# BRUNEL – THE GREATEST ENGINEER?

## PREAMBLE

I have not followed a strict chronological approach in this study but have written it as a series of topics and themes. If the length seems a bit forbidding, it is possible to read sections in isolation. I have added a brief timeline to show the main events in Brunel's life.

Figures for project costs can be multiplied by 120 to give an approximate current equivalent.

## INTRODUCTION

Was it inevitable that someone christened ISAMBARD...KINGDOM...BRUNEL would become famous? Not one, not two, but three big, unusual and memorable names. And did his distinctive appearance captured in iconic photographs – stovepipe hat, frock coat, muddy trousers, cigar, confident stance, short in stature, standing in front of heavy duty chains – also help to enhance his reputation?

Certainly, they helped to create the image and he is probably one of the few engineers that most people can readily identify. However, his fame was based on more than his name and memorable appearance. As I discuss, he had his failures and personal shortcomings but, by any standards, he is justly viewed as one of the greatest figures in engineering history.

## FAMILY BACKGROUND

Brunel's father, Marc Isambard Brunel, was French, born on 25th April, 1769. From an early age his interests were in engineering and he studied at a college in Rouen. He served on a naval frigate before returning to France in 1792. He was a Royalist – and France in 1792 was not a good time or place to be a Royalist. He obtained a passport for the United States and arrived in New York in September 1793 where he started a career as a surveyor. His talents were recognised and he became Chief Engineer to the City of New York in 1796. Through an influential friend, Alexander Hamilton (Yes, he of the musical) he met a French émigré visitor who told him that the British Navy needed thousands of wooden rigging blocks (pulleys) each year (they got worn out in use) and that current supply was too slow. Marc saw an opportunity here and was already considering ways of mechanising production. This, and a desire to marry Sophia Kingdom, an English girl whom he had earlier met in France, seems to have drawn him to England and he arrived in March 1799 with a letter of introduction from Hamilton to Lord Spenser, Secretary to the Navy in William Pitt's government. With Henry Maudslay, a brilliant mechanical engineer, he designed block-making machines. Production lines were established in Portsmouth between 1803 and 1805. Ten unskilled operatives could produce as many perfect blocks as 110 craftsmen in Fox and Taylor's workshop (the established manufacturer.) The workshops became something of a tourist attraction. (Landing craft on D-Day were equipped with blocks made on the Brunel/Maudsley production line.)

Marc's output and invention was remarkable. He developed powered saws, veneer-cutting machines, army boots, steam engines, knitting machines, water-supply system for Paris, crossing for River Neva at St Petersburg. Unfortunately, not all were successful. He paid little attention to business matters, his bank became insolvent and he and his wife, Sophia, were arrested for debt and put into a debtors' prison in Southwark. He approached influential friends and threatened to leave the country for Russia. The authorities were clearly keen for Marc and his talents to remain in Britain since, with the help of the Duke of Wellington, not only were he and Sophia released from prison but were given a grant of £5000 to remain in the country.

## EARLY LIFE

Isambard Kingdom (his mother's maiden name) was born on 9th April 1806. He inherited many of his father's talents and interest in engineering. Marc wanted his son to be the very best in all that he did. He introduced him to engineering and engineers from an early age; he also ensured he was able to sketch quickly and accurately, a skill that Marc considered to be critical for an engineer. He spent time in the workshop of Henry Maudsley and was into Euclidean geometry from age eight. He was sent to board at Dr Morrell's school in Hove for his early education where he displayed gifts for drawing and maths, and also studied modern languages, Latin and Greek. A good technician education was not available in Britain, and at age 14 he was sent to study in France, initially at a college in Caen and then concentrating on science and mathematics at Lycee Henri IV, before entering the workshop of clockmaker Louis Breguet. The high standards of workmanship had a great influence on Isambard, helping to explain why for the rest of his life he always sought perfection in all that he did.

In August 1822, Isambard returned from France and started work in his father's office. His father was always a great support to him. The two of them worked on a range of projects including a cannon-boring machine for the Dutch government, a rotary printing press, paddle tugs for the River Rhine, a sawmill for Trinidad, two suspension bridges on the island of Reunion, marine engines (that later were to form the basis for larger engines in SS *Great Britain*), a gaz engine based on carbonic gas. Marc spent several years and£15000 of his own money on the last project, but it could not be made to work.

## THE THAMES TUNNEL

In 1823 Marc began work on his best-known project, the Thames Tunnel. Previous attempts to construct a tunnel under the Thames had failed. A major concern was that the strata under the Thames was unstable, consisting of mud, gravel, clay and quicksand. There was a more stable layer of rock, but this meant that the tunnel roof at mid-point would be only 14' below the river bed. Reputedly inspired by a ship worm that bores into ships' timbers, Marc designed a tunnelling shield, 36' wide and 21'4. It consisted of 36 working positions, 12 across and three storeys high. The shield supported the surrounding earth during excavation and was moved forward hydraulically.

He planned to sink a shaft at Rotherhithe, on the south side of the river, about 70' deep and lined with brick. From here miners would tunnel north with the shield whilst a group of bricklayers would construct the lining behind them, eventually meeting up with the northern shaft at Wapping. Marc was offered £1000 per year by the Thames Tunnel Company to act as engineer. The first stone was laid on 2nd March 1825.

Work was slow and laborious. Initially candles were the only form of lighting, but from March 1826 Marc introduced lamps lit from gas canisters. There were many problems – foul air (the Thames had, after all, been London's main sewer and refuse dump for hundreds of years), flammable marsh gas, keeping the work in line, water ingress, breakages to the shield...

Isambard, aged 19, was appointed Resident Engineer at salary of £200 per annum. It was an introduction to the realities and dangers of pioneering civil engineering – and potentially gave him the chance to show what he could do. At about the same time the Board chose to reduce the miners' wages. It was Isambard who convinced the men not to strike. He was excited about the project, working the fantastic hours that came to characterise his whole career and directly involving himself in resolving the many problems. There were several times when he put his life at risk - he rescued a man who had been caught in one of the floods that regularly affected the tunnel; went down in a diving bell to inspect the bed of the river; fell into a water tank and was off work for weeks. He lived dangerously.

Despite all the privations, Isambard presided over a grand banquet in the tunnel in November 1827. Directors and their guests and 120 workmen dined and listened to the band of the Coldstream Guards playing patriotic music. It was a display of defiance, confidence and bravado. In his diary Isambard wrote, *"My self-conceit and love of glory or rather approbation vie with each other which shall govern me... my self-conceit renders me domineering, intolerant, even quarrelsome with those who do not flatter..."*

Such celebrations were premature, as in January 1828 the river burst in again, and six men died. Isambard nearly drowned and was seriously injured and went to Brighton for several months to convalesce. This latest disaster drove the company into financial crisis. Isambard was depressed. Rather than the tunnel being a stepping-stone to fame for him, it now seemed he would be associated with an abandoned project. Work was suspended in August 1828 and Isambard played no further part in the project. A giant mirror was erected at the far end and the partially completed tunnel was opened to the public as a peepshow. Work did begin again in 1835, after Marc had secured a Treasury loan of £270000, and the tunnel was opened to the public in March 1843, albeit purely as a pedestrian thoroughfare. It was the first tunnel to be built under a navigable river.

## RAILWAYS

Bristol merchants were desperate to maintain their city as the second port of the country and the main one for American trade. Liverpool had always been the great competitor, with its advantage of a natural harbour, against Bristol's tendency to silt up. By 1830 Liverpool was connected to its hinterland by the Liverpool and Manchester Railway, whilst Bristol could only rely on winding roads and canals. Liverpool money was also behind schemes to build railways southwards to Birmingham and London. It was clear that Bristol, too, needed a railway linking to London. After several failed attempts to set up a railway company, a number of local merchants in 1832 finally got the venture off the ground. A public meeting was held in January 1833, funds were raised to pay for a survey and the committee started to look for an engineer.

Brunel had travelled for the first time by train in December 1831 on the Liverpool and Manchester Railway. He evidently found it a rough and jolty ride. He had no experience of designing a railway, but wrote in his notebook about the prospect of "*going noiselessly and smoothly at 45 mph. Let me try."* He saw the possibilities and opportunities in railways and the potential of technology in developing the industry. He let it be known that he wanted the job of engineer and the committee appointed him to the post on 7th March 1833 – by a majority of one. There was a proviso that he should work with William Townshend, who had local knowledge by virtue of his work as surveyor on the Bristol and Gloucestershire Railway. On 9$^{th}$ March they set out together up the Avon Valley to begin their survey. It was probably the turning point of Brunel's career and for the first time, with a salary of £2000 per year, he had considerable means of his own.

Brunel worked on the basic principle that the line needed to be as level and straight as possible to allow safe, smooth running and high speed. An "improved passenger experience" was at the centre of his design. He opted for a northern route – London,Reading, Didcot, Chippenham, Bath, Bristol. For nine weeks he worked up to 20 hours each day searching on horseback for the ideal route. William Townshend could not stand the pace.

On 30$^{th}$July Brunel presented his proposals to the company's first public meeting, with an estimate of £2.5M for the whole line. He wrote the initials *GWR* in his diary for the first time on 27$^{th}$ August 1833. He leased 53 Parliament Street in London and began to assemble office staff. He also commissioned a travelling coach or *britzka* that was large enough to house a bed, drawing board and instruments. For the next nine months he lived largely on the road, negotiating with land owners and directing staff. By January 1834 Brunel and his staff had completed basic plans and drawings for the whole line and deposited them with the Parliamentary Bills Office. GWR argued their case through the Parliamentary Committee for Scrutiny and Approvals, in the face of opposition from stagecoach and canal companies, landowners, but also from towns that were being bypassed. The first enquiry lasted 57 days and ended in defeat. The second enquiry, another 40 days during which Brunel gave evidence over several days, was successful and the Act of Parliament for construction of the GWR finally received royal assent on 31$^{st}$ August 1835.

Brunel insisted on being both engineer <u>and</u> architect. His education and skill in drawing enabled him to do this, and he always carried a sketchbook with him on his travels. He questioned the assumption that rails had to be 4'8 ½" apart (as adopted by George Stephenson because many colliery tramways in the North-East were built to that gauge). He argued that a wider gauge could accommodate larger locomotives and rolling stock with a lower centre of gravity, making it more stable, smooth and comfortable at high speeds. He proposed rails 7' apart. He also designed his own kind of wrought-iron rail and new ways of laying the track. From the start he controlled everything – design process, setting out the route, estimates, letting of contracts, negotiations with landowners, purchase of property, sale of shares.....he even designed the lampposts on the stations.

The line was divided into sections, sub-divided into contracts that were then let. It was a massive undertaking, on a far greater scale than the canals. He encountered never-ending problems and clearly felt the strain. Some of this was arguably self-inflicted, exacerbated by his desire for micro-control and pursuit of perfectionism. He complained that *"I have involved myself in a mass of novelties...no one part can be copied from what others have done...I am obliged to do it all myself."* (It seems it was not unusual for Victorian engineers to act as the single point of contact for all stages of a project.) Pressures were increased as GWR announced in August 1837 that the line from London to Maidenhead would be open by Christmas. This was wildly optimistic for by Christmas no track had been laid at all.

The Act of Parliament of 1835 provided for a joint GWR/London and Birmingham Railway terminus at Euston. Difficulties with leasing terms and the different gauges could not be resolved and the GWR terminal was moved to Paddington. Shortage of funds meant that a temporary station, rather than the grand structure that Brunel had originally envisaged, was built initially. (With an associate, Matthew Digby Wyatt, Brunel produced drawings for a much grander station in 1851. It was approved in February 1853. The design appears to have been inspired by Crystal Palace. Brunel wanted it built by Fox, Henderson and Co who were also building the Crystal Palace in Hyde Park. Much of the steelwork was produced in Smethwick and shipped by canal to London. Fox, Henderson and Co had taken on too much work and the station, incorporating a massive glazed roof in three spans supported by wrought-iron arches, was not completed until 1855. (Fox, Henderson also built the original New Street Station.)

On 31st May 1838 the first train ran from Paddington to Maidenhead and back, and the route opened to the public a few days later. GWR was at last starting to earn some income. On the eve of the opening, Brunel's anxieties were exposed. He confided in a colleague about his doubts about opening on time and the reliability of the locomotives. He was under pressure from shareholders, the company itself and supervising contractors,

Brunel made some strange and perverse specifications for the locomotives, restricting their weight and speed. They were underpowered and unreliable. Problems gradually eased as GWR took delivery of new locomotives from George Stephenson. Also, the 21 year old Daniel Gooch was appointed locomotive superintendent and started to develop his own range of reliable, fast locomotives. There were also problems with track design and carriages. Tracks had to be re-ballasted and re-laid so that they would absorb some of the impact and provide a more comfortable ride.

However, costs were soaring and criticism of Brunel mounted throughout 1838, particularly from the northern investors in Liverpool. They had watched the building of the first railways in the north and seemingly had more trust in George Stephenson and his 4'8 1/2" gauge. There was much criticism of the broader gauge, but in January 1839 Charles Saunders (the GWR secretary and a great Brunel supporter) and the directors won the vote against Liverpool opposition and Brunel and the broad gauge were saved – for the present.

Brunel and Gooch picked Swindon as the site for GWR's 'principal engine establishment', it being close to the summit of the line. Brunel designed the 'New Swindon' model village to house the workforce. A deal was struck with a local contractor to build the station and village in return for the revenue they would earn, including that for a catering concession. All the trains stopped at Swindon where the only place to eat was the 'refreshment rooms' at the station. This seemed to have started the tradition of poor railway food. Even Brunel himself wrote "I avoid taking anything there when I can help it."

Progress was slower at the Bristol end of the line, but the Bristol Committee were apparently far more generous than their London counterparts in allocations for architecture. Tunnel entrances were more elaborate; at Bristol Temple Meads Station Brunel was able to indulge in a Tudor Gothic design in contrast to the temporary affair at Paddington. He had great plans for the roof, to be built of timber and spanning 72'. It proved impossible to build a pure timber truss of such width, so the structure had to be held together with wrought-iron straps and hidden strengthening.

The line from Bristol to Bath opened in August 1840. Sections of the line required embankments, cuttings and tunnels. Box Tunnel, 1 ¾ miles through solid rock was the most difficult challenge of all. Contractors had been reluctant to tender. Gunpowder was required before miners with picks could start working in hot, damp, unventilated, fume-filled, dark and, at times, flooded conditions. Spoil had to be winched up shafts. A ton of candles and a ton of gunpowder were consumed each week. It took over three years and cost over 100 men's lives. It was completed in March 1841(the tunnel was perfectly straight and when the two sides met they were out by only 1 1/4") and was the longest tunnel in the world at the time.

The full London to Bristol line was opened on 30th June 1841. The journey from Bristol to London was reduced from two days to five hours. The first dividend was paid to shareholders that year.
It was conceived as a railway for the upper classes, with first class carriages for the gentry and second class for their servants. There was no third class.

GWR progressively acquired more subsidiary or allied companies – Bristol and Exeter line, South Devon, Cornwall, West Cornwall, South Wales, Gloucester and Dean Forest, Oxford, Worcester and Wolverhampton - in a period of 'Railway Mania'. They all appointed Brunel as engineer and, as the work grew, even he had to trust more and more to his assistants. When he died over 1200 miles of railway had been built to his design or under his direct supervision.

Like so many early railway projects, GWR was a leap in the dark. The London to Bristol line had cost more than £6M against initial estimates of £2.5M.

Brunel had some involvement in many other railway projects – Merthyr and Cardiff Railway, Cheltenham Railway, Bristol and Exeter Railway, Bristol and Gloucester Railway. He demonstrated a less attractive side of his character when he expressed his apparent s disinterest in some of these projects - *"I hold it only because they cannot do without me" and "I have condescended to be engineer."* Once Railway Mania had subsided (afterc1845) Brunel was looking overseas for work and he was involved at arms length in the Florence to Pistoia Railway, East Bengal Railway and Melbourne to Williamstown Railway.

## BRIDGES

Bristol's prosperity was rooted in trade, much of it based on the slave trade. Its merchants and bankers had played a major part in developing the triangular trade, whereby manufactured goods were shipped from Bristol to West Africa in exchange for slaves, who were then exchanged for sugar, cotton, tobacco and timber in the Americas for shipment back to Bristol. It had been highly profitable and part of the fabric of the city. The trade ceased in 1807. With Liverpool overtaking
Bristol as a trading port, the city's merchants were looking for ways of restoring Bristol's commercial position. Many of them were in a strong financial position to progress this as they had received reparation payments for the loss of the slave trade. The narrow Avon gorge between Bristol and the sea was an obstacle to communications and development of trade. The Society of Merchant Venturers advertised a competition for the design of a suspension bridge, with entries to be submitted by November 1829.

Maybe it was serendipity, but Brunel had relocated to Bristol from Brighton in 1829 (some sources suggest his parents dispatched him there because he was consorting with actresses in Brighton). He was attracted by the spectacular visual appeal of the gorge and clearly could not resist the challenge it offered. 22 plans were submitted; four were from Brunel, with spans ranging from 760' to 1180'. The widest span anywhere to date was Thomas Telford's Menai Bridge at 600'. Brunel's plans and those of four other competitors were short-listed and submitted to Telford who was to be the judge. He rejected them all, maintaining that Brunel's were unsafe as the spans were excessive. The Committee asked Telford to design a bridge himself!

Telford duly produced his design, with a central span of only 360'made possible by the construction of enormous Gothic towers rising from the bottom of the gorge. This time the people of Bristol rejected the proposal. Another competition was held and on 18th March 1831 Brunel's design was declared the winner. There was a 630' span supported on Egyptian-style towers. Brunel was appointed Project Manager and the foundation stone was laid in August 1831. In October 1831 there were riots for political reform in Bristol and investors lost confidence in the project. As a result, it ran out of money, work stopped and was not resumed until 1836. Once work restarted, to

transfer materials from one side to the other a wrought iron rod, one inch in diameter and 1000' long, was pulled across the gorge and a travelling basket, pulled by ropes, was slung underneath it. At some point it got stuck and Brunel, prepared as usual to be hands-on, went across in a basket to free it. It was brave – and good for publicity. The towers were built and suspension chains ordered. Once again the bridge company became insolvent and work stopped in 1843. This marked the end of Brunel's involvement in the venture. It is strange that the bridge with which he is most associated was not finished in his lifetime.
New techniques and materials for bridge building were being developed in the late 18th and early 19th century along with the development of turnpike roads, the spanning of rivers and canal aqueducts.

As engineer and architect to GWR, Brunel probably designed and built hundreds of bridges. Railways, even more than canals, raised new problems. There was the need to keep the line as straight and level as possible. Also, as railways were operating in an already mature landscape with roads, canals, rivers, properties, towns and so on to negotiate, many bridges were required and that in turn made railway building very expensive.

Brunel was adept at designing elegant elliptical arches and his notebooks contain page after page of detailed calculations for individual bridge designs. He understood weight distribution, stresses, ways of minimising weight and economising on materials.

His first major bridge was the Wharncliffe Viaduct over the River Brent in West London, started in February 1836. It had eight arches, each 72' wide and with hollow piers. At Maidenhead he built a bridge to cross the Thames consisting of just two 128' arches, the two widest brick arches ever built. The arches had to be kept very shallow to avoid a 'hump' in the bridge. The contractor removed the timber centring before the mortar was completely dry and a gap of half an inch opened. Brunel, always seeking perfection, ordered the contractor to jack it back up and make good. As with so many projects, Brunel was stepping where angels had feared to tread and critics were ready to argue that the design was flawed and that the arches would not stand. They were wrong as the bridge is still in use today. It was made famous in a Turner painting in 1844.

He designed and built timber bridges also, and some commentators describe him as the greatest timber engineer that Britain has ever seen. Unfortunately, none remain. They were relatively cheap to build and a way of getting companies up and running. The Swindon to Gloucester line had nine timber bridges and there were five timber viaducts on the South Devon Railway. The biggest of these was at Ivybridge with 11 openings 61' wide, carried on tall, slender masonry piers. The Llandore Viaduct, near Swansea on the South Wales Railway near Swansea was 580yards long with 37 spans carried on tall timber trestles.

His culminating achievement as a timber engineer was the 43 viaducts he designed for the Cornwall Railway and West Cornwall Railway between 1850 and 1859. He used wooden trestles where possible, but for the deeper valleys he designed tall masonry piers. The directors of the company were grateful to him because they were saving money on the initial build, but you can imagine passengers being terrified as the trains slowly crossed the creaking and flexing structures. These bridges and viaducts were massive feats of engineering, but they were expensive to maintain. They were gradually replaced, the last of them at Collegewood in 1934.

Robert Stephenson was ahead of Brunel in building iron bridges. Stephenson's first iron bridge – at Uxbridge Road in Hanwall, East London – was particularly complicated. Beams broke on two occasions and then the deck caught fire and had to be rebuilt. He designed more than 30 bridges in cast-iron, a brittle material that does not bend or pull very well. It seems that it was a material that Brunel did not trust. However, cast iron was being replaced by wrought-iron by the 1840s. It required a repeated hammering and reheating process, before being run through a rolling mill at red heat to make rods, bars, angles and plates. It has a higher tensile strength than cast-iron and is able to bend or distort in the middle.

Brunel's first large wrought-iron bridge was the Hungerford suspension pedestrian bridge over the Thames, 1841-45. Most of his wrought iron girder bridges have been destroyed
Stephenson completed the two most ambitious and technically advanced iron bridges the world had seen – Conway Bridge (1846-48) and the Britannia Bridge over the Menai Straits (1848-50). Brunel's career as a bridge designer

culminated in his widest spans – Chepstow Railway Bridge (1850-52) over the River Wye and the Royal Albert Bridge over the Tamar at Saltash (1852-59)

At Saltash the Admiralty demanded a clearance of 100' above high water. Brunel designed the bridge with two main spans of 455' each with one pier in the middle of the river. To find a base for the pier Brunel had to go down through 80'of water and mud. In simple terms, a cylinder within a great cylinder was then sunk into the river bed and the pier built up inside the inner cylinder. This procedure alone took more than two years. It was a revolutionary approach at the time, but it was to become the usual method of a carrying out under-water engineering works of this kind. The main spans consisted of huge wrought-iron cylindrical top tubes and a good deal of cross-bracing. The contractor, who had also worked on the Menai Bridge, grossly underestimated the coast of the work and went bankrupt. Brunel proceeded with directly employed labour. Hydraulic jacks were used to raise each truss into position whilst the piers were built underneath them. The total cost was £225000, compared with £602000 for the Menai Bridge.

Given the range of problems that Brunel had to solve to bring his design to fruition, the bridge is arguably the finest surviving example of his engineering genius.

The Royal Albert Bridge was opened by the Prince Consort on 2$^{nd}$ May 1859. Brunel was not there – he was on the Continent for health reasons on doctor's orders. He saw the completed bridge only once. The stark legend *"I K Brunel Engineer 1859"*was added soon after his death.

## DOCKS AND HARBOURS

Bristol docks had a tendency to silt up. The civil engineer, William Jessop, had created a new waterway – "The New Cut" – as a feeder canal to boost the water supply and a "Floating Harbour" to retain water at a consistent level. There were still problems and Brunel was asked to investigate. He produced some solutions and the Dock Company allowed him to proceed with some modest improvements, including a new dredging and sluicing system and enlarged locks. However, he considered that the Floating Harbour was basically too small (The *Great Western* and *Great Britain* were both too large to operate out of the floating harbour.) Brunel pressed the Dock Company to build new ocean-going facilities on the Severn at Avonmouth and Portbury. Work started on a pier and railway link to Portbury in 1846 but stopped again in 1852. There were vested interests who owned property in the Floating Dock area and they did not want to see it devalued.

He also designed several other dock systems. These included the dock at Briton Ferry on the Neath Estuary, to handle coal and goods from the Vale of Neath Railway, Brentford Dock, Plymouth Great Western Dock, new harbour facilities at Monkwearmouth near Sunderland, and a pier at Neyland Milford Haven that became the Welsh terminus of the GWR.

## THE THREE GREAT SHIPS

In the early 18$^{th}$ century shipbuilding was a traditional industry, something of an enclosed world. Scientific advances of the 17$^{th}$and 18$^{th}$ centuries had made little impression on the industry and it was remarkable that so much had been possible with only timber, masts, sails and rigging. But it was probably reaching its ultimate point of development.

Brunel was outside this world, just as he had been with railways, so was not a prisoner of established practices. His move into the industry was what he saw as a natural progression from Great Western Railway to *Great Western* steamship. Maybe the industry was ripe for someone like Brunel to apply the intellectual leaps that were required.

He was not necessarily the pioneer, but he applied the use of iron as a material and steam power to drive the ship. He had particular skill in combining technologies and ideas to create something unique and revolutionary. He looked at the optimum size of the ship – he examined the relationships between the size of hull, size of engine, fuel required, the days' fuel that a ship could carry and the resistance of the sea. Several people were starting to work on the application of steam to ships' propulsion, including Marc Brunel.

The accepted wisdom was that no ship-big or small- could carry enough coal to cross the Atlantic. But Brunel realised that the bigger the ship the more favourable the energy to weight ratio would be. In simple terms, four times the surface area equals eight times the volume. The larger the ship, the more economic it became.

***SS Great Western***

The merchants of Bristol saw the potential of New York and the United States as a source of riches but needed a high-speed transatlantic service to move the goods. In 1836, directors of GWR in Bristol set up the Great Western Steamship Company to build a ship capable of crossing the Atlantic. The idea excited Brunel's interest from the start. His view was, "We've built a railway from London to Bristol; why stop there?" It might be seen as a very early integrated transport system. A building committee was set up consisting of Thomas R Guppy (an engineer turned sugar refiner), Christopher Claxton (semi-retired Royal Navy officer), William Patterson (local shipbuilder) and Brunel. The ship was to be 236' long, constructed of oak with a copper-sheathed hull. Brunel's main contribution was in the design of a pair of engines to drive twin paddle wheels 28' in diameter. The engines were manufactured by Maudslay, Son and Field in Lambeth and the hull at William Patterson's shipyard on the floating harbour in Bristol. Dr Dionysius Lardner, a self-appointed authority on all things scientific and technological, probably reflected prevailing opinion when he maintained that an Atlantic crossing was *"chimerical, and they might as well talk of making a voyage from New York or Liverpool to the moon."*

In defiance of Lardner's doubts, the *Great Western* was launched on 19 July 1837 and sailed to London for the engines to be fitted. This was completed by March 1838. Meanwhile, other companies had been converting existing ships to compete with her (having realised that maybe it WAS possible to cross the Atlantic). One of these, the Sirius, set off for New York on 4th April. *Great Western's* departure was delayed by an engine-room fire and she did not leave Bristol (with just seven passengers on board) until 7th April. Not surprisingly, Sirius won the 'race'- perhaps an incipient blue riband - by a few hours. *Great Western* had 200 tons of coal left, proving the advantage of steam power over sail and that it WAS possible to cross the Atlantic by steam. *Great Western* went into regular and profitable service for her owners, making 67 crossings in eight years. She crossed the Atlantic in about 14 days compared with the six weeks that had hitherto been required.

Some commentators argue that Brunel's reputation may well have over- exaggerated his role in the creation of the *Great Western.* He was, after all, preoccupied with the Great Western Railway
throughout its construction. But he always did have a remarkable capacity to multi-task.

***SS Great Britain***

The company started to develop their ideas for their next ship as a running mate for the *Great Western* and to compete with the newly- established Cunard line on the North Atlantic. The building committee was the same as that for the *Great Western*, but Brunel played a far greater part, focussing especially on the interior structure of the hull, the engine and the propeller. They were considering an iron construction, knowing that wrought iron could now be produced on a large scale. An iron hull had only about 70% the weight of an equivalent timber hull and was drier and thinner. Many draft designs were produced and these culminated in the largest and most innovative hull design the world had ever seen – and Brunel was doing all this whilst building the Great Western Railway. The hull was of a two-skinned cellular construction, with six watertight compartments running across the hull and two longitudinal bulkheads. The keel was laid in Patterson's yard at Bristol on 19th July 1839. Against Brunel's wishes the company decided that the engines should be designed and manufactured by Francis Humphrys. He soon ran into problems and found that there was no hammer in the world big enough to forge the main drive for the paddles. Brunel approached his friend, James Nasmyth, who invented the steam hammer for the purpose, one of the key innovations behind Victorian heavy engineering.

In May 1840, an experimental vessel, the *Archimedes*, arrived in Bristol. It was the world's first propeller-driven ship. Brunel was immediately interested and the directors suspended work on the paddle engines and chartered the *Archimedes* for six months of trial voyages. Brunel realised that a propeller made more efficient use of energy.

Humphrys was told to stop work (he died shortly afterwards). Brunel designed the 1500hp engines himself and they were manufactured on site by the company. Brunel also designed a six-bladed propeller, 15' in diameter.

The *Great Britain* was launched by the Prince Consort in July 1843, after four years of delays, revisions and spiralling costs, and was moved to the Floating Harbour for initial fitting out. Stonework had to be removed so that the 322' x 51' ship could reach the Avon on 12 December 1844. She then sailed to London for fitting-out to be completed. Unique in being the first wholly iron ship driven by screw propeller, it made its maiden voyage to New York in July 1845 in 14 days. She was too big to be operated out of Bristol (and the Dock Company refused to make the necessary improvements to accommodate ships of such size and wanted to impose very heavy dock charges) , so was moved to the rival port of Liverpool. She was prone to excessive rolling and propeller breakages. Her first season on the Atlantic, of only two round trips, was a financial and technical disaster. Alterations were made but there were still severe technical problems. In September 1846 the ship ran aground in Ulster. The Great Western Steamship Company was in poor financial health and did little to move the ship. Brunel insisted on a protective barrier of wood being built to preserve it from the waves. The ship was refloated in August 1847 but by then the company was already ruined. The Company sold the ship in 1849.

***SS Great Eastern***

The *Great Eastern* dominated the last six years of Brunel's life. It was his ambition to design the world's largest ship. The Australian Mail Steam Company approached him about designs for a ship that would only need to take on coal once, at the Cape of Good Hope. Brunel wanted to go further than this and started thinking about how big a ship would need to be to carry its own fuel for a journey to the Middle East and back. This would require an enormous ship. He finalised his design in late 1853 – a ship 692'long, 18915 tons in weight, with room for 4000 passengers and 3000 tons of cargo, powered by a single propeller and paddle wheels, supplemented with sails. It was six times the size of the *Great Britain*, itself the biggest ship in the world when it was launched.
Brunel was convinced that demand would appear once the ship was built and he approached Eastern Steam Navigation Co. The company had been founded to bid for mail contracts for the Far East but had lost out to P and O. Brunel convinced them that he could offer another way forward and by 1854 ESNC had become the vehicle for construction of his great ship. With a number of friends, including Charles Geach, a banker and ironmaster, and Henry Thomas Hope, a wealthy conservative MP, he set about reconstructing the company and selling shares.

It was a massive commitment, unprecedented and a step into the unknown. Did they really consider how many ports could accommodate such a vessel? Would they fill the cargo space? Or the passenger space? It looked like a super-ambitious act of faith.

In 1852 Brunel had tentatively estimated the cost of the ship at £500,000. Tenders were invited in May 1853. Only one company, John Scott Russell's, tendered for building the entire ship – for £377200. This was accepted by Brunel – there was, after all, no one else. The contract specified that the ship must be built in a dock. There was not one big enough, but Russell agreed to build one at a cost of £10000. His estimate was clearly over-optimistic. Eventually Russell and Brunel agreed to build the ship on timber launching ways - a series of massive beams set on piles driven into the Thames foreshore. This committed them to a sideways launch – and this was to pose major difficulties. It must have been an extraordinary site for Londoners as construction of the *Leviathan* (the original name) progressed on the side of the Thames. Scott Russell and Brunel were at loggerheads throughout the build, not least because Scott Russell seemed determined to take all the glory for building the ship. By February 1856 Scott Russell was insolvent. Most of the contract price for the hull had been paid but only half of it had been built. ESNC took over the yard and work resumed with Brunel himself managing the completion and launching of the ship. The ship was ready for launching in autumn 1857. Scott Russell had favoured launching the ship down greased timber launching ways, in the traditional manner. Brunel thought this was dangerous. He had iron plates fitted to the underside of the launching cradles and iron rails fitted to the launching ways. A system of pushing and pulling, using hydraulic presses and winches, would lower the ship to the low water mark to then be floated off at high tide. That was the theory.

To Brunel's displeasure, directors of ESNC sold tickets for the event. Regrettably, it was a massive anti-climax. The ship moved just a few feet and a labourer was killed by flying debris. After Brunel's assistants had scoured the country for more hydraulic plant, the ship finally floated on 31st January 1858. The vessel had cost £600000 (Brunel having put much of his own money into the ship) and the launch had cost £120000, with another £200000 still needed to install the engines (built by James Watt&Co of the Soho Foundry, Birmingham) and fit her out. ESNC was unable to raise this. A new company, the Great Eastern Ship Co, was formed and bought the incomplete vessel from ESNC for £165000. ESNC went into liquidation with enormous losses.

In late 1858 Brunel and his family went abroad, his doctors having told him that he must spend the winter in a warm climate. Scott Russell had mysteriously revived his business and, in Brunel's absence, his tender to fit out the *Great Eastern* was accepted by the Great Eastern Ship Co, much to Brunel's consternation. When Brunel returned he found the work was in chaos and far behind time. Despite his failing health, he took command of the work once again so that the ship was finally able to sail on 7th September. The omens were not good from the start as a massive explosion a few days later killed five stokers.

Once again Brunel had explored the limits of technology. The ship was a masterpiece of design, bringing together for the first time a range of innovative features including a double-skinned hull, transverse bulkheads, longitudinal strength and ' luxury' passenger accommodation. She embodied much of the future of shipbuilding and, until the *Lusitania* was launched in 1906, it remained the largest movable man-made object in the world. Unfortunately, she was just too big for her time. She could not get through the Suez Canal (opened on 1869) and never operated the Far Eastern routes for which she was designed. The vessel operated on the North Atlantic but lost money on both the passenger and cargo business, and suffered many misfortunes, including storm damage and running aground. She did come into her own as a cable-laying ship between 1867 and 1874. For several years she served as a music hall and floating advertising hoarding on the Mersey. Even the shipbreakers lost money when they destroyed her in 1889.

Brunel was probably the only man in the world who could have imagined such a ship, designed her in detail and brought her into being. It has been called *"his ultimate triumph... and his greatest folly"* and *"the ship that killed Brunel."*

He said himself that *"I never embarked in any one thing...on the success of which have staked so much reputation...and that required for its conduct and success that it should be entrusted so entirely to my individual management and control..."*

## THE RENKIOI HOSPITAL

In February 1855, Brunel was approached by the War Office to design a temporary, prefabricated hospital for the Crimea that could be built in England and then shipped out for erection on the chosen site. Within a few weeks he had designed a system whereby each element could be carried by one or two men and assembled by an unskilled workforce. John Brunton, one of Brunel's assistants, and 30 men from the Army Works Corps, sailed for the Dardanelles and found a site. Demonstrating his organisation skills and drive, Brunel orchestrated matters in Britain, got components and a small group of men shipped out and gave Brunton precise instructions, telling him not to *"let anything induce you to alter the general system and arrangement that I have laid down."* Despite a shortage of reliable local labour, a hospital of 1000 beds with modern sanitation and air conditioning was built by December. It was in use for only a few months, but was the blueprint for so many prefabricated structures since.

## ARCHITECT and DESIGNER

Drawing and design was a part of Brunel's early education. Throughout his life he produced immaculate detailed sketches and architectural drawings that demonstrated his interest in the aesthetics as much as the engineering aspects of his projects. His sketches were often accurate enough to be used in the final design.

He saw the creation of the GWR not only as a great commercial and technical undertaking, but also as a project with great artistic potential. It was to offer a picturesque tour through the south and west of England. His designs were eclectic; stations and other buildings along the route were in the style of Tudor lodges, fashionable villas, country houses, medieval ruins, Italianate mansions. Tunnel entrances were built in classical, Romanesque and Gothic styles.

He opted for an Egyptian style for the pylons of Clifton Suspension Bridge. He certainly did not want Temple Meads to be merely functional. It should celebrate the grandeur and significance of the GWR. He wanted a grand and ornamental frontage and submitted two alternative designs for Temple Meads Station. A Tudor Gothic design was eventually selected, but much reduced in scale and ambition for cost reasons.

He also wanted an impressive train shed at Temple Meads, covering platforms, waiting and luggage areas in one single span, and constructed in timber. Wrought-iron plates were required as strengtheners, but demonstrated again the Brunel was not just interested in stone and iron, but admired the old ways of country life, landscape and the beauties of nature. There was an element of the romantic in his work that contrasted with the objective facts, materials and construction methods that he relied on as an engineer.

In July 1836 he married Mary Horsley, the daughter of a cultivated, well-connected family, with many artists and musicians in their circle. Increasing wealth enabled him to spend money on lavish decorations and furnishings at his house and office in Duke Street, Westminster, London – a chamber organ, artworks, porcelain, Venetian chandeliers, bronzes, neo-Gothic dining rooms...

He bought land at Watcombe near Torquay in 1847. He developed and improved the estate, and apparently was a model landlord, building cottages for his staff, planting trees and paying for their holidays. He planned to build a chateau-style house and produced detailed architectural plans for this. Unfortunately, he saw only the foundations completed before he died in September 1859.

## A FEW ODD JOBS

Brunel had many projects going on at the same time. Some of the lesser-known ones that he managed to fit in were:

- Frustrated that railway timetables could not be reliably produced because time was not consistent across the country, he promoted the standardisation of time by basing it on GMT
- Designed a floating iron barge and gunboats for use in the Crimean War. However, a lack of interest on the part of government prompted one of his frequent brushes with the Admiralty who, needless to say, refused to move at his pace. It appears he was hostile to any state interference.
- When the Crystal Palace was moved and reconstructed in Sydenham in South London, Brunel designed the 200' water towers that were required to feed the fountains in the surrounding gardens. (The towers were finally demolished in 1941 as it was thought they would present a target for German aircraft.)
- He built an observatory for the astronomer, Sir James South, on the site of what is now Observatory Gardens in Kensington.

## FAMILY

In July 1836 Brunel married Mary Horsley, daughter of the composer William Horsley. Shortly after the wedding they set up home and office in Duke Street, Westminster. Draughtsmen and clerks were housed in a detached building in the garden. They had three children - Isambard (b 1837), Henry Marc (b 1842) and Florence Mary (b 1848). Isambard became an ecclesiastical lawyer and Henry Marc entered an engineering apprenticeship with Sir William Armstrong and became the structural engineer for Tower Bridge. Mary died in 1881.

## 1859

1859 was a fateful year in all senses for Brunel. Two of his greatest projects came to fruition with the opening of the Royal Albert Bridge in May and the launch of the *Great Eastern* in September.

The last known photograph of Brunel, looking thin and frail, was taken on the *Great Eastern* on 2$^{nd}$ September 1859. He collapsed on the ship on 5$^{th}$ September and died at home at Duke Street on 15$^{th}$ September. Some accounts suggest glibly that he died from stress and overwork caused by building the *Great Eastern.* Certainly his physical and mental health deteriorated whilst building the ship. He had been sick for some time and, on doctors' orders, had spent the winter of 1858/9 in Italy, Egypt and the Mediterranean. He more likely died from a kidney condition, exacerbated by 40 cigars a day and the aftermath of numerous serious accidents.

## FAILURES AND FAILINGS

Brunel's career was not one of unbroken achievement. Many of his projects were well over budget, late and dogged with difficulties along the way. One or two of them had to be abandoned altogether. His dealings with contractors, employees and investors were also difficult at times. At the risk of exaggerating these failures and shortcomings, I have gathered them together. They demonstrate that it was perhaps inevitable that someone as imaginative, innovative and radical as Brunel, who pushed engineering and construction technology (and the forbearance of those he worked with) beyond the limits of possibility, would have failures and disasters along the way.

**The Atmospheric Railway**

There was a railway in Ireland, just two miles long, that was worked by an atmospheric system. In simple terms a slotted pipe was laid between the rails, and the leading vehicle of each train carried a piston that ran inside this pipe. A large stationary steam engine pumped the air out of the pipe ahead of the train so that it was driven along the line by atmospheric pressure acting on the back of the piston – effectively it was sucked along. The pressure was maintained by a longitudinal leather flap along the slot. In theory it could cope with steeper gradients and was more efficient as it did not need a heavy locomotive. However, it was a difficult technology. The vacuum was created in an engine house that could be several miles away and, critically, the system depended on maintaining a perfect seal to create the vacuum. Notwithstanding these limitations, Brunel, always the risk-taker, decided that it was worth trying out on a bigger scale in England. He planned to use it on the South Devon line – Exeter, Teignmouth, Newton Abbott – where he believed steam locomotives might struggle on the steeper gradients. The pipe was laid down and eight pumping stations were built, one every three miles. Trains started to run in September 1847 but very soon troubles began. The continuous leather flap that was used to create the seal was affected by weather conditions and deteriorated, causing leaks. The engine houses had to work so hard that the system became prohibitively expensive. There was no feasible solution and, whilst he liked to think that nothing was incapable of improvement and ultimate success, even Brunel had to admit defeat on this occasion. The project was abandoned in August 1848 and the line was converted to locomotive traction. Investors lost their money.

**Battle of the gauges**

Nothing would divert Brunel from his belief in the broad 7' gauge. It was a battle that he would ultimately lose.

The Midland Railway and the London and Northwest Railway opposed the GWR bid to bring broad gauge into the Midlands. A Royal Commission was set up to consider the two competing gauges. The broad gauge GWR engines clearly won on speed, but these services were seen as being primarily for first class passengers. By the time the Commission reported in 1846, 274 miles of broad gauge line was in operation against 1901 miles of standard line. 4'8 1/2" was to be <u>the</u> national standard from now on. GWR was on the defensive and would need to make out a special case if they wanted to build anything other than standard width in the future.

Despite the Royal Commission's decision, Brunel still refused to admit defeat. He and Gooch designed and built a massive locomotive, the *Great Western*, which covered the journey from Paddington to Swindon at an average speed of 59 miles per hour, far exceeding what had been achieved on rails before and apparently confirming his claims for broad gauge. The *Great Western* was developed into the Iron Duke class of locomotives that hauled the first express trains in the world. Unfortunately, although Brunel had much support for broad gauge in the West Country, he still could not win over all the narrow gauge operators in the Midlands and North. In 1863 the narrow gauge West Midland Railway was taken over by Great Western and because it was essential to move through-traffic over this line from London, narrow gauge line had to be laid inside the broad gauge from Oxford to Paddington. This clearly was not a long-term solution and spelled defeat for the broad gauge, though it was not finally abolished on his old main line to the west until 1892. Commercially, broad gauge was a failure but, arguably, it forced the narrow gauge proponents to make improvements in terms of speed, safety and comfort.

**Not so grand designs?**

Some critics take a jaundiced view of his success as a shipbuilder. The technological commitment and achievement was immense. However, his involvement in the *Great Western*, the most successful of the vessels, was relatively limited, whilst the two ships in which he had a critical role were commercially unsuccessful. Similarly two major projects with which his name is most associated – the Thames Tunnel and Clifton Suspension Bridge-were not completed by him. The obituary that appeared in the Engineer immediately after his death commented, *"Notwithstanding the number and imposing character of his works, many of them, often indeed through no fault of his own, have proved unsuccessful."*

**Personal failings**

Even the most pro-Brunel writers have to concede that Brunel was not the easiest of people to live – or work – with. In attempting to explain his character and motivation, the following are some of the descriptions, many of them intended to be less than complimentary, that various writers have used. It should be added that many of these could have been written by Brunel himself, as entries in his journal show him to have been well aware of his own shortcomings.

*Complex character, self-doubt (he talked about his 'blue devils, insecure (, unorthodox, uncompromising, driven, unjust, ambitious, <u>wanted</u> to be famous, obsessed with personal glory, snobbish, controlling, micro-manager, self-publicist, loved any spotlight, perfectionist, obstinate, over-optimistic, not prepared to listen to reason, obsessive about his projects, workaholic, emotional, quick to anger, afraid of failure, reluctant to delegate, arrogant, egotist, authoritarian with those he considered to be his social inferior, paranoid....*

At the same time, some point out, he had a softer side to his personality. He could be light-hearted, had a sense of humour, being fond of jokes and pranks, and was a fond and affectionate father who regretted not seeing enough of his family.

**Employees**

He was a tough taskmaster who could not understand why those working for him could not achieve similar high standards and work unconscionably long hours. He could be brusque with employees; some called him a bully. He expected his assistants to faithfully reproduce his sketches into presentation drawings for boards and committees. In a letter to a would-be employee, he said he must *"consider their whole time...at the service of the company" and "liable to instant dismissal should they appear to me to be inefficient from any cause whatsoever"* and *"a great want of industry is that of which I principally complain."* Equally, he was loyal to his most trusted employees – for instance, Daniel Gooch, his locomotive superintendent, Joseph Bennett the linchpin of the office who stayed with him from 1835 until his death, assistants William Bell and Robert Brereton – who gave him their support and trust in return. He had a strong sense of his responsibilities as an employer. He regretted having to get rid of young engineers when the railway boom had crashed. He expected much of his employees, but at the same time did not expect them to do anything that he was not prepared to do himself.

**Contractors**

One commentator has said that *"Brunel's approach was to starve all contractors of funds to keep them subservient."* He was certainly hard on contractors, insisting on high standards and strict interpretation of his contracts. He would withhold payment for the smallest infractions, vary terms and conditions without expecting to pay extra and would order contractors to dismiss anyone he found not meeting his standards. His defence was that he had absolute responsibility to directors and shareholders. Two contractors on the GWR spent many years in litigation with Brunel. Hugh McIntosh sued Brunel for £100000 unpaid. It dragged through the courts for 20 years until the House of Lords finally found in McIntosh' favour and awarded him the £100000 plus costs plus interest. William Ranger similarly won his case eventually. Many others were declared bankrupt as a result of Brunel’s unreasonable behaviour and demands. It seemed to be the contractors who took the biggest risk of all in bringing Brunel’s ideas to fruition.

**Investors**

Many investors also seem to have lost money. One less than charitable obituary in the Morning Chronicle said that he was *“a favourite with those very shareholders whose pockets he so unceasingly continued to empty.”* And an obituary in The Engineer, shortly after his death, maintained that *“Judged...by the financial results of the vast sums of money the expenditure of which he controlled, Mr Brunel was almost uniformly unsuccessful.”* Adrian Vaughan believes that *“his perfect taste, his insistence on only the best workmanship, his obsession with his status and his frequent changes of mind and grievous mistakes cost his shareholders dear*.” A contemporary critique in the Quarterly Review called him *“the very Napoleon of engineers, thinking more of glory than profit.”* Daniel Gooch provided a defence in this regard*: “The commercial world thought him extravagant, but although he was so, great things are not done by those who sit down and count the cost of every thought and act.”* It also has to be said that Brunel invested- and lost- much of his own money in schemes, if only to demonstrate how much faith he had in them and therefore encourage others to follow.

**Health and safety**

Death and injury was seemingly a regular and accepted cost of industrial progress in the nineteenth century. Brunel’s working methods were probably no more dangerous than those of his engineering contemporaries. It is not known exactly how many men died in the course of his projects but, as mentioned earlier, it is said that the Box Tunnel alone accounted for 100 deaths. There were even tales of a riveter being sealed up in one of the *Great Eastern’s* watertight cells. There is little doubt, however, that he was concerned for the safety of his employees and contractors, on several occasions taking extreme risks, and suffering injuries, to rescue men who were in danger. In some recently discovered letters he even shows concern for the environmental impact of the industrial revolution.

## LEGACY

Many works have stood the test of time and remain as his monument:

- Royal Albert Bridge over the River Tamar at Saltash
- Hundreds of miles of railway network in England and Wales
- Railway stations, tunnels, bridges and viaducts. On the route of the original Great Western Railway alone we can see Paddington Station, Bristol Temple Meads Station (his original terminus is now an enterprise hub called the Engine Shed), Box Tunnel, St James Viaduct, Bath, nine-arch viaduct at Chippenham, Swindon Railway Village, several stations
- Wharncliffe Viaduct, Maidenhead Bridge, Gatehampton Railway Bridge
- Thames Tunnel. Completed by Marc Brunel. Became a railway tunnel in 1869 and is now part of London Overland
- Clifton Suspension Bridge. Designed by Brunel. Completed in 1864 after his death. Towers do not have his intended Egyptian style and the deck built of wrought-iron rather than the timber Brunel had envisaged. The suspension chains from Brunel’s demolished Hungerford Bridge were incorporated in Clifton Bridge.
- Ss *Great Britain* went through several changes. Served as emigrant ship to Australia, laid up, engines removed, became sailing ship, then storage facility in Falklands. In 1970 towed back to Bristol. Following massive restoration is now a major tourist attraction/museum.
- All of his timber bridges and viaducts have now been replaced. The last to be demolished was The Loughor Viaduct near Gorseinon in 2013, though a small section has been preserved.

Brunel is probably one of the best-documented engineers in history. He left a huge archive of letters, research notes, engineering plans and drawings, sketchbooks, office diaries, calculation books. He also kept a journal that provided an insight into his innermost thoughts, insecurities, frustrations and ambitions.

He is commemorated in many statues, a university is named after him and locomotives, roads, shopping centres and schools bear his name.

The topmast of the *Great Eastern* is now a flagpole at the entrance to Anfield (bought at auction in 1889 by Everton F C, the first residents at Anfield).

## THE GREATEST ENGINEER? – WHAT MADE HIM SPECIAL

Had the Guinness Book of Records been around in Victorian England, Brunel's name would have appeared with boring regularity in the lists of superlatives...THE FIRST...THE BIGGEST...THE FASTEST... THE LONGEST.

And there are many features of his work that, taken together, make him exceptional, if not unique.

**The range and versatility of his work**

Many other engineers, contemporaries of Brunel, have lasting prestige – Robert  Stephenson, George Stephenson, Thomas Telford, Joseph Locke, Joseph Bazalgette, John Crowley, John Whitworth. However, Brunel's reputation overshadows that of all of them. They are all renowned in their field; but in all cases this is in just one, or maybe two, fields.  The near-contemporary who came closest in terms of versatility was probably Sir George Armstrong (presented by Peter Calver last September).

However, Brunel was super-versatile, adept in many disciplines – civil engineer, mechanical engineer, architect, nautical engineer, project manager, structural engineer, surveyor..... Had he been around 50 or so years later there is no doubt that he would have been involved in the development of aircraft.

He pushed the cause of prefabrication, mass production and multi-disciplinary design practice. He designed and built 1200 miles of railway systems, including tracks in Ireland, Italy and Bengal; built 25 railway lines, five suspension bridges, 125 other bridges, eight pier and dock systems, three ocean-going ships, an observatory, water towers, the Crimean hospital, much of Swindon. To make matters even more demanding, he took on multiple large projects simultaneously, often immersing himself in every detail at every stage. And for good measure he apparently managed the hotel at Paddington Station for a time!

It would be impossible for one individual to achieve this range of activities now. How do Clive Sinclair, Bill Gates, Richard Branson, James Dyson....match up as modern-day equivalents?

**The size and daring of his projects**

Many of undertakings were monumental, dangerous and unprecedented. Never one to spurn the impossible, he was determined to design on a grand scale.  *"Whatever was fullest of engineering perils had the greatest charms for him."*(Quarterly Review) He was always restless and ambitious to move on to new, complex, challenging projects

No other engineer can claim to have bridged gorges, created tunnels under rivers, built a 700' ship side-on to a river....and put himself in so many hazardous situations.  It appears that he had an understanding of the behaviour of structures that gave him the confidence to attempt work that other engineers might reject.

**The longevity of his projects**

As seen in the Legacy section above, much of his work is still in evidence.  We are still using his railways, tunnels and bridges.

He opened up global travel and communications. Jeremy Clarkson declared, *"Darwin told us where we came from, but it was Brunel who took us where we wanted to go."* He led the way in an engineering revolution that changed the world for ever and, effectively, made the world a smaller place.  His ships were massive leaps of faith, not totally successful in themselves, but the pioneers of modern ocean travel. He was prepared to wrestle with massive technical problems and so make progress easier for those who followed him.

**Innovation**

He was a compulsive innovator – everything he picked up he wanted to do differently and better than everything that had gone before. Progress and innovation were his strongest motivators. Conditions were right for him to apply his ingenuity, radical thinking and energy to a range of technologies – machinery, application of science, steam power and coal – that were being born at the same time in the early nineteenth century.

Academic and engineer Chris Wise says of him, *"He took people straight from the medieval to the industrial age as he cut the journey time from London to Bristol from two and a half days to two and a half hours."* and Gooch said he was a man with –*"the greatest originality of thought and power of execution."*

James Dyson talks about the contribution he made to research and development - *"with the propeller, Brunel took the design and progressively refined it by adding elements, seeing if it made a difference, until it was near-on 92% efficient."*

He was particularly adept at combining technologies. Someone had thought about building ships from iron before Brunel and someone had come up with the idea for a screw propeller. It was Brunel who had the imagination to combine and refine the two technologies.

His sketchbooks suggest that all the all the original design work emanated from Brunel. But even he could not do it all alone and he clearly depended on skilled engineers, draughtsmen and clerks to help convert the designs into reality. He never had large numbers of staff working for him; one source suggests that he never operated with more than 36 directly employed people.

*The Engineer*, not always a fan of Brunel in his lifetime, argued that "*his reputation was largely due to the application which he had made of the ideas of others."* Clearly intended as a criticism, this comment unwittingly identifies one of Brunel's greatest skills.

Perversely for someone who excelled at new ideas, he was against the patent laws as he felt they stifled the spread of knowledge and invention. He never took out a patent to protect his own inventions.

**Great Powers of Persuasion**

To initiate and finance many of his projects he needed the support of Parliament, the public and shareholders. He was a formidable advocate, speaker, networker and raconteur who clearly had great powers of persuasion to get people to believe in him and his vision. He was a member of the Athenaeum Club where he enticed the great and the good to back his projects. One of those who heard his submissions for approval of the Great Western Railway said, *"I do not remember ever having enjoyed so great an intellectual treat as that of listening to Brunel's examination."*

**Peer approval**.

He evoked envy and criticism, and even ridicule, from some contemporaries, and this is evident in some obituaries. But he attracted the respect of his professional rivals. His contemporary, Robert Stephenson (1803-59), was steady, cautious, unflamboyant, temperamentally the opposite of Brunel. But they were friends. Brunel helped Stephenson with the Menai Bridge and Stephenson helped Brunel with the *Great Eastern.* There was a cooperative spirit amongst engineers despite the commercial rivalry.

He was elected a Fellow of the Royal Society at age 26. He was probably amongst the youngest FRS ever – the youngest living member now was elected at the age of 32.

A survey conducted amongst engineers by *The Engineer* in 2016 placed Brunel top of "the most influential engineers of the last 160 years."

**Popular approval**

He has a legendary status and is probably Britain's most recognisable engineer.

In 2001 the BBC ran a poll inviting people to vote for their "greatest ever Briton". The top ten nominations were the subject of ten one-hour films. Brunel was sponsored by Jeremy Clarkson and came second only to Sir Winston Churchill. Remarkable, given the average individual's perception and understanding of the engineering profession. Other engineers in the top hundred were Frank Whittle (42), George Stephenson (65), James Watt (84) and Barnes Wallis (95). Interesting to see some of the favourites; Boy George was placed 46. What names would a similar poll generate 20 years later?

And, of course, Kenneth Branagh appeared as Brunel at London Olympics opening ceremony in 2012.

## CONCLUSION

In simple terms Brunel can be seen as a flawed genius.

*"Over his career, Brunel contrived great triumphs and equally great failures. Everything about him was exaggerated; he vividly displayed both the strengths and deficiencies of genius. He reasonably believed that he knew more, across a wider range of engineering fields, than almost anybody he encountered...only Robert Stephenson...was greeted as a peer*." (Stephen Fox)

However, I am sure that the legendary status is warranted by the sum of his achievements. Yes, there were failed projects and personal faults, but the extent, range and daring of his work make him quite rightly one of the greatest engineers. Dan Cruickshank sums him up - *"one of the most inspiring and compelling figures of the 19th century. A man born into the old world yet pivotal in the creation of the modern age...."*

**Main Sources**


| | |
|---|---|
| Brunel – The man who built the world | Steven Brindle |
| The Ocean Railway | Stephen Fox |
| Brunel – A pocket biography | L T C Rolt |
| Great Britons – Brunel essay | Jeremy Clarkson |
| Isambard Kingdom Brunel – Engineering Knight Errant | Adrian Vaughan |
| Brunel – Building a Great Britain | Channel 5 documentary |

# Brunel Timeline

| | |
|---|---|
| **1806 9 April** | Isambard Kingdom Brunel born in Portsmouth |
| **1820** | Sent to college and lycee in France. Apprenticed to watchmaker Louis Breguet |
| **1822** | Returns from France and a starts work in father's office |
| **1823 September** | Marc Brunel finalises scheme for tunnel under River Thames |
| **1825 2 March** | Work starts on Rotherhithe shaft of Thames Tunnel |
| **1826 3 January** | Appointed Resident Engineer for Thames Tunnel |
| **1828 11 January** | Second major flooding of tunnel. Brunel seriously injured |
| **1828 August** | Work on tunnel suspended |
| **1829 November** | Submits four entries for competition for Clifton Suspension Bridge. All entries rejected by Thomas Telford, the judge |
| **1831 16 March** | Brunel's revised design for Clifton Bridge is accepted. Work starts – but then very soon stops |
| **1831 5 December** | Takes first train ride, on Liverpool and Manchester Railway |
| **1833 7 March** | Appointed engineer to Bristol Railway Company |
| **1833 30 July** | Publishes route for Bristol Railway (later re-named Great Western Railway) |
| **1834 25 July** | Great Western Railway company's first parliamentary bill rejected by House of Lords |
| **1835 31 August** | GWR's second parliamentary bill receives royal assent |
| **1835 October** | Presents ideas for 7ft railway gauge to GWR directors<br>First proposes idea of building steam ship to cross Atlantic |
| **1835 December** | Appointed engineer for Hungerford Footbridge |
| **1836 February** | Work starts on GWR at the Wharncliffe Viaduct, west London |
| **1836 5 July** | Brunel marries Mary Horsley |
| **1836 July** | William Patterson begins building steamship *Great Western* to Brunel's design |
| **1837 22 July** | *Great Western* launched at Bristol |
| **1838 31 March** | *Great Western* makes first voyage under steam. Brunel seriously injured following a fire in the engine room |
| **1838 7 April** | *Great Western* embarks on maiden voyage |
| **1838 23 April** | *Great Western* arrives in New York |
| **1838 31 May** | GWR runs its first train from Paddington to Maidenhead |
| **1838 November** | Starts work on design of a hull for a new steamship, the future *Great Britain* |
| **1839 7 January** | Meeting of GWR shareholders votes to retain broad gauge track |
| **1839 19 July** | Keel *of Great Britain* laid in Bristol |
| **1841 March** | Box Tunnel completed |
| **1841 30 June** | GWR runs first continuous train service from Paddington to Bristol |
| **1842 1 July** | Bristol and Exeter railway opens from Bridgwater to Taunton |
| **1843 19 July** | *Great Britain* launched in Floating Harbour Bristol |
| **1844** | Brunel appointed engineer to several railway companies |
| **1844 1 May** | Bristol and Exeter Railway opens to Exeter |
| **1845 Spring** | Work begins on South Devon atmospheric railway |
| **1845 1 May** | Hungerford Footbridge opens to public |
| **1845 26 July** | Maiden voyage of Great Britain to New York |
| **1847 August** | South Devon atmospheric railway opens between Teignmouth and Exeter |
| **1848 February** | Atmospheric railway opens from Teignmouth to Newton Abbott |
| **1848 19 August** | Brunel recommends atmospheric traction be abandoned |
| **1849 May** | Work starts on Brunel's Chepstow Bridge |
| **1850** | Begins work on designs for Paddington Station |
| **1852** | Produces design for bridge over Tamar at Saltash |
| **1852 March** | First calculations and sketches for *Great Eastern* |
| **1852 July** | Appointed engineer to Eastern Steam Navigation Company |
| **1853 November** | Appointed to design two water towers for new Crystal Palace |
| **1853 22 December** | John Scott Russell signs contract to build *Great Eastern* |
| **1854 16 January** | First train leaves new Paddington Station |
| **1854 May** | Work starts on Tamar Bridge, Saltash |
| **1854 May** | Keel laid for *Great Eastern* |

| | |
|---|---|
| **1855 16 February** | Brunel asked by War office to design prefabricated hospital for Crimea |
| **1855 May** | Prefabricated hospital built at Renkioi in Crimea |
| **1856 19 September** | Scott Russell resigns, leaving Brunel in sole charge of work on *Great Eastern* |
| **1857 1 September** | First span of Tamar Bridge floated into position |
| **1857 3 November** | Abortive attempt to launch *Great Eastern* |
| **1858 31 January** | *Great Eastern* floated out on high tide |
| **1858 10 July** | Second span of Tamar Bridge floated into position |
| **1859 2 May** | Royal Albert Bridge, Saltash opened to traffic |
| **1859 5 September** | Brunel collapses on board *Great Eastern* |
| **1859 15 September** | Brunel dies at home at Duke Street |

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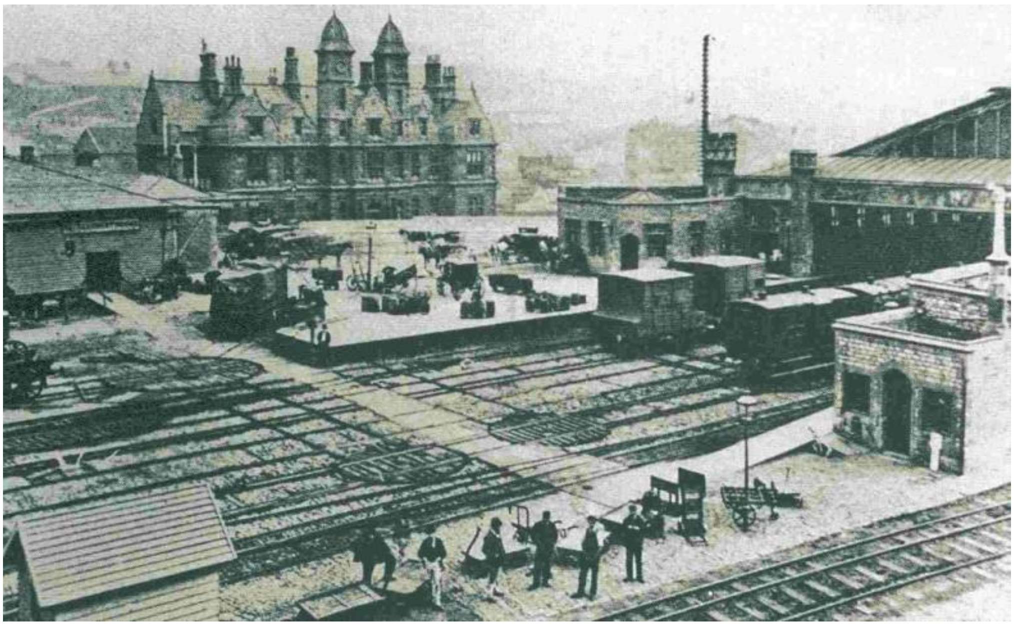
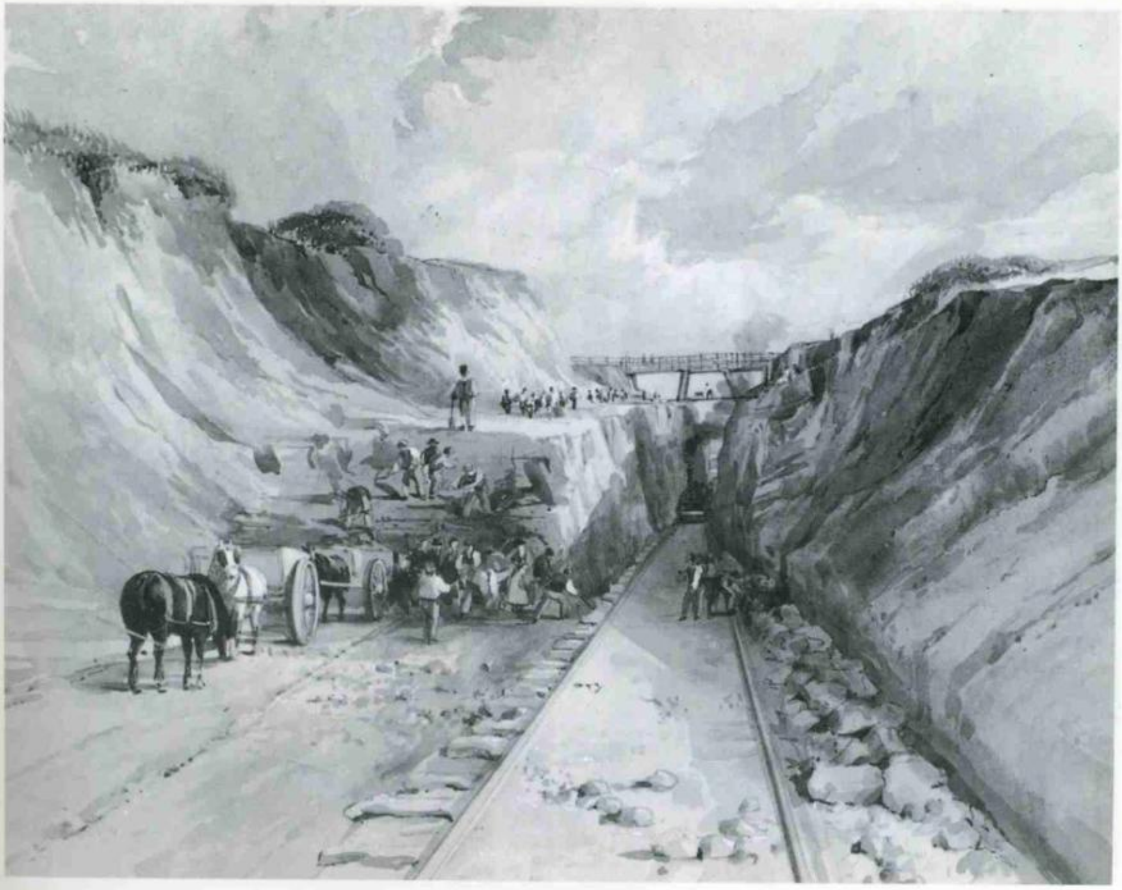


**Figure 1Building Temple Mead Station**


**Figure 2 SS Great Britain**

13. Making a cutting on the Great Western, 1841

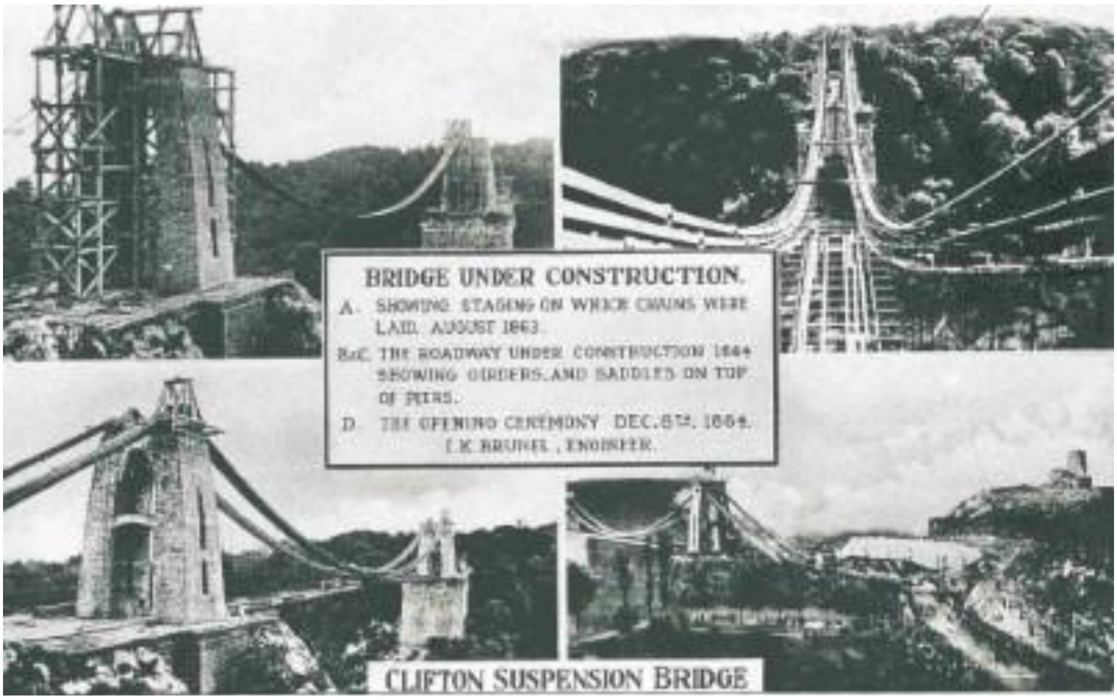



**Figure 3 Clifton Suspension Bridge**