the technicians drill through the hole. If a void is present, the epoxy will stick to the core and provide physical evidence.

Common stabilization materials are pozzolan-cement grout and polyurethane. The requirements for slab stabilization are strength and the ability to flow into or expand to fill small voids. Colloidal mixing equipment is necessary to use the pozzolan-cement grouts. The contractor should place the grout using a positive-displacement injection pump or a non-pulsing progressive cavity pump. A drill is also necessary but it must produce a clean hole with no surface spalling or breakouts. The injection devices must include a grout packer that is capable of sealing a hole. The injection device must also have a return hose or a fast-control reverse switch in case workers detect slab movement on the uplift gauge. The uplift beam helps to monitor the slab deflection and has to have sensitive dial gauges.

Joint Sealing

Also called joint and crack repair, this method's purpose is to minimize infiltration of surface water and incompressible material into the joint system. Joint sealants are also used to reduce dowel bar corrosion in Concrete Pavement Restoration (CPR) techniques. Successful resealing consists of old sealant removal, shaping and cleaning the reservoir, installing the backer rod and installing the sealant. Sawing, manual removal, plowing and cutting are methods used to remove the old sealant. Saws are used to shape the reservoir. When cleaning the reservoir, no dust, dirt or traces of old sealant should remain. Thus, it is recommended to water wash, sand-blast and then air blow to remove any sand, dirt or dust. The backer rod installation requires a double-wheeled, steel roller to insert the rod to the desired depth. After inserting the backer rod, the sealant is placed into the joint. There are various materials to choose for this method including hot pour bituminous liquid, silicone and preformed compression seals.

Safety considerations



Pedestrian crossing, line markings and street furniture.

Careful design and construction of roads can increase Road traffic safety and reduce the harm (deaths, injuries, and property damage) on the highway system from traffic collisions.

On neighborhood roads traffic calming, safety barriers, pedestrian crossings and cycle lanes can all protect pedestrians and cyclists.

Lane markers in some countries and states are marked with Cat's eyes or Botts dots, bright reflectors that do not fade like paint. Botts dots are not used where it is icy in the winter, because frost and snowplows can break the glue that holds them to the road, although they can be embedded in short, shallow trenches carved in the roadway, as is done in the mountainous regions of California.

For major roads risk can be reduced by providing limited access from properties and local roads, grade separated junctions and median dividers between opposite-direction traffic to reduce likelihood of head-on collisions.

The placement of energy attenuation devices (e.g. guardrails, wide grassy areas, sand barrels) is also common. Some road fixtures such as road signs and fire hydrants are designed to collapse on impact. Light poles are designed to break at the base rather than violently stop a car that hits them. Highway authorities may also remove larger trees from the immediate vicinity of the road.

Environmental performance



Air pollution along Pasadena Highway in Los Angeles, United States

Careful design and construction of a road can reduce any negative environmental impacts.

Water management systems can be used to reduce the effect of pollutants from roads. Rainwater and snowmelt running off of roads tends to pick up gasoline, motor oil, heavy metals, trash and other pollutants and result in Water pollution. Road runoff is a major source of nickel, copper, zinc, cadmium, lead and polycyclic aromatic hydrocarbons (PAHs), which are created as combustion byproducts of gasoline and other fossil fuels. De-icing chemicals and sand can run off into roadsides, contaminate groundwater and pollute surface waters; and road salts can be toxic to sensitive plants and animals. Sand applied to icy roads can be ground up by traffic into fine particulates and contribute to air pollution. Sand can alter stream bed environments, causing stress for the plants and animals that live there.

Roadways are a chief source of environmental noise generation. In the early 1970s it was recognized that design of roads can be conducted to influence and minimize noise

generation. Noise barriers are used to reduce Noise pollution, in particular where roads are located close to built-up areas. Regulations can restrict the use of Engine braking.

Motor vehicle emissions contribute air pollution. Concentrations of air pollutants and adverse respiratory health effects are greater near the road than at some distance away from the road. Road dust kicked up by vehicles may trigger allergic reactions.

Terminology



The A22(T) with line markings near Summer Hill, East Sussex, England, United Kingdom



Road with guard rails in Kaluga Oblast, Russia



Road with traffic signs in the outskirts of Bern, Switzerland



Highway 401, a route with a collector/express setup.

- Alignment (road) - horizontal and vertical curvature of a road.
- Adverse camber - where a road slopes towards the outside of a bend, increasing the likelihood that vehicles travelling at speed will skid or topple. Usually only a temporary situation during road maintenance.
- All-weather road - Unpaved road that is constructed of a material that does not create mud during rainfall.
- Banked turn
- Camber - the curvature of the road surface that encourages surface water to flow freely from the carriageway, or on bends angling of the surface to lean traffic 'into the bend' reducing the chance of a skid.
- Cant - superelevation
- Cross slope
- Grade - longitudinal slope
- Belisha Beacon - an orange globe, lit at night, used to highlight a pedestrian crossing.
- Bollard - Rigid posts that can be arranged in a line to close a road or path to vehicles above a certain width
- Byway - Highway over which the public have a right to travel for vehicular and other kinds of traffic, but which is used mainly as footpaths and bridleways
- Bypass Road that avoids or "bypasses" a built-up area, town, or village
- Bottleneck - Section of a road with a carrying capacity substantially below that of other sections of the same road
- Botts' dots - Non-reflective raised pavement marker used on roads

- Cat's eye - reflective raised pavement marker used on roads
- Chicane - Sequence of tight serpentine curves (usually an S-shape curve or a bus stop) in a roadway
- Chipseal - Road surface composed of a thin layer of crushed stone 'chips' and asphalt emulsion. It seals the surface and protects it from weather, but provides no structural strength. It is cheaper than asphalt concrete or a concrete, in the U.S. it is usually only used on low volume rural roads
- Corniche - Road on the side of a cliff or mountain, with the ground rising on one side and falling away on the other
- Curb - Edge where a raised pavement/sidewalk/footpath, road median, or road shoulder meets an unraised street or other roadway.
- Curb extension - (or also kerb extension, bulb-out, nib, elephant ear, curb bulge and blister) Traffic calming measure, intended to slow the speed of traffic and increase driver awareness, particularly in built-up and residential neighborhoods.
- Drainage gradient
- Farm-to-market road - a state road or county road which serves to connect rural or agricultural areas to market towns.
- Fork - (literally "fork in the road") Type of intersection where a road splits
- Green lane - (UK) Unsurfaced road, may be so infrequently used that vegetation colonises freely, hence 'green'. Many green lanes are ancient routes that have existed for millennium, similar to a Byway
- Guard rail - Prevents vehicles from veering off the road into oncoming traffic, crashing against solid objects or falling from a road
- Gutter - UK a drainage channel between the main carriageway and the edge of the road.
- Interstate Highway System - United States System of Interstate and Defense Highways
- Layby (Pullout, pull-off) - A paved area beside a main road where cars can stop temporarily to let another car pass.
- Loose chippings - the hazard of stone chippings which have come loose.
- Median - On divided roads, including expressways, motorways, or autobahns, the central reservation (British English), median (North American English), median strip (North American English and Australian English), neutral ground [Louisiana English] or central nature strip (Australian English) is the area which separates opposing lanes of traffic
- Mountain pass - Lower point that allows easier access through a range of mountains
- Milestone - One of a series of numbered markers placed along a road at regular intervals, showing the distance to destinations.
- National Highway - Road built and maintained by a national authority.
- Pavement - The road regarded as a geoconstruction. In the UK the term is road surface and the pavement is a pedestrian walkway alongside the road.
- Pedestrian crossing - Designated point on a road at which some means are employed to assist pedestrians wishing to cross safely
- Pelican crossing - (officially *Pelican crossing*) UK a PEdestrian LIght CONTROLled crossing.

- Private highway - Highway owned and operated for profit by private industry
- Private road - Road owned and maintained by a private individual, organization, or company rather than by a government
- Public space - Place where anyone has a right to come without being excluded because of economic or social conditions
- Ranch road - U.S. road which serves to connect rural and agricultural areas to market towns
- Road number - Often assigned to a stretch of public roadway. The number chosen is often dependent on the type of road, with numbers differentiating between interstates, motorways, arterial thoroughfares, and so forth
- Road-traffic safety - Process to reduce the harm (deaths, injuries, and property damage) resulting from crashes of road vehicles traveling on public roads
- Roadworks - Part or all of the road has to be occupied for work or maintenance relating to the road
- Roughness - Deviations from a true planar pavement surface, which affects vehicle suspension deflection, dynamic loading, ride quality, surface drainage and winter operations. Roughness have wavelengths ranging from 500 mm up to some 40 m. The upper limit may be as high as 350 m when considering motion sickness aspects; motion sickness is generated by motion with down to 0.1 Hz frequency; in an ambulance car driving 35 m/s (126 km/h), waves with up to 350 m will excite motion sickness.
- Roundabout UK a road junction where typically three or more roads are joined by a circular section of road. Traffic 'on the roundabout' has priority over traffic on approach roads, unless indicated otherwise. In countrys where traffic drives on the left the roundabout is travelled in a clockwise direction. Also known as an island in parts of the UK.
- Shoulder - A clear, level area beside the driving lane(s). It helps support the roadway, helps drain the pavement, provides room for bicyclists and, in areas without sidewalks, pedestrians, allows disabled to get out of the road; a hard shoulder is paved, a soft shoulder is unpaved.
- State highway - Road numbered by the state, falling below numbered national highways (like U.S. Routes) in the hierarchy *or* a road maintained by the state, including nationally-numbered highways
- Texture (roads) - Deviations from a true planar pavement surface, which affects the interaction between road and tire. Microtexture have wavelengths below 0.5 mm, Macrotecture below 50 mm and Megatecture below 500 mm.
- Traffic calming - Set of strategies used by urban planners and traffic engineers which aim to slow down or reduce traffic, thereby improving safety for pedestrians and bicyclists as well as improving the environment for residents
- Traffic island - UK a small raised area used to help define the traffic flow, and which may also act as a refuge for pedestrians crossing the carriageway or a location for signs, barriers or lights. A synonym for roundabout in some parts of the UK.
- Traffic light - also known as a traffic signal, stop light, stop-and-go lights, robot or semaphore, is a signaling device positioned at a road intersection, pedestrian

- crossing, or other location in order to assign right of way to different approaches to an intersection
- Zebra Crossing - UK a pedestrian crossing marked by black and white stripes on the carriageway.

Regulation



Right- and left-hand traffic

Traffic flows on the right or on the left side of the road depending on the country. In countries where traffic flows on the right, traffic signs are mostly on the right side of the

road, roundabouts and traffic circles go counter-clockwise/anti-clockwise, and pedestrians crossing a two-way road should watch out for traffic from the left first. In countries where traffic flows on the left, the reverse is true.

About 33% of the world by population drive on the left, and 67% keep right. By roadway distances, about 28% drive on the left, and 72% on the right, even though originally most traffic drove on the left worldwide.

Economics



A city street in Mumbai, India with left-hand traffic.

Transport economics is used to understand both the relationship between the transport system and the wider economy and the complex network effects when there are multiple paths and competing modes for both personal and freight (road/rail/air/ferry) and where Induced demand can result in increased or decreased transport levels when road provision is increased by building new roads or decreased (for example California State Route 480). Roads are generally built and maintained by the public sector using taxation although implementation may be through private contractors). or occasionally using road tolls.

Economics and society depend heavily on efficient roads. In the European Union (EU) 44% of all goods are moved by trucks over roads and 85% of all persons are transported by cars, buses or coaches on roads. The term was also commonly used to refer to roadsteads, waterways that lent themselves to use by shipping.

Construction costs

According to www.nysthruway.gov, some typical costs to construct roads in several USA states include: CONSTRUCTION COST Expressway Section Per-Mile Cost Connecticut Turnpike \$3,449,000 New Jersey Turnpike \$2,200,000 Pennsylvania Turnpike (Delaware Extension) \$1,970,000 Northern Indiana Toll Road \$1,790,000 Garden State Parkway \$1,720,000 Massachusetts Turnpike \$1,600,000 Thruway, New York to Pennsylvania Line \$1,547,000 Ohio Turnpike \$1,352,000 Pennsylvania Turnpike (early construction) \$736,000

Statistics

The United States has the largest network of roadways of any country with 6,430,366 kilometres (3,995,644 mi) (2005). The People's Republic of China is second with 3,583,715 kilometres (2,226,817 mi) of roadway (2007). The Republic of India has the third largest road system in the world with 3,383,344 kilometres (2,102,312 mi) (2002). When looking only at expressways the National Trunk Highway System (NTHS) in People's Republic of China has a total length of 45,000 kilometres (28,000 mi) at the end of 2006, and 60,300 km at the end of 2008, second only to the United States with 90,000 kilometres (56,000 mi) in 2005.

Chapter- 6

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, signaling 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 fluvimetric 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 requests 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:) "Infrastructures have had harmful, long-term, and potentially irreparable 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