

**Development and Economic Impacts of Elevators**  
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## **I. Introduction**

The elevator is a mechanical device that essentially relates to a platform that is pushed or pulled with mechanical hoists, for the purpose of transporting goods and/or people vertically from one level to another (wikipedia.org). Few can argue with the impact the Elevator has brought upon urban life. Today, one would be hard pressed to travel in any urban center without coming across, or making use of, an elevator. The invention and innovation of this particular apparatus had enabled travel over vertical distances with greater speed and efficiency, impacting the height of buildings and the factor intensity of land use. In the 19<sup>th</sup> century, an Economist known as Johann Heinrich von Thünen produced a variation on the Ricardian Rent Theory model, popularizing the idea of spatial or “Location” rents on property, claiming the accessibility of market centers as the greatest determinant of rent calculations (class discussion). According to Thünen’s model, the factor intensity of land use would naturally be closest to the market centers (or more commonly, urban centers) in a largely agricultural economy. The concept of elevator’s was not present at that time, which could allow “Stacking” of businesses further increasing the intensity of land use. Hence, the “Skyscrapers” (a term given to tall buildings) could be envisioned and put into use. Today, the use of tall buildings is quite prominent (and even necessary) all over the world, and the commonality of elevators is at such a point, that it has become mandatory policy to have elevators in almost all buildings greater than three stories high, and is an important aspect of the ADA (American Disabilities Act) to make higher floors accessible to incapacitated individuals.

The purpose of this paper is to outline the evolution of the elevator, and to measure the impacts it has brought about into contemporary life. Over the past two centuries, the market leader in the elevation industry has been the Otis Company, a wholly owned subsidiary of United

Technologies Inc. The company has been so successful in its marketing of its products, that it has carried its parent company through the devastation caused to the aerospace industry after September 11<sup>th</sup> 2001. United Technologies was the only company posting 28 straight quarters of improving profit margins and revenue. This reliable foundation is largely cited as a direct cause of the name brand recognition of the Otis Company, allowing not only sales, but huge service demands of its own, as well as competitor-manufactured elevators (25).

## **II. History and Evolution**

From the early times in history, the idea of “lifting” had captivated mankind. The aforementioned hoists were extremely important in the development of early cities. Since centuries past, man has sought to build taller and taller buildings, which served as designated monuments (as in the cathedrals of the Roman Empire), or even earlier as in the time of the Pharaohs in Egypt, and their great pyramids. The majesty of such buildings, though grossly underutilized, withstood as testaments to the greatness of their respective nations. Such feats would not have been possible without first, the solution to the lifting problem ([theelevatormuseum.org](http://theelevatormuseum.org)).

The first notable issue was, in fact not the lifting of materials, but rather, the lifting of water. For centuries before the industrial revolution, the world was largely dependant upon agriculture to provide the most basic necessities of man. Water was well regarded as the primary giver of life, replenishing the soil and allowing food to be grown and harvested. As such, many of the cities we find today grew out of a need for farmers to be close to a water source, and as such, the closer to the source the better. The transport of water itself was not viewed as an enterprise for humans, with much of the supply coming from naturally endowed areas. To this

end, as the population of the world grew, and as linkages between agricultural land ownership and wealth came to be drawn, the demand for greater crop supplies and greater cultivable land came to be realized. It soon became obvious to the people of the time that water needed to be “lifted” out of river beds and spread out over greater distances away from the rivers. Hence, the idea of “irrigation” was born. Soon, simple mechanical devices consisting of levers and water traps were realized carrying water from the rivers to irrigation ditches. From there, the concept of the “water wheel” took shape, driven by human and/or animal power (Table1).

Trade had always taken place throughout the ages, and with the ideas born out of the simple increase in the usage of land, surpluses began to accumulate within nations, hence greater and greater trading began to take place. This then, caused greater and greater social divides between the different social classes of human beings, with displays of wealth becoming almost a necessity in order to prove greatness. As more and more cities began to take shape, and flourish, the need to lift heavy objects, such as earth and stone, became overwhelming. War began to take place simply as a means of accumulating wealth and manpower (read: slaves) in order to establish dominance, the symbols of which lied in tall majestic structures built by the dominating nations. Therein lay the need for more efficient methods of erecting structures as places of worship, defensive walls, palaces, art/entertainment houses etcetera ([theelevatormuseum.org](http://theelevatormuseum.org)).

Such was the romance between the lifting of heavy materials and man. As is the case with many a modern device, lifting mechanisms served as an extension to human beings, and allowed them to overcome their own physical limitations. Mining is another great illustration, for it serves to display how heavily dependant upon lifting equipment man would become. Out of these simple necessities was the simple concept of the modern day elevator to arise. From the days of the Iron Age, the mining of this most useful material would become heavily in need of

further innovations in lifting devices. It is perhaps no great coincidence that iron and steel would next become the bases of the modern day hoists. By and large, the actual mechanical hoisting devices were a product of the early 19<sup>th</sup> century.

The first inception of the modern day elevator was actually powered by steam, which was the most prominent power source at the time. In 1769, with the invention of the first steam engine, the use of lifting devices in factories was soon realized ([theelevatormuseum.org](http://theelevatormuseum.org)). Multistoried factories came into inception with steam power being used to drive gears connected to belts to allow the up and down movement of lifts. The problem of reversing direction was solved by using two belts moving in opposable directions, and a gear mechanism to alternate between the two.

Then, early in the 19<sup>th</sup> century, the hydraulic elevators were invented and replaced the steam powered lifts fairly quickly and extensively in factories. The mechanism behind this device consisted of a hydraulic plunger that sinks into a cylinder inserted into the ground. The cab rested upon the cylinder, and was lifted upwards by means of water forced into the cylinder by hand. This type of hoist was known as the “Hydraulic plunger elevator”. Slowly they moved outside of factories into docks, foundries and such, and then to commercial lifting areas and finally high speed passenger applications as well (table1).

Arguably, perhaps, the modern concept of the elevator was first invented and patented by Elisha Graves Otis in 1853, the term “elevator” itself denoting a hoist with automatic safety devices using steam as the power source ([wikipedia.org](http://wikipedia.org)). The patent information is given below, however it is noted that Otis actually invented a concept far more important than the device itself. Otis used the knowledge he had gained from his work as a Master Mechanic earlier in his life, wherein he had invented the Railway safety brake, to actually implement that technology to

the “hoist” in order to transform it into the modern safety elevator. The major innovation that Otis introduced to the public was an elevator capable of “catching” itself if the chain hoisting the cab were to break. This was the major breakthrough that allowed a surge of consumer confidence, such that it began to become infused into daily life.

Over the last century, better, faster and more efficient elevators have often been regarded as an indicator of prestige. To this end, and also due to direct competition faced by Otis in the form of Westinghouse Corp. have led further advancements in the technology behind high-usage models developed recently. Smarter logic has been deployed in the industry causing sleep modes in the device whereby it shuts off between extended periods of downtime, smarter logic whereby the cabs wait at the ground floor in the mornings to account for greater traffic anticipation and are now equipped with generators which allow electricity to be pumped back into the power grid as the cab descends, allowing greater energy efficiency (25). Speed has also been a factor such that elevators need to make more efficient decisions of travel. Overall, efficiency has been at the forefront of modern elevator development once the safety concerns have been addressed. To this end, Westinghouse developed the “Dual” elevator (16), which allowed two cabs to co-exist with the same shaft, load balancing between higher and lower floors, allowing reductions in building space allocated to elevator shafts. Aesthetics have also factored into the use of elevators, with music incorporated into the rides, open shaft elevators have also found use, whereby one can see outside the shaft by use of plastics and glass used to make the cab as a more pleasing alternative to the usual steel “box”. Future incorporations of Televisions running commercials have also gained in popularity cutting down on the boredom of riding the elevator (26).

Today, elevators have managed to become part of the industrial and urban landscape. There are several forms of legislation denoting the usage and safety standards applicable to all

lifting materials, so much so, that it is now deemed the safest form of travel known to man. But this was not always the case, over the course of history, and more so present in the grain elevator variety, accidents were quite commonplace, such that it was even considered a hazard of mine work (4). The main cause was often cited as the dust rising from the grain, causing a flammable atmosphere, and hence elevator blasts ensued. Much of this discomfort was dissipated by Otis' safety demonstration, but evidence from certain countries where the devices have recently gained popularity, displays problems that have yet to be sufficiently tackled. In China, certain older models are said to take up to an hour to arrive, largely putting a damper on commerce wherever located (29). In addition to this efficiency lag, there are still safety concerns that bring about consumer mistrust which have not been sufficiently addressed. While this issue remains largely overseas in developing nations, it still displays the need for further improvements.

### **III. Social Impacts:**

Overall high levels of consumer confidence arose really with Otis's invention of the safety elevator. Before this invention, there was a profound sense of mistrust associated with such devices, primarily due to the numerous accounts of accidents incurred with the usage of the mechanism. In the late 19<sup>th</sup> century, as elevators became more and more common, at least in factories, quite a few accounts of worker safety violations were recorded and reported on. As a direct response to this, legislation began to take form to prevent misuse and timely servicing of all elevating equipment.

Electricity was beginning to take shape as the main power source in the United States, roughly about the same time as the development of passenger elevators. This new avenue augmenting machinery was viewed as the most stable power source known to man (much as it is

to this day). As was the almost rapid induction of this technology, it was quickly applied to the elevator industry as well, as cities began to grow larger and larger. Urbanization had begun to take shape across the U.S., and along with it, came the problems of human relocation to these large market sectors (class discussion). More and more people began to move into the cities as the demand for skilled labor arose, with people moving closer and closer to the factories and workplaces. Congestion was the main byproduct of urbanization, due in no small part, to the impacts elevators brought upon the business sector. Industries came closer to each other because of the transport costs associated with bringing goods to market. Hence, residential quarters of the country were destined to become further closer in to each other because the potential of these mechanisms were being realized.

Land prices have continued to rise across the world. They say, one of the best investments people can make, is that of investing in land, which almost always guarantees a slow, but steady return on investment. As any home buyer now knows, the land price and rent is always cheaper further away from the cities. This phenomenon is a direct result of the high increases in the factor intensity of land use over the past century. Part of the story (and admittedly, an extremely large part) is of electrification. But there is also the impact of elevators that have caused the high factor inputs of land. More and more high-rise buildings are being built to accommodate more and more companies, be they large or small. Today, if you were to open a small business, chances are you would open your office in a multi-story office building. Were there no elevating technology at work, one could so easily be climbing stairs just to get to the office, and since we are leaning towards a service based economy, very few businesses could stomach their customers being asked to climb stairs and arrive at their offices in a completely exhaustive state.

As this avenue of technology began to diffuse itself into the population, the high demand for this product, as well as maintenance, continued to grow (5, 6, 7, 10, and 19). Specific skilled engineers were needed to not only conform to the exacting standards placed upon the industry, but to develop greater and greater efficiencies as well. While we, as consumers, take for granted the fact that once a call button is depressed, the elevator will hurry to our floor and carry us to our destination, it is perhaps naïve to consider that the simple mechanics behind this device will not need to be constantly assessed and improved. By today's standards, the standard computer microprocessor behind the elevator is quite simplistic in nature. The algorithm used for quite a while was a simple two step command process, whereby the elevator was to continue in a direction if there were any calls from that direction (wikipedia.org). Otherwise it was to stop and remain idle in its current position, waiting for future calls to guide its direction. While the industry has now moved away from such a simplistic method, mainly in passenger elevators, most freight elevators have maintained this design. These efficiencies are the direct result of strong competition within the industry, which remains, to this day, one of the most underappreciated, yet necessary, industries to date.

Efficiencies over time have also caused a reduction in the number of people employed by this industry. Over time, elevator mechanics have faced steep downturns, with only a fraction remaining to service the elevators. This is due to improved safety features and steep reductions in elevator malfunctions which are a direct result of better manufacturing techniques and sophisticated electronic safeguards (8). This particular job category is of importance as it is another indicator of the changing landscape of what constituted "work" in the early 20<sup>th</sup> century. Engineers were gaining popularity over manual labor as the quest for greater automation took over in the industrial era. In addition, elevator operators were employees that sat in the elevator

all day taking decisions that have now been wholly replaced by electronics. This particular job sector was both created and destroyed by the elevator industry over its various generations, giving us another indicator of the value placed on automation, and the resulting cost savings (class discussion).

#### **IV. Economic Impacts:**

When Elisha Otis won over consumer confidence with his display of the safety elevator, he soon formed the Otis Company, whose dealings were primarily to supply the safety elevators to all manner of businesses. Today, the company remains a cash cow of the United Technologies Corporation (25), which is the global market leader in vertical transport systems, followed by Schindler and Thyssen-Krupp and Kone. Acquisition of the Otis Company has often been cited as the “single greatest investment” ever made by UTC. With Otis’ display, and his elevator brake patent, the industry literally took off, becoming akin to a utility company soon thereafter.

Builders saw the potential in the device and soon implemented it into their residential markets, allowing greater usage of their land developments. Factories (though already having used this device to a large extent) could now visualize all manner of work being conducted within the same buildings. While buildings already were quite high, further heights could be reached with nominal use of stairs. Pretty soon, elevators became the main form of conveyance between floors of a building and had a great impact on construction. To illustrate the importance of this industry on construction, in 1964, a strike carried out by the elevator installers and maintenance men in Pittsburg brought construction to a halt (2).

Economies of scale that were previously out of the reach of companies also came to be realized, and soon the demand for faster and more reliable elevator technology became as

important as the device itself (1). The spatial distances within certain types of industries began to decline, and soon stacks of businesses began to be formed. One of the impacts of businesses moving into the same building is that of startup costs of small businesses became to decline. Office space became cheaper and cheaper over the years so that today, an office is deemed necessary for any sort of credibility to be lent to a business. As a direct result of the decline in startup costs, the amount of small businesses grew, which would further augment technology and development. The classic Schumpeterian argument of “creative destruction” would start to manifest itself, as small businesses could now start competing with established companies (class discussions). While this argument may sound like it gives ultimate credit to the elevator, it should not be deemed as such, as there were a great many other factors involved as well. However, the fact that the elevator was also an accessory to economic landscape (as it exists today in the U.S.) should not go unnoticed. Earlier in this paper, I gave the case of the small business opening its doors to customers in a multi-story building. While almost a childish example, it speaks volumes as to what we accomplished by use of elevator technology. To wit, I feel this example serves as an efficient backdrop to my analysis.

Over time, with the amount of diffusion this industry has faced, I feel it necessary to comment upon its declining costs of production. Due mostly in part to the declining costs of the steel industry (to make the cab and infrastructure of the shaft to carry the cab) coupled with the more recent decline in microprocessor costs, and to an extent, favorable legislative climate, have caused this technology to enjoy a declining overall cost structure. By the legislative conditions, I refer to the continued monitoring of the standards set upon the industry to keep its product in optimum condition, which then have caused evolutionary changes, as manufacturing companies constantly look for declining maintenance costs, which are largely borne on the companies

themselves. I would also be remiss if I did not state that some of the older, less safe versions of elevators are today replaced rather than inspected for failure as it is deemed less economically efficient to take apart an old model for the purpose of inspection. Steel was also considered a very viable replacement to the earlier wood models of high performance elevators (such as the grain elevators) given the greater weight they could support, resulting in declining costs for food production and mining, among others (9).

#### **IV. Current Innovations and Future Developments:**

Although the industry has faced relatively slow progression since the inception of the electrical elevator (by Siemens in 1880), there have been quite a few notable upgrades, based on demand as well as product differentiation caused by energetic competitors (1). While these demands may not be relegated to the United States itself, but rather, more globally evident, they have caused the market leader (Otis Co.) to respond fairly quickly.

One of the main features over the last decade was that of efficiency. Otis Co. as well as others have looked to employ heuristic algorithms in their microprocessor chips in order to optimize travel between floors and to load balance themselves between multiple elevators (30). What this means is that the simple algorithm stated above in the paper may not be the most efficient way to accomplish its goals, hence the chips are designed to ignore calls to floors if the call is deemed less optimal than the alternative. Also in production are specific error trapping and solution methodologies whereby a solution is implemented (if possible) to prevent stoppage of the mechanism. An augmentation of this is the REM (Remote Elevator Monitoring) capability recently introduced by Otis, where, in the case of an error which cannot be handled by the internal software of the elevator, an automated call for service is placed with the manufacturer,

allowing for near instant deployment of solution specialists, severely cutting down on the “downtime” of the product (25).

The age-old claustrophobic idea of an elevator stopping between floors due to a loss of power, or a malfunction, has become more fiction than fact, given the programming within the product, which will store enough power to reach the nearest level and stop there rather than in mid transit. Furthermore, with the immense increase in the valuation of time by consumers, the demand has risen for faster service to be performed with the highest safety and optimality standards. In direct response to this elevators have become faster and faster, and depending on the amount needed to travel, can reach speed of about 1200 feet per minute (roughly around 14 miles per hour) (wikipedia.org).

Perhaps the largest scale innovation in this technology to date would be the idea of the “Space Elevator”. While this has rather loose ties to the innovation studied in the paper, it is the idea that manifests itself into the development of this entirely new form of space travel. What this entails is the simple method of a boxcar with a base on Earth, and a counterweight outside the atmosphere which will allow it to climb out of the Earth, by means of a cable, into space with a fraction of the costs associated with current space travel. While it is early in the design phase of the latest incarnation of this technology, and its impacts to the economy are difficult to identify, it is a nice diversion which puts the progression of this method into perspective (wikipedia.org). Regardless of scale, however, it is clear that the product has room for improvement, as evidenced by users in China, and while these issues have been dealt with on our shores, affordability is the key factor, hence it would seem that there is still a certain economy that will be realized with greater global diffusion.

## **V. Discussion and conclusions:**

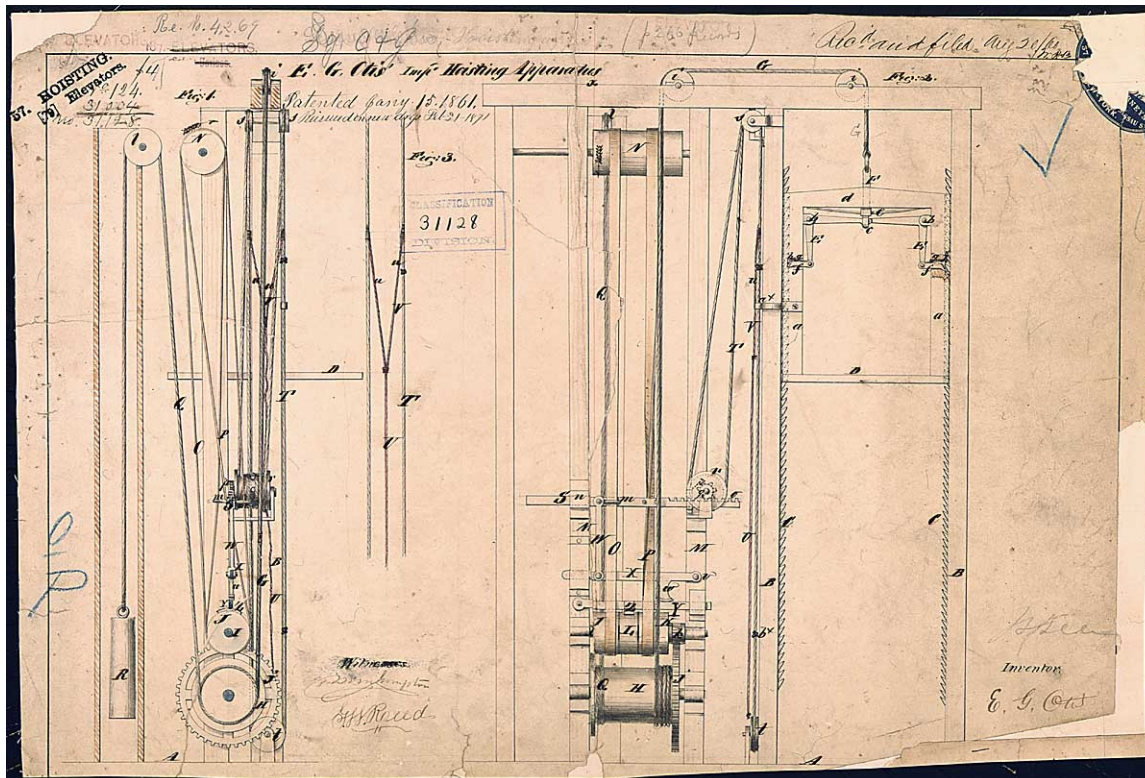
So why is going higher and higher captivated us human beings for so long? Were scaling mountains and erecting comparable buildings not enough for us? The timeline of lifting devices and means to accomplish physical obstacles date back to well over 4000 years, one would think we were ready to give it up. Perhaps we have.

The space elevator notwithstanding, demands continue to grow upon the elevator industry, but it really is under a threat. Further demand seems to be coming from the lesser developed countries as they struggle to catch up, whereas innovations in telecommunications are largely making the necessity of close interaction quite unfeasible. As with almost any other industry, the threat from the I.T. revolution looms large on this sector as well. The reasons for this most bold statement? Well, as is prominently the case in Dallas, there is evidence of movement away from city centers, into suburban developments, rather than the opposite trend that has manifested itself for the greater part of the last two centuries. Telecommuting is on the rise, as well as the breaking away of companies to less congested sectors, rather than clustering themselves around similar companies. Large scale development is not nearly as sexy as it used to be, with a great many small towns placing limits on the height of buildings, and studies showing the degrading effects of commercial properties near residential neighborhoods. Consumers, themselves are beginning to value the openness of the countryside, rather than the congestion of the cities, as the high rises of urban centers face a steady decline. It is essentially the factor usage of land that is slowly being reduced in a cyclical manner that is all too evident throughout the course of history within the economy. All these aspects point to a decline, at least in the U.S., of public transport elevators. The counterpoint I routinely get is that of commercial elevators, and how factories would find it difficult to survive without them. To this I say that with more and

more outsourcing taking place, as far as the U.S. is concerned it may well be on the decline as well. The global aspect is another matter entirely, but we are soon reaching a point where the industry may well need a revolution, rather than product improvement. Perhaps harnessing electro-magnetism to drive elevators (in so much as they are pushed upwards rather than pulled) may be the next stage of development. Otis reportedly is spending a lot on elevator research and development, but how much further can we take this relatively simple concept? The space elevator seems to be a good candidate to revolutionize the industry, more so from the lessons learned in developing the structure, rather than its execution.

Few would agree with me on the points stated above, and to the disagreeable, I leave a simple quote: "An economist is an expert who will know tomorrow why the things he predicted yesterday didn't happen today." -Laurence J. Peter (1919 - 1988).

Elisha Otis Patent Source: Wikipedia <http://www.answers.com/elevator>



(Table1) Selected timeline source: <http://www.theelevatormuseum.org/timeline.htm>

2900 B.C.	The Great Pyramid of Cheops at Giza, one of the Seven Wonders of the Ancient World, covered over 13 acres and was built to a height of 481.14 feet. Stones weighing as much as five tons were moved into place with primitive lifting mechanisms. Some accounts cite the involvement of 4,000 stonemasons and 100,000 laborers.
2500-1500 B.C.	Water of the Nile was ladled into irrigation ditches by use of a counterweighted lever -- the shaduf
3500-600 B.C.	Tiered temples common to Sumerians, Babylonians and Assyrians were built of brick with the lowest tier being as high as 500 feet. A shrine was at the summit.
600 B.C.	Temple of Diana in Ephesus used a ramp of sandbags to raise almost 2,000 stone columns supporting the roof of the edifice.
285 B.C.	A 300-foot-high lighthouse on the island of Pharos in Alexandria's harbor served as a beacon for ships in the eastern Mediterranean. One of the Seven Wonders of the Ancient World, it remained a navigational aid for 1,600 years.
236 B.C.	Greek mathematician, physicist and inventor Archimedes designed several hoisting devices incorporating windlasses and the block and tackle. He was best known for the Archimedean screw with crank to lift water and other light material..
100 B.C.	Treadmill powered by teams of men operated block and tackles on a crane to lift material for Haterii's Tomb.,
50	The water wheel with a horizontal axis was developed, driven by the force of flowing water.

<b>1203</b>	A treadmill hoisting machine powered by donkeys was installed at the Abbey of Mont St. Michel on the French seacoast.
<b>1690</b>	French engineer Denis Papin developed the idea of using steam to pump water out of mines. He invented the high-pressure steam boiler in 1707.
<b>1698</b>	Capt. Thomas Savery, a military engineer, refined a steam pump, the vacuum of which lifted water out of English mines subject to flooding..
<b>1712</b>	English ironmonger Thomas Newcomen designed an atmospheric steam engine that pumped water from deep mines. One built in 1739 to pump water from a French mine lifted as much in 48 hours as had been raised by 50 men and 20 horses working around the clock for a full week!
<b>1743</b>	A counterweighted personal lift was commissioned by Luis XV to be built linking his apartment in Versailles with that of his mistress, Madame de Chateauroux..
<b>1765</b>	James Watt patented and perfected a steam engine..
<b>1774</b>	Englishman John Wilkinson's mill facilitated the boring and manufacture of cylinders for steam engines.
<b>1782</b>	James Watt invented the double-acting rotary steam engine. Watt and partner Mathew Boulton installed the first rotary motion steam engine in a cotton spinning mill in Papplewick, Nottinghamshire..
<b>1796</b>	Englishman Joseph Branah invented the "U" leather-packing cup making the piston efficient within the cylinder..
<b>1819</b>	Danish physicist Hans C. Oersted discovered electro-magnetism.
<b>1821</b>	Faraday discovered the fundamentals of electromagnetic rotation..
<b>1823</b>	Burton and Horner built an "ascending room that led to a 37-meter-high platform upon which a maximum of 20 paying visitors discovered an exceptional panorama of London."
<b>1827</b>	Wilhelm August Julius Albert performed the first tests upon iron wire rope..
<b>1829</b>	American physicist John Henry constructed an early version of the electromagnetic motor..
<b>1833</b>	Burgomaster Durrell of Clausthal in the Harz Mountains developed a system whereby men were raised and lowered by reciprocating rods extending the length of the mineshaft up to 200 meters. Two years later, the depth was about 420 meters..
<b>1835</b>	Englishman William Barnett patented the compression of a gas charge before igniting. He later patented a two-stroke engine..
<b>1835</b>	The famed "Teagle" belt-driven, counterweighted, steam-driven lift was developed in England by Frost and Stutt..
<b>1841</b>	John Roebling introduced the manufacture of wire rope in America, primarily for bridges. He was one of the first to provide wire rope for the elevator industry in 1862..
<b>1844</b>	Two hydraulic stage tables were installed in the Vienna Opera House..
<b>1845</b>	Sir William Thompson conceived and patented the idea of the first hydraulic crane. His first crane was used to handle cargo at the Newcastle docks with roped sheaves providing a 3:1 ratio..
<b>1845</b>	British engineer William M'Naught developed the first compound steam engine.
<b>1846</b>	The first hydraulic industrial lift driven by water pressure appeared.
<b>1847</b>	The German electrical firm of Seimens and Halske was formed..

<b>1847</b>	The first parachute (safety) was invented by the Frenchman Marchecourt. The device, preventing the mine cage from dropping when the suspending rope broke, was first put into service two years later in Decize Mines. It was improved in the same year by Fontaine, workshop manager in the Anzin coal mines..
<b>1850</b>	Henry Waterman of New York City was credited with inventing "standing rope control" 1851 -- George Fox and Company of Boston introduced idea of self-locking worm gear to drive an elevator drum hoist.
<b>1851</b>	To remedy insufficient water pressure from the city water mains, Sir William Armstrong developed the first "accumulator" -- in this instance, a large diameter vertical piston supporting a huge wrought iron bucket filled with stones. The weight of the bucket, load and piston upon the water a steam engine had pumped into the accumulator assured a steady supply of pressure of as much as 700 psi.
<b>1851</b>	George Fox and Company of Boston introduced the idea of self-locking worm gear to drive an elevator drum hoist.
<b>1854</b>	Elisha Grave Otis demonstrated the first safety elevator at the New York exposition in the Crystal Palace proving elevator travel for passengers was safe.
<b>1856</b>	William H. Thompson and Eustus P. Morgan patented their "Safety hatch for warehouses," a system of sliding or hinged hatch doors placed in the opening of each floor, reducing the spread of fire.
<b>1857</b>	Otis Elevator Company recieved the first order for a passenger elevator. They had only made freight elevators ince 1853 when they opened.
<b>1857</b>	The first elevator for public use was a steam-driven type installed by Otis Brothers in the five-story department store on Broadway for E.W Haughtwhat & Company.
<b>1860</b>	Augusto Stigler founded an engineering company in Milan. First Stigler electric elevator was installed in 1898.
<b>1860-1864</b>	The five-story Grosvenor Hotel at Victoria Station in London was the first hotel to install lifts using city water pressure. The clientele initially termed them "ascending rooms."
<b>1862</b>	Otis Brothers developed a new "Patent Hoisting Engine" having two vertical steam-fed cylinders situated below a crankshaft upon which was keyed a pulley. A belt from this sheave drove the winding drum located on the same bedplate..
<b>1861-1866</b>	Otis Tufts abandoned improvements upon his vertical screw lift drive and with five new patents addressed safe lifting with multiple hoist ropes. He concentrated upon equalization of two or more ropes, reduction in rope bending and longer lasting connection within the drum..
<b>1862</b>	First funicular railway was built by Frenchmen Molinus and Pronier in Croix-Rousse, Lyons. Its slope was 16 degrees and it traveled 1,530 feet.
<b>1863</b>	Baker Street Station opened and London becomes the first city to develop an underground railway (subway).
<b>1863</b>	William Miller patented the first elevator using worm rack integral with car platform for lifting and preventing fall of car.
<b>1864</b>	William Smith of Philadelphia patented the first worm-driven winding drum.

<b>1865</b>	The British firm of Easton and Amos installed a direct-action passenger lift, with a travel of 56 feet, in the Brighton Hotel.
<b>1865</b>	American Morgan Willard patented a system whereby screws on either side of the car extended the length of the elevator shaft. Unlike the Miller system, the screws turned (not unlike the Otis Tufts "Vertical Railway" patented in 1859 where the screw was in the center of the car). The screw(s) supported the car should power fail. The Ashcroft Brothers improved upon this system in 1868, as did William Edison (assignor to E.H. Ashcroft) in 1869.
<b>1865</b>	When the six-story Grand Hotel in Paris installed hydraulic elevators, the city pressure was so low a gas engine had to be installed to keep water pressure up to the required level. Two years later, the system was replaced by Leon Edoux.
<b>1866</b>	Otis Tufts developed a system of three spring-loaded roller guides at four points of rail contact on the car assuring a snug fit and reducing either sway or binding. In the same year, Tufts patented an improvement in guide rails, citing the need for a smooth, quiet ride in hospitals..
<b>1867</b>	Campbell, Whittier & Company began production of the Miller Patent Screw Lift Machine with capacities from 2000 to 8000 pounds.
<b>1867</b>	Leon Edoux displayed at the Universal Paris Exhibition the "first secure direct action hydraulic elevators." His elevator carried visitors to an observation platform 65 feet high. The four hollow cast iron columns guiding the lift were also containers for four counterweights, attached to chains that ran over sheaves down to the car. This made the passengers "secure"!
<b>1867</b>	Atmospheric gas engines developed by Otto & Langen were awarded the Gold Medal for "the most economical power for small business."
<b>1867</b>	The Miller Patent Screw Hoisting Machine was marketed by Campbell, Whittier & Company of Massachusetts and received a Gold Medal at the Lowell Fair.
<b>1867</b>	Werner von Siemens developed the shuttle armature for generating alternating current. Called the "dynamo," it paved the way for the universal use of electrical heavy current..
<b>1868</b>	Otis Brothers patented its own variation of the worm-driven drum.
<b>1868</b>	Construction of the New York City subway started..
<b>1868</b>	Waygood manufactured its first hydraulic elevator. Richard Waygood founded the company in 1842.
<b>1869</b>	William E. Hale patented and introduced the "Hale Water-Balance Elevator" in Chicago. Its novelty -- using the force of gravity for its operation.
<b>1870</b>	The hydraulic spur-gear drive was introduced..
<b>1870</b>	C.W. Baldwin patented The Hydro-Atmospheric of water balance elevator; it employed the weight of water, not its pressure as motivation.
<b>1870</b>	The nine-story Equitable Life Assurance Society Building, tallest in New York City, became the first to have passenger elevators specifically designed by the architect for office building use. Otis Tufts' two steam elevators cost a bit less than \$30,000. Almost 2,500 people used the elevators the first day!

<b>1870</b>	Lane & Bodley, manufacturers of steam- and hand-powered elevators since 1860, commenced making direct hydraulics operating off city water supply. In 1872, they exhibited their design at the Cincinnati Industrial Exposition. By that time, they and two other hydraulic manufacturers had installed about 100 such units in the area, making Cincinnati a center of elevator manufacturing with a trade area of several hundred miles.
<b>1871</b>	Albert Lucius of New York City designed and patented the first hydraulic-driven rack and pinion utilizing a horizontal cylinder.
<b>1871</b>	The Great Chicago Fire destroyed 18,000 buildings in the city center..
<b>1871</b>	The British Parliament gave a group of London Merchantmen the monopoly power to establish the Wharves Warehouse Steam Power and Hydraulic Pressure Company. In 12 years, it laid seven miles of mains along the Thames with 700 pounds of pressure being generated against water by the Falcon Wharf Pumping station.
<b>1872</b>	Timothy Stebins designed and patented a rack and pinion machine driven by a vertical hydraulic piston. By changing gear size, the carrying capacity and speed could be modified.
<b>1872</b>	The first vertical geared hydraulic elevator was installed -- in New York City.
<b>1872</b>	German engineers, Nickolas August Otto and Eugene Langen, began marketing a two-cycle gas engine. Although 5,000 were sold, its size allowed use only at a permanent site.
<b>1874</b>	Wire hoist ropes were first used in the mines of the German Harz Mountains.
<b>1874</b>	U.S. Patent No. 147,853 was issued to J.W. Meeker for counter-balanced steel doors used in protection of freight elevator hoistways.
<b>1875</b>	Philander P. Lane and Samuel R. Smith assigned to manufacturers Lane and Bodley in Cincinnati a patent for the first pull roped hydraulic elevator system. Leakage from the cylinder head could not fall upon the hoist ropes.
<b>1875</b>	Holske patented a device that shifted the gears, rather than belts, in an elevator machine's reduction gearing. Although the New York City inventor's claims were "fully substantiated" in newspaper reports, the mechanism was never put to practical use.
<b>1875</b>	The nine-story Western Union Telegraph Building in New York City introduced mixed usage elevators including two New York Safety Passenger Elevators by Otis Brothers, each with a 30 hp steam engine. Cyrus W. Baldwin designed the third passenger elevator for the use of Western Union employees, constantly on the move. During his distinguished career, Baldwin had received over 35 elevator-related patents. Four related directly to the Western Union contract. William Ellery Hale purchased the patent for the Hydro-Atmospheric Elevator installed as the third elevator, this system becoming known as the Hale Water Counterbalance Elevator. Operating through the force of gravity, it could approach speeds of 1500 fpm. Although operated within more sensible limits, it was the ideal elevator for the young boys delivering telegrams!
<b>1875</b>	Nicolas August Otto built the first commercially successful four-cycle gas engine, immediately patenting it in the U.S. and the U.K.

<b>1875</b>	Schindler -- to become the world's second-largest elevator manufacturer -- was founded when Robert Schindler opened a machine shop on an island in the River Reuss, near Lucerne.
<b>1877</b>	Traction drive invented by Friedrich Koepe, a German mining engineer, in the Ruhr Area by German Patent No. 218 1878 -- Leon Edoux's four direct-action hydraulic elevators in the --Trocadero Towers at the Universal Exposition had three times the travel of any previous lifts. Each cabin could carry 60 passengers to a height of 280 feet. A large steam engine in the base of each tower returned water to a tank at the peak. Edoux's demonstrations had no equal on either side of the Atlantic!
<b>1878</b>	First electric elevator was built by Siemens in Mannheim, Germany and patent issued same year to Seimens and Halske.
<b>1878</b>	Charles Hill Morgan patented a direct-action hydraulic elevator and installed the first such type in the Washburn & Moer Wire Works in Worcester, Massachusetts.
<b>1880</b>	To connect separate stores of the Grande Magasins du Louvre in Paris, a small tramway was installed in a tunnel under the intervening Hotel du Louvre. Cabins were placed on the interior railway by hydraulic elevators.
<b>1881</b>	Werner von Siemens connected a steam engine to a dynamo.
<b>1881</b>	Edison displayed a 300 hp steam-driven dynamo at the Paris Exhibition.
<b>1882</b>	Otis Tufts installed his first "Vertical Screw Railway," driving a screw that extended the length of a shaft way. A passenger car was fastened to the traveling nut.
<b>1882</b>	A 1000 hp direct-connected steam-driven dynamo was installed by Siemens in the West Berlin Power Station.
<b>1882</b>	Englishman Hart developed idea of a continuous human bucket elevator called "The Paternoster." 1884 -- J & E Hall installed the first Cyclic lift (Paternoster) in England.
<b>1885</b>	The Home Insurance Building in Chicago became the first steel skeleton type building with bolted construction.
<b>1885</b>	Prof. G. Forbes obtained Patent No. 1288 for the first carbon brush.
<b>1886</b>	First concept of a gearless elevator machine was a U.S. patent by Reynolds.
<b>1886</b>	Victor Popp, an Austrian engineer, created a compressed air network in Paris, supplying a driving force for craftsmen, public clocks and some elevators that were termed, "Aero-hydraulics."
<b>1887</b>	William Baxter is reported to have installed the first American electric elevator in the U.S. The lift was probably provided with an electric motor manufactured by Frank Alvord Perret, whose Elektron Mfg. Company was founded in Brooklyn the previous year.
<b>1888</b>	Charles Platt made an attempt to solve the high-rise electric elevator problem by mating a horizontal cylinder roped machine with a motor-driven screw that forced a traveling nut and attached sheaves apart. Frank Sprague developed the motors and control .
<b>1888</b>	Otis Brothers & Company introduced electric operation for hydraulic valves, deriving power from storage batteries.
<b>1888</b>	J. Richard & Company installed a direct-action hydraulic lift with a travel of 134 feet in the Columbus Monument in Barcelona, Spain.

<b>1889</b>	At the Paris Universal Exhibition, the Gustave Eiffel Tower contained five steam-driven hydraulic elevators -- two by Roux-Combaluzier, two inclined Otis elevators and one Edoux with one car balancing another.
<b>1889</b>	An electric elevator built by Chretien for the 1889 Paris Exhibition was installed in the tower pylon at the entrance to the Gallery of Machines.
<b>1889</b>	The Hall of the Machines at the Paris Exhibition costing as much to create as the Eiffel Tower, included electrically driven moving platforms running the length of the hall.
<b>1889</b>	Otis produces the first AC operated elevator in New York City.
<b>1889</b>	Amiot introduced his curved staircase private elevator at the Paris Universal Exhibition.
<b>1890</b>	De Bueren, a Frenchman, is said to have installed the first gearless elevator in New York City's German-American house.
<b>1890</b>	Japan's longest travel elevator was installed in the country's tallest structure -- the 12-story Ryoukaka Tower.
<b>1890</b>	Otis entered the U.K. market under the name American Elevator Company. At this time, the American company's other offices were Otis Brothers in New York City and Hale Elevator Company in Chicago.
<b>1890</b>	The Tacoma Building in Chicago became the first steel skeleton building with riveted construction.
<b>1890</b>	Houghton Elevator Company was founded in Toledo, Ohio, specializing in steam and hydraulic elevators.
<b>1891</b>	Roux-Compaluzier built a direct-action hydraulic in Paris' Alma Hippodrome to lift lions from cages into the arena in a reenactment of the Christian martyrs in the Roman Coliseum.
<b>1893</b>	At the Chicago Columbian Exposition, Jesse Reno presented his "mobile ramp," and Otis displayed an electric directed-connected drum including a range of safety devices. An electric train conveyed visitors on a track that looped around the fairgrounds and a rudimentary moving sidewalk carried those entering from the pier.
<b>1891-1894</b>	The world's first funicular railway was built at Weehawken, New Jersey to carry vehicles up a 200-foot track. Associated with the system was a tower with three roped-hydraulic elevators that would carry 130 persons each.
<b>1892</b>	Generator field controlled DC motor was first proposed by Harry Ward Leonard with a number of patents to follow.
<b>1892</b>	Forty-eight elevators manufactured by the Sprague Elevator Company of Watessing, New Jersey were the first electric elevators installed in the London Underground.
<b>1892</b>	Chicago subway -- second in the US -- opened.
<b>1892</b>	Jesse Reno designed and patented a moving inclined ramp with cleated platforms on the belt.
<b>1892</b>	G.H Wheeler invented and patented a flat-step moving stairway with a handrail.
<b>1894</b>	Waygood designed a "triple-jigger" hydraulic lift that saved water by using only the necessary number of pistons.
<b>1895</b>	The 21-story Masonic Building in Chicago became the world's tallest building, remaining so for 10 years.
<b>1896</b>	Budapest subway opened.

<b>1897</b>	U.S. Patent No. 595874 was awarded to August L. Duwelius for a gearless machine concept.
<b>1897</b>	Glasgow subway opened.
<b>1900</b>	Fraser elevators with elaborate roping were installed in Chicago's 12-story Merchants' Loan Building.
<b>1900</b>	The Paris Universal Exposition, again held at the foot of the Eiffel Tower, was the largest ever held in Europe and a two-speed moving sidewalk -- the Trottier Roulant -- looped the main sites at 2.5 and 4.5 miles per hour. Seeberger, in partnership with Otis, presented the first escalator. The exposition hastened the development of the Paris Metro with 23 stations, one at the fair.
<b>1900</b>	A patent of the present form of 1:1 roping for a gearless elevator machine was awarded to C.W. Baldwin.
<b>1901</b>	The first Otis electric drum machine elevator was imported by Takata Import Co. and installed in Japan's Nihon Seimei Building. It is now in the Tokyo National Museum 1902 -- Waygood, because of an interest in the Reno Stairway, bought shares in the Reno Company.
<b>1902</b>	The first direct plunger elevators were installed by Otis for high-rise passenger service.
<b>1904</b>	Otis introduced its gearless elevator machine 1904 -- Joseph Richmond/Carey "press button" control in England was touted to be a "first."
<b>1904</b>	The Standard Plunger Elevator Company sold 110 hydraulic elevators to the John Wanamaker Stores in New York City and Philadelphia.
<b>1905</b>	The Majestic Building in Chicago became the world's tallest building, surpassing the Masonic Temple Building.
<b>1906</b>	G. Falconi established his elevator business in Milan.
<b>1906/07</b>	Sprague and Otis combined to win order for 170 elevators for the London Underground -- each to carry 70 persons.
<b>1907</b>	First Collective Push button Control installed by Otis.
<b>1909</b>	The Blackstone and LaSalle Hotels in Chicago become the world's tallest, Chicago holding the record for 22 years.
<b>1909</b>	The 41-story Singer Building in New York City was the first in which elevator operators were equipped with telephones connected to an "elevator supervisor" who controlled departures and confirmed departures.
<b>1914</b>	Boston's first elevator code became effective.
<b>1916</b>	Otis acquired R. Waygood, the new entity becoming Waygood-Otis.
<b>1918</b>	New York City adopted its first "elevator rules" comprising 16 pages. It restricted speed to 700 fpm.
<b>1919</b>	The 60-story Woolworth Building, constructed in New York City, remained the world's tallest for 15 years.
<b>1922</b>	The Edison Company changed the current in New York City from two-phase DC to three-phase AC, generating thousands of elevator changeovers.
<b>1924</b>	A system invented by Otis allowed proper distribution and stopping of elevator cars at four m/s without any action of operator other than pressing the buttons and closing the doors.
<b>1924</b>	Otis installed the first automatic "Signal Control" in New York City. The elevator cars required no attendants.

<b>1926</b>	Haughton developed the automatic car door and gate closer. It was patented in 1929.
<b>1926</b>	The first parking garage, moving cars automatically in three directions -- Ruth Safety Garages of Chicago -- was completed in that city's Pure Oil Building.
<b>1929</b>	Japan's first gearless machine (500 fpm) was installed in the Mitsui Bank.
<b>1930</b>	Chrysler Building in New York City became world's tallest.
<b>1931</b>	New York City elevator code was revised to allow 1,000 fpm elevators in the Empire State Building. Included are 67 elevators.
<b>1932</b>	Empire State Building in New York City became the world's tallest.
<b>1947</b>	Otis and Stigler combined in Italy to become Stigler-Otis.
<b>1948</b>	Schindler entered the Italian market with a main office in Genoa and branches in Milan and Turin.

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