Cost Overruns on Early Canal & Railway Projects [1]

Patrick Weaver

Introduction

A previous paper ***The Origins and History of Cost Engineering***[2] identified a range of deficiencies in the estimating, and cost control, of early engineering projects. These deficiencies were particularly noted in the United Kingdom (UK) during the canal mania of the late 1700s, followed by the railway mania of the early 1800s. This paper takes a closer look at these two classes of project.

J. A. Sutcliffe, in his ***Treatise on Canals and Reservoirs***, published by Law and Whittaker, London, 1816[3] has this to say at page 168 *"Had the engineer told the subscribers at first what would be the fatal consequences of this canal……..; and had he given them a true statement of the expense, and a rational estimate of the probable quantity of tonnage [to be shipped on the canal], most likely the spade would never have been put into the ground; but whether giving this kind of plain, useful information, is any part of the engineer's creed, I leave the subscribers to judge by his estimates."* Similar comments could easily be applied to the early railway projects, although as this paper will show, the causes may be different.

The difficulties in determining a realistic cost for a new class of project are understandable. But, significant transport projects in the UK pre-date the industrial revolution by many decades. This suggests that in addition to the lack of empirical cost information, the problem with the cost estimates identified in ***The Origins and History of Cost Engineering*** may have been caused, or exacerbated, by various combinations of poor governance, questionable ethics[4], and optimism bias. The same set of issues that continue to plague many modern megaprojects such as the London Crossrail[5] project.

[1] How to cite this paper: Weaver, P. (2022). Cost Overruns on Early Canal & Railway Projects; *PM World Journal*, Vol. XI, Issue V, May.

[2] Download ***The Origins and History of Cost Engineering***: https://mosaicprojects.com.au/PDF_Papers/P207_Cost_History.pdf

[3] Download ***Treatise on Canals and Reservoirs***, by J. A. Sutcliffe: https://mosaicprojects.com.au/PDF-Gen/A_Treatise_on_Canals_and_Reservoirs.pdf

[4] Daniel Defoe published: ***An essay upon projects*** in 1697 which discusses projects from the year 1680 onwards (but also recognizes there were earlier projects). The essay discusses the Projectors (in today's language entrepreneurs) responsible for raising funds for their pet projects, often in less than flattering terms [page 11]: *Wherefore 'tis necessary to distinguish among the projects of the present times, between the honest and the dishonest*. See: https://books.google.com.au/books?id=-5oxAQAAMAAJ

[5] The Crossrail construction project will become the Elizabeth Line when operational. Operation with end-to-end services are now expected in May 2023, a delay of 4 years and a cost overrun of £4 billion: https://www.crossrail.co.uk/

The objective of this paper is to identify and understand the reasons for the cost control challenges on many of the canal and railway projects built between the 1760s and 1840s.

Project timeframes

The canal and railway projects discussed below occurred in the same general timeframe as second phase of the industrial revolution; the transition from water power to steam power. Richard Arkwright is credited with building the prototype of the modern factory in 1769 when he established Cromford Mill as the world's first water-powered cotton spinning mill. Water powered factories quickly spread along suitable rivers. The transition to steam power from the late 18th century on, removed the dependence on flowing rivers, and facilitated the concentration of industries and the expansion of cities. The factories and cities created a demand for both the transport of raw materials (particularly coal) to the city, and then the shipping of manufactured materials to market. This demand initially created a need for more canals and wagonways, and then steam powered railways.

There were very few canals in the UK prior to the boom in canal construction between the 1790s and 1830s. Most of the earlier canals were designed as simple improvements to the navigability of a river, and were described as *navigations*. Despite construction cost overruns, most canals were initially profitable. The factor that ended canal boom was a new round of technological advances that allowed the widespread construction of efficient railways.

The oldest of the large-scale transportation systems in the UK were the wagonways (alternatively spelled as waggonway). Most wagonways were built between a mine and a river wharf and were used to transport coal, or ore, from the mine down to ships or barges for onward transportation to market. The first wagonways were built in the 16th century, and the concept continued to be viable through to the 19th century.

Wagonways were initially constructed as horse drawn railways using timber rails, later various forms of iron rail were introduced, and by the 19th century, most of the horses had been replaced by steam powered locomotives. The first steam powered railways were the result of converting a horse powered wagonway to steam power. Based on these early successes, the use of steam power spread remarkably quickly:

- The first viable steam locomotive was created in 1812
- The first intercity railway opened in 1830, and
- The railway mania discussed below was in full swing by 1840.

The challenges of managing factories also caused major changes in the way businesses were managed and controlled, these aspects are discussed in two previously published papers and will only be lightly touched on here:

- ***The Origins of Modern Management***[6] looks at the way production was organized from Egyptian times through to the present day.
- ***The Origins of Modern Project Management***[7] considers the specific factors that created the profession, or practice, of project management as we know it today.

Engineering requirements

Building canals (artificial waterways), wagonways, and later railways, involved significant engineering and surveying challenges first to identify a viable route with manageable gradients, and then cost the engineering works needed to deliver the project. Many of the engineered deliverables are similar, canals, wagonways and railways all involve cuttings, embankments, tunnels and bridges of various kinds. But given the rapid spread of first canal construction, then railway construction, the outcome of each project was very much dependent on the skills of the engineer appointed to undertake the work - there was very little in the way of standards, or established practice to draw on.

Land surveying was well established by the 16th century, but there were few maps in the detail needed for a canal or railway. The use of triangulation to create accurate maps did not start until the second half of the 18th century and many of the maps created were treated as state secrets due to their potential military use[8]. Most of the surveys for canals and railways were undertaken by the engineer who then designed the project, provided cost estimates, and supervised the work. In most cases, the engineer was employed by the person, or company, funding the project and engaged the project workers on behalf of the employer.

The design process was also very dependent on the skill of the engineer. While there were clearly well-established heuristics for different types of structures, the concept of modern engineering design was not formalized until the 18th century by French mathematician Gaspard Monge. He published *Géométrie descriptive* (1798), which is regarded as the first book to formalize orthographic projection and descriptive geometry. Orthographic projection is a way of accurately representing three-dimensional objects using two dimensional drawings, usually a top view (plan), a front view and one side view (elevation)[9]. And, as discussed in ***The Origins and History of Cost Engineering***[10], the techniques of cost estimating and control were not formalized until the early 20th century.

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6 Download ***The Origins of Modern Management***: https://mosaicprojects.com.au/PDF_Papers/P050_Origins_of_Modern_Management.pdf

7 Download ***The Origins of Modern Project Management***: https://mosaicprojects.com.au/PDF_Papers/P050_Origins_of_Modern_PM.pdf

8 For more on land surveying see: https://en.wikipedia.org/wiki/Surveying

9 See ***The Origins of Schedule Management*** (page 3): https://mosaicprojects.com.au/PDF_Papers/P202_The_Origins_of_Schedule_Management.pdf

10 Download ***The Origins and History of Cost Engineering***: https://mosaicprojects.com.au/PDF_Papers/P207_Cost_History.pdf

Canals

Until the industrial revolution, canals were not particularly important in the UK, most of the significant developments occurred in China and Europe. Canal knowhow was imported to the UK and used on some early river navigations, but true canal[11] construction did not start until the middle of the 18th century. The success of the first four canals built in the UK, discussed below, was the trigger for canal mania.

1742: the Newry Canal, located in Northern Ireland appears to be the first true canal built in the UK and opened in 1742. It was built to link the Tyrone coalfields to the Irish Sea at Carlingford Lough near Newry, via Lough Neagh and the River Bann. There were issues with the lock construction, the width of the summit level section of the canal, and the water supply. Later, a ship canal was opened below Newry in 1769, and both Newry and the canal flourished for a time. This canal was authorized by the Commissioners of Inland Navigation for Ireland, and was publicly funded.

1779: the Stroudwater Navigation appears to be the next significant canal constructed in the UK. It links the town of Stroud in Gloucestershire to the Severn Estuary. The original plans authorized by Act of Parliament in 1730 were based on making the small River Frome, also known as the Stroudwater, navigable. This plan was strongly opposed by mill and land owners who were concerned about the navigation reducing flow of water in the river and harming their businesses. After a delay of 80 years, the project was redesigned as a canal which opened in 1779 at a cost of £40,930. The Stroudwater is eight miles in length and has a rise of 102 feet and 5 inches requiring numerous locks. Coal was the main cargo carried.

The canal company had run up debts to cover the construction cost, but these were cleared by 1786 when a dividend of £7.50 (5%) was paid to shareholders. Dividends were then paid regularly occasionally exceeding 20 per cent, until competition from railways in the 1880s caused a major decline. The last toll was paid in 1941 and most of the canal formally abandoned in 1954[12]. The Stroudwater Navigation connects to the Thames and Severn Canal at Stroud to form a link between the River Thames and River Severn. Both canals are in the process of being rehabilitated for the pleasure use.

1757: the Sankey Canal, also known as the Sankey Brooke Navigation was the first British canal of the Industrial Revolution. The canal was eventually extended to connect St Helens, Lancashire, with Spike Island in Widnes[13]. The Act of Parliament authorizing the construction of the *navigation* was passed on 20 March 1755, and the canal was opened in stages between 1757 and 1773.

The original canal started where the Sankey Brook joins the River Mersey at Warrington, and followed the Sankey valley to end at Parr, north east of St Helens. It was primarily intended for

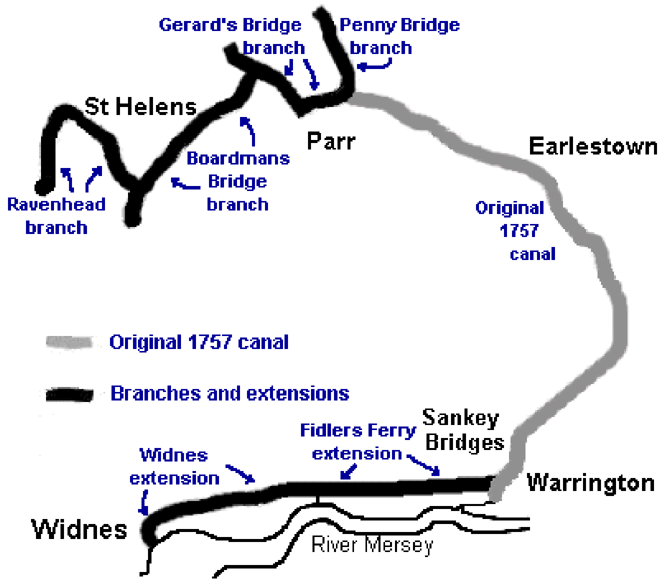
[11] For the purposes of this paper, the term navigation applies to works designed to improve the navigability of a river or stream. A true canal is an artificial body of water, largely independent of natural waterways.

[12] See: https://www.cotswoldcanals.net/stroudwater-navigation-history

[13] See: http://www.penninewaterways.co.uk/sankey/sa2.htm

the transport coal from Haydock and Parr Collieries to the growing chemical industries of Liverpool. Over time the canal was extended, and branches bult, to service additional collieries.

The canal was a financial success and quickly became an important factor in the industrial growth of the region. Industries expanded, and spread along the line of the canal to St Helens, Haydock, Newton le Willows, and Widnes. In addition to sending out coal, it was used for bringing in raw materials for the various chemical works that grew up all along the route, including a concentration of glassworks in St Helens.



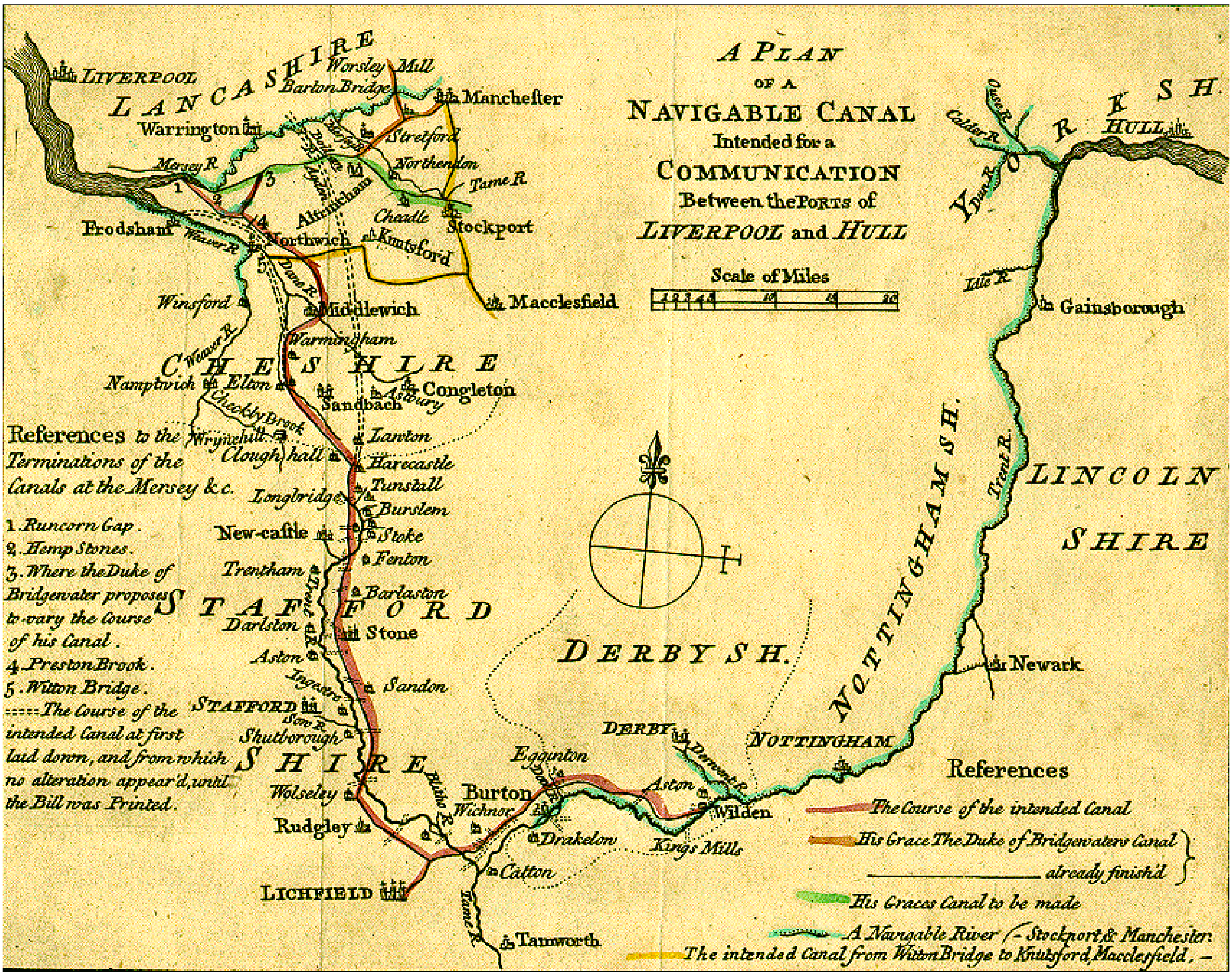
In 1830, the company faced competition when construction started on a railway between St Helens and Runcorn Gap, Widnes. The canal company's response was to go ahead with a further 3-mile extension from Fidlers Ferry to Widnes, which opened in 1833, five months after the railway. The canal extension, with its twin locks onto the Mersey, proved very successful, while the railway's business was disappointing. A toll-cutting battle almost left the railway bankrupt and it was obliged to merge with the canal in 1845 to form the St Helens Canal and Railway Company.

The canal continued to carry more tonnage than the railway for many years. Sugar was still being carried to the Sankey Sugar Company in Earlestown until the 1950s but after that trade ceased the canal was officially abandoned in 1963. The Sankey Canal Restoration Society (SCARS) was formed in 1985 to try to prevent further deterioration and begin restoration.

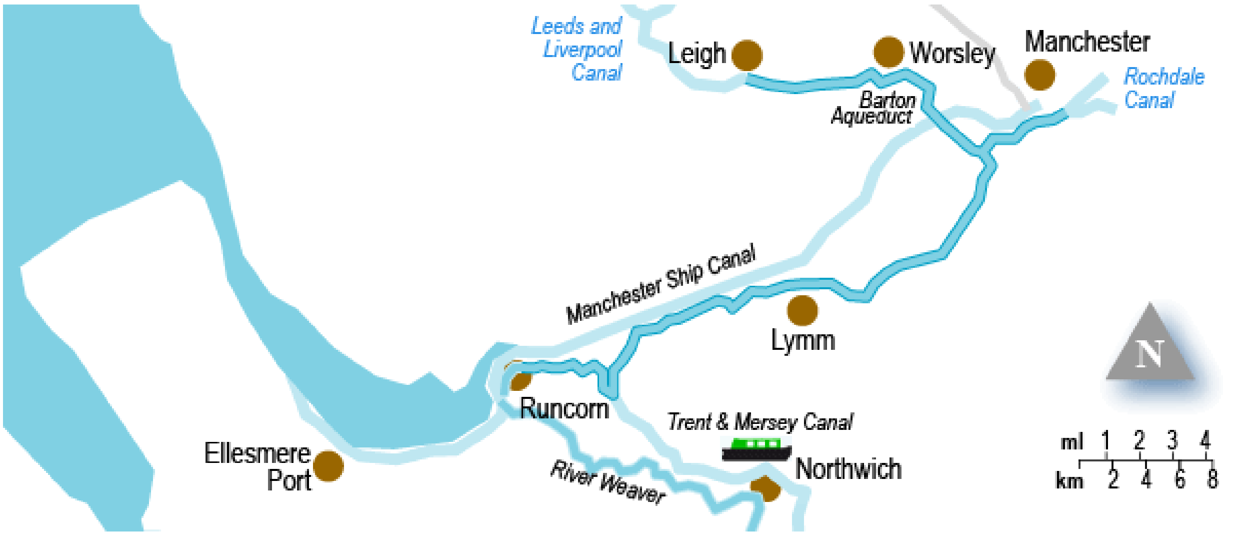
1761: the Bridgewater Canal was built by Francis Egerton the third Duke of Bridgewater to transport coal from his mines at Worsley to the industrial areas of Manchester. As a young man the Duke, had taken a grand tour of Europe, and was evidently impressed with the canals in use on the continent which may have inspired him on to develop this means of transport for his mines. Unlike the other British canals described in this section, the Bridgewater Canal was the first to be built without following an existing watercourse, and can be seen as the forerunner of British canal network

The Act of Parliament approving the Bridgewater canal received Royal Assent on 23rd March 1759. The initial proposed was for two separate cuts from Worsley keeping north of the River Irwell via Patricroft to Salford, and the other going in the direction of Warrington to link with the River Mersey at Hollins Ferry. The route towards Patricroft made good progress but the cut to Hollins Ferry ran into difficulties with peat deposits, forcing them the re-examine the route.

At the time the Duke's brother-in law was surveying the route of a proposed Canal from the Trent to the Mersey. Following a meeting at Worsley Old Hall a complete change of plan emerged combining the two proposals.



The new route abandoned the Hollins Ferry line and the section which had reached Patricroft was redirected to cross the Irwell by a Stone Aqueduct, joining Trafford Park to Streford and Manchester. An amendment to the Bill was passed in March 1760 to give approval to the change of route. The construction of the original stretch of canal from Worsley to Manchester cost the Duke an estimated £168,000, and was opened on 17th July, 1761.



The Barton Aqueduct, a three arch sandstone bridge that carries the canal over, and 11.9m above, the River Irwell flanked by embankments 183m long was the most impressive structure on the canal. The aqueduct's novelty meant that it soon became a tourist attraction, but being narrow it was also a traffic bottleneck. It was demolished in 1894 to make way for the Manchester Ship Canal and replaced by Barton Swing Aqueduct, though the north abutment of the old structure remains.

Some large embankments were also required to carry the canal across other valleys, the biggest is the one flanking the single arch aqueduct over the River Mersey at Stretford. Each side is 823m long and 5.2m high with a 34.1m wide base. To waterproof the canal timber supports were used for the bank, and the channel was lined with puddled clay[14], this method was adopted as a standard canal waterproofing technique until the 20th century.

The other innovative feature of the canal, was extending the canal underground at Worsley to produce a navigable level within the coal measures for both drainage and the transport of coal by boat. The main Navigable Level is a tunnel 8 feet (2.4 m) high, providing 4 feet (1.2 m) of headroom and 4 feet (1.2 m) of water. It was cut northwards from Worsley into the hillside towards the coal seams and mines owned by the Duke. The first workable seam (the Worsley Four Foot mine) was reached in 1761, 770 yards (700 m) from the tunnel's portal. As new coal

[14] Puddled clay is made by mixing the clay into a plastic state with water. The 'puddle' is then laid and compacted to create a thick waterproof layer. It has to be kept wet in order to remain waterproof.

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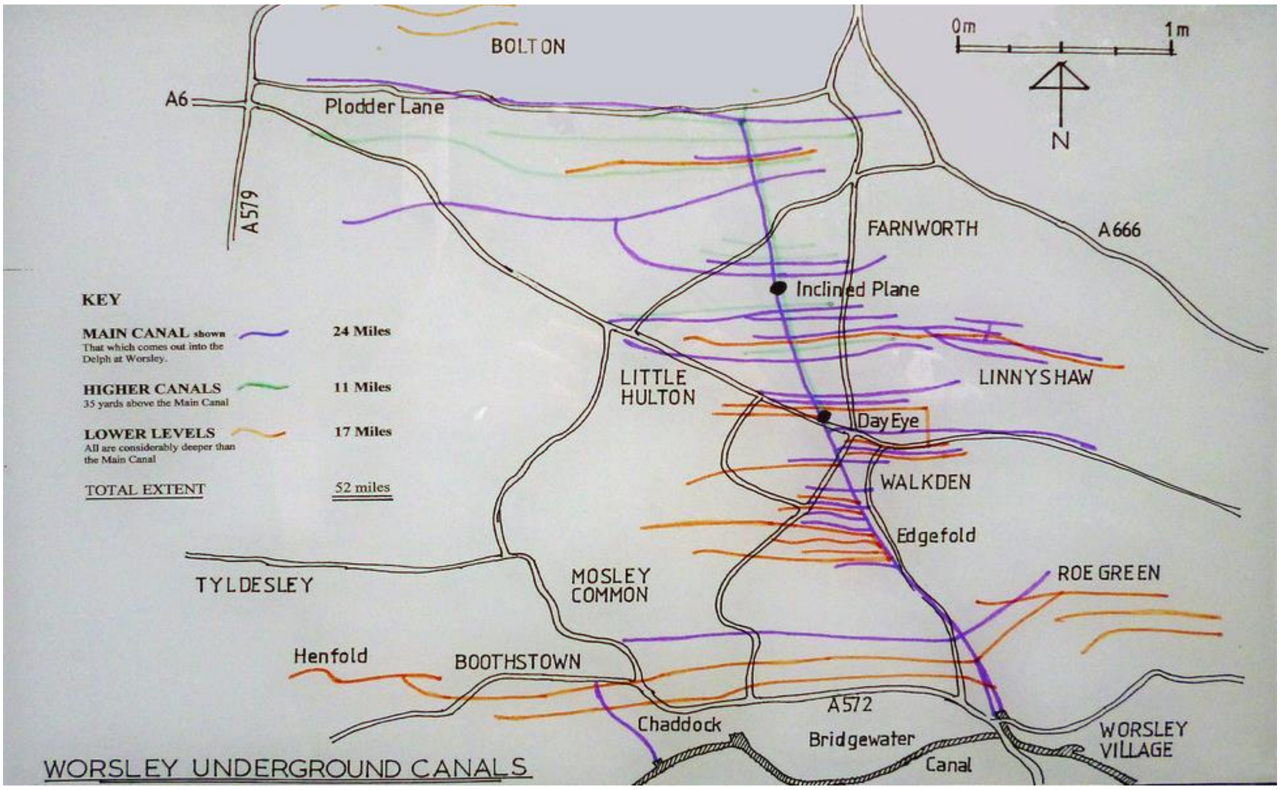
seams were intercepted, branch levels were dug into the seams and extended as the coal was mined. The branch level along the Four Foot seam eventually reaching a length of 1.75 miles (2.8 km). The water level in the mine was designed to be the same as in the canal, and the drainage from the mine kept the rest of the canal in water.

The navigation was progressively lengthened reaching a final length of 4 miles (6.4 km)[15].



As part of the agreement discussed above, the Bridgewater canal was extended from Manchester to Liverpool in 1776, an additional 48 km (30 miles). And, the Tent & Mersey canal was completed in 1777, including more than 70 locks and five tunnels, joining the extended Bridgewater canal at Preston Brook in Cheshire.

Despite struggling financially at times during the expansions and additions to the original canal, the Duke had made a very healthy profit by the time of his death in March 1803. At the height of its popularity the Bridgewater canal was transporting more than 3 million tons of cargo between the rapidly expanding towns and cities of the industrial revolution.

More notable perhaps, was the canal's impact on the price of coal. By 1762, one year after the canal opened, the price of coal in Manchester had been reduced by fifty per cent compared to the pre-canal price; literally powering the start of the industrial revolution.

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[15] See: https://en.wikipedia.org/wiki/Worsley_Navigable_Levels

Canal Mania

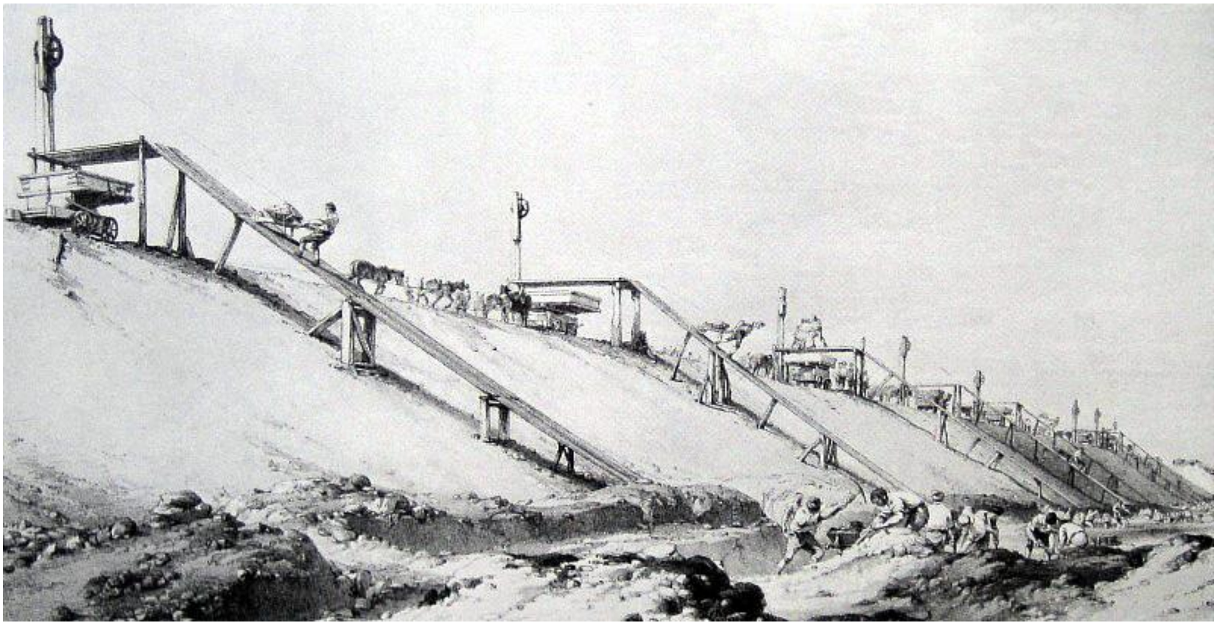
The success of the Sanky and Bridgewater canals sparked a raft of imitators in a period of frenetic canal building between the 1780s and 1810s which would become known as 'canal mania'. Nationwide the canal network expanded from just a few miles to nearly 4,000 miles (6,400 kilometers) in length.

The Staffordshire and Worcestershire Canal is one of the earlier canals built at the start of the 'canal mania' period. It is a 46 miles (74 km) long narrow canal in Staffordshire and Worcestershire in the English Midlands. The Act of Parliament authorizing this canal was passed on 14 May 1766. This created "The Company of Proprietors of the Staffordshire and Worcestershire Canal Navigation", which was empowered to raise an initial £70,000 (equivalent to £9,951,996 in 2020), with a further £30,000 (equivalent to £4,265,141 in 2020), if needed, to fund the canal's construction.

The canal was completed in 1771 and opened to trade in 1772, but as with most of the canals constructed in this period, the cost exceeded the authorized capital. Despite the cost overrun, the canal was a commercial success, with trade from the Staffordshire Potteries southwards to Gloucester and Bristol, and trade from the Black Country northwards to the Potteries via the junction with the Birmingham Canal at Aldersley.

Canal summary

From the perspective of project cost control, the major cost overruns identified in ***The Origins and History of Cost Engineering*** may be understandable. Prior experience of canal building in the UK was limited. While the people involved in the Sanky and Bridgewater canals clearly had some knowledge of canals constructed in Ireland and Europe, this knowledge would not appear to have been widely spread.



Barrow runs removing soil from a cutting. A horse was used to pull the barrow up the ramp with the soil being tipped into a cart for removal.

The technology used for excavation and waterproofing was practical and simple, but was almost entirely dependent on manual labour and therefore highly susceptible to ground and weather conditions.

Given the lack of experience and the rapid expansion of canal building, developing accurate cost estimates would be difficult. However, despite cost overruns, most of the canals built in the mania period were profitable. The massive savings in transportation costs created by a canal generated traffic, tolls, and profits, and the increase in trade encouraged more industrial development along the canals, creating even more traffic and tolls.

The factor that killed off the canal boom was another major advance in technology, the introduction of viable intercity railways powered by steam locomotives. Railways were generally cheaper to build, easier to maintain, and could transport goods significantly faster than the canals. The primary disadvantage of the railways was the cost of running trains meant the freight charges were higher which in turn meant many of the established canals' sill had a future moving heavy cargos that were not time dependent. It was not until the 20th century the speed and convenience of railways, combined with the competition from road transport, evenly killed off the British canal industry.

The railway experience discussed below appears to be in a different league. The railway promoters had access to the experience derived from building canals, plus 200 years of experience constructing numerous wagonways.

Railway Projects

The construction of railways in the UK was a direct continuation of the construction of wagonways. Wagonways had been in use since the 1560s, and the number and length of the wagonways built increased substantially through the 18th century. Most wagonways were built to carry coal from a mine to a wharf, and were owned and funded by an individual coal owner. Only a few public wagonways were constructed with users paying a toll.

The progression to the steam powered railways discussed in ***The Origins and History of Cost Engineering*** began with the introduction of steam locomotives, to replace the use of horses, pulling coal wagons along existing wagonways.

Introducing steam power to railways

The earliest use of steam engines was to pump water from mines. Various design concepts were tried in the 17th century with little success. Vacuum pumps could only lift water 30 feet, and the metallurgy and machining capabilities of the time were limited.

The invention of the atmospheric engine by Thomas Newcomen in 1712, created the first practical device to harness the power of steam to produce mechanical work, and lift water from deep mines. Hundreds of Newcomen engines were constructed in the 18th century, and were used throughout Britain and Europe. They were effective stationary engines in both mines and factories, but lacked the mechanical efficiency for any other use.

James Watt invented and patented an improved steam engine in the 1760s using a separate condenser that significantly improved engine performance and producing significantly more work per ton of coal burned in a boiler. However, it was not until the Boulton & Watt partnership was formed in 1775 that this improved design was exploited. Boulton & Watt continued designing and making their marine and stationary steam engines through the 19th century[16].

The improved power to weight ratio of the Boulton & Watt engine made the use of steam power for locomotives viable. There were three early innovators:

- **Richard Trevithick** a British inventor built the world's first full-scale working railway steam locomotive (unnamed). On 21st February 1804 this locomotive hauled a train along the tramway of the Penydarren Ironworks, in Merthyr Tydfil, Wales. This experiment was abandoned after three runs due to breakdowns and damage to the wooden rails. He also built a number of steam-powered road vehicles, but none were particularly successful.
- **Matthew Murray** was an English steam engine and machine tool manufacturer, who designed and built the first commercially viable steam locomotive, the twin cylinder *Salamanca* in 1812[17].
- **John Blenkinsop** is also credited with being the designer of the first practical and successful railway locomotive. Four of Blenkinsop's two-cylinder, geared, steam locomotives were built between 1812 and 13, to haul coal from Middleton, Yorkshire (where the inventor was employed as a mine inspector), to nearby Leeds[18].

In 1813 George Stephenson visited Middleton to examine a "steam boiler on wheels" constructed by John Blenkinsop to haul coal out of the mines. Blenkinsop believed that the heavy contraption could not gain traction on smooth wooden rails, so he had designed his engine with a ratchet wheel running on a cogged third rail. This arrangement caused frequent breakdowns.

Stephenson thought he could do better, and, after conferring with Lord Ravensworth, the principal owner of the Killingworth mine, he built the *Blucher*, in 1814. The engine was capable of pulling eight loaded wagons carrying 30 tons of coal at 4 miles (6 km) per hour. Not satisfied, Stephenson sought to improve his locomotive's power and introduced the 'steam blast', which redirected exhaust steam was the chimney, pulling air after it and increasing the draft in the boiler. This new design made the locomotive truly practical[19].

These locomotives and others, started the railway revolution that ended canal mania. The track gauge used by Stephenson for his later railways also went on to become the standard gauge for railways which is used around the world to the current day[20].

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16 See: https://en.wikipedia.org/wiki/Boulton_and_Watt

17 See: https://en.wikipedia.org/wiki/Matthew_Murray

18 See: https://www.britannica.com/biography/John-Blenkinsop

19 See: https://www.britannica.com/biography/George-Stephenson

20 Download ***Myths and Legends: The Origins of Standard Gauge Railways*** from: https://mosaicprojects.com.au/Mag_Articles/AA016_The_Origins_of_Standard_Gauge_Railways.pdf

These early steam-powered railways seem to have been built cost effectively. I have been unable to find evidence of unexpected cost overruns on the:

- Killingworth wagonway
- Hetton colliery wagonway, the first railway built to be powered entirely by steam[21]
- Stockton and Darlington railway, the world's first public railway to use steam locomotives. The railway had significant issues with the early steam locomotives, but the rail lines seem to have been effective and built for a reasonable cost. Shares in the Stockton and Darlington railway that were purchased for £100 in 1821 could be sold for £260 in 1838
- Liverpool & Manchester railway, the first intercity line when it opened on the 15th September 1830. The estimate for building the line was calculated at over £400,000. The final cost was £637,000, but despite the cost increase (which may include a number of extensions and technical challenges), annual dividends of 10% were regularly paid.
- London and Birmingham railway. Sanctioned in 1833, the Company appointed Robert Stephenson as chief engineer. The 112-mile line took 20,000 men nearly five years to build. The total cost of building the railway was £5,500,000 (£50,000 a mile). The railway was opened in stages and finally completed on 17 September 1838. While the cost was significant, there's no information suggesting this was unexpected.

Railway Mania

The railway mania of the 1840s appears to have been driven by an entirely different factor, share market speculation. The government promoted an almost totally 'laissez-faire' system of non-regulation in the railway industry. Companies had to submit a bill to Parliament to gain the right to acquire land for their railway line, which required the route of the proposed railway to be approved, but there were no limits on the number of companies, and no real checks on the financial viability of the proposed lines[22].

The speculation was driven in part by the success and profits generated by the early railway lines, including the Stockton and Darlington railway and the Liverpool & Manchester. In part by the glamour of new technology, and in part by the change railways were brining to industrial Britain such as enabling the supply of fresh milk and produce into the major cities from places 100s of miles away. However, the biggest factor driving the 'mania' was speculation on the ever-increasing value of railway shares. Novice investors were duped into using their life-savings to buy shares in projects that in many cases had no prospect of ever being built.

There were a wide range of outcomes:

- Some projects were funded, built, and operated profitably. These were largely associated with the big railway companies.

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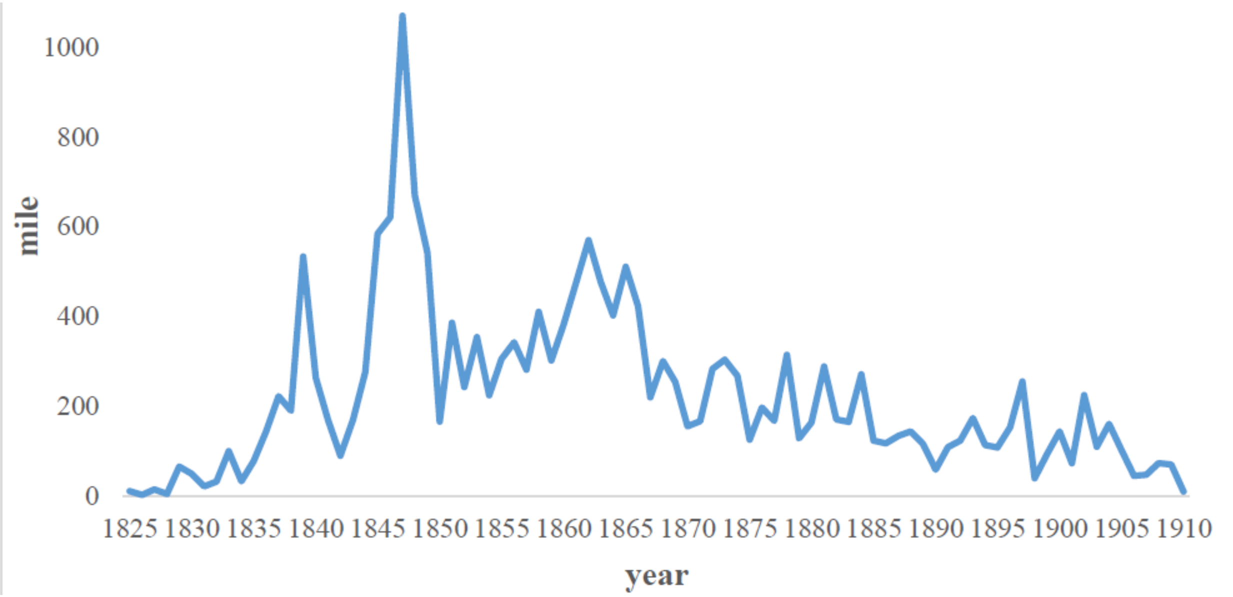
[21] See: https://en.wikipedia.org/wiki/Hetton_colliery_railway

[22] See: https://spartacus-educational.com/SteamRailwayMania.htm

- Some projects were built and operated, but were not viable. These were often bought out by the big railway companies at a massive discount and added to their networks. The original investors losing most of their money.
- Some projects simply consumed the investments and the company folded with the investors losing everything.

The 'railway bubble' burst in the late 1840s. However, unlike many other speculative bubbles, some good came out of the railway mania. The annual growth of railway mileage in Britain between 1825 and 1911 is shown in the graph below[23].

As a result of the 'mania', around 6000 miles of rail track were constructed in a very short period of time and the big railway companies bought up the defunct company lines for a fraction of their value creating a financially viable UK railway network, which provided a massive boost to trade and the industrial revolution. And, unlike the end of the canal boom, railway construction continued at a steady rate for many years after the collapse of the 'bubble'.



Some of the companies involved in the railway mania certainly underpriced the work, and over valued the future revenues, on their new lines. But this deception was to profit from speculation rather than a direct consequence of cost engineering failures.

Conclusions

The primary difference between the canal mania and the ability to accurately price the construction costs of a canal, and the subsequent railway mania appears to be engineering knowledge. The canal boom followed the successful, and profitable, building of a couple of canals, but there was no inherent understanding of canal construction within the British engineering community. Many of the engineers responsible for designing and building a canal

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23 Source: *The development of the railway network in Britain 1825-1911*, Leigh Shaw-Taylor and Xuesheng You: https://www.campop.geog.cam.ac.uk/research/projects/transport/onlineatlas/railways.pdf

were literally learning on the job. Knowledge was acquired over time, but the short timeframe of the canal boom, just 60 years from the 1770s to the 1830s inevitably meant this knowledge was not generally available.

Paradoxically, to a large extent the cost of building a canal did not matter! The revolutionary change in transportation costs introduced by canals meant the build costs were quickly offset by the income generated from tolls. As a result of canals, coal could be sold in Manchester at half the pre-canal price, and still generate profits for both the mine owner, the boat owners, and the canal company[24]. Very few canals seem to have been built without a pre-established, viable, commercial purpose although the level of profitability varied.

The decline of the canal industry was caused by a paradigm shift in technology rather than either the cost of construction, or the cost of operation.

The railway boom of the 1830s could build on the knowledge gained over the previous 200 years building wagonways, plus the knowledge from the canal construction boom. The early railways were built by wagonway builders and appear to have been financially successful. The factor driving the short-lived railway mania was speculative greed. When the bubble burst in the late 1840s, many small speculators lost everything, but the UK gained some 6000 miles of new railway that was exploited by the big railway companies, and the big companies kept on building railways.

The lack of structured cost engineering capabilities identified in ***The Origins and History of Cost Engineering***[25] during both of the booms may have been a factor in underestimating the cost of these projects. However, it would be difficult to establish reliable rates for canal work in the short period of the canal boom, and reliable cost information would be unwanted and ignored by the unethical promotors of speculative rail companies being floated in the unregulated stock market of the 1830s and 40s.

Paradoxically, the professional engineers involved in the canal, and particularly railway construction works, were the people who developed the foundations of modern cost engineering and project management.

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[24] **Note**: Government policy prevented canals operating as a monopoly, all canals had to provide toll access to canal boat owners.

[25] Download ***The Origins and History of Cost Engineering*** from: https://mosaicprojects.com.au/PDF_Papers/P207_Cost_History.pdf

About the Author

Patrick Weaver

Melbourne, Australia

Patrick Weaver, PMP, PMI-SP, FAICD, FCIOB, is the Managing Director of Mosaic Project Services Pty Ltd, an Australian project management consultancy specialising in project control systems. He is a Fellow of the Chartered Institute of Building, Australasia (FCIOB) and a Fellow of the Australian Institute of Company Directors (FAICD). He is a member of the PMI Melbourne Chapter (Australia), as well a full member of AIPM, and the Project Management College of Scheduling (PMCOS).

Patrick has over 50 years' experience in Project Management. His career was initially focused on the planning and managing of construction, engineering and infrastructure projects in the UK and Australia. The last 35 years has seen his businesses and experience expand to include the successful delivery of project scheduling services and PMOs in a range of government, ICT and business environments; with a strong focus on project management training.

His consultancy work encompasses: developing and advising on project schedules, developing and presenting PM training courses, managing the development of internal project control systems for client organisations, and assisting with dispute resolution and claims management.

In the last few years, Patrick has sought to 'give back' to the industry he has participated in since leaving college through contributions to the development of the project management profession. In addition to his committee roles he has presented papers at a wide range of project management conferences in the USA, Europe, Asia and Australia, has an on-going role with the PGCS conference in Australia and is part of the Australian delegation to ISO TC258.

Patrick can be contacted at patw@mosaicprojects.com.au or at www.mosaicprojects.com.au.