National Heritage Protection Plan

NHPP 4B3: Transport and Communications
4B3.102: Historic Railway Buildings and Structures: Overview of development pressure and review of significance

Volume 2: Statements of Significance

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Introduction

Railway stations are among the icons of the modern industrial age. As an entirely new building type, it took a while for default layouts, facilities and building forms to develop. Once they had become established in Britain, they were rapidly propagated world-wide by British and other engineers.

A number of the new railways managed to secure the services of an engineer who was also an accomplished architect. Most notable of these was Isambard Kingdom Brunel. Many others employed an engineer for formations, tunnels and bridges, and a local or national architect to design the stations and to provide input on other key structures as needed. The exact relationships between promoters, engineers and architects remains unclear. Brunel only ever worked with Digby-Wyatt, and then only occasionally and only on the Great Western. Many independent railways within the Great Western Railway's sphere of influence also employed Brunel's and were content to use his one-stop-shop for formations, structures and buildings, which were built increasingly built to a relatively small number of standard types as Brunel's personal workload increased. Joseph Locke worked almost exclusively with William Tite, including in France. The relationship was so close, that it seems probable that it was Locke who persuaded the various railway boards to employ Tite for their buildings. Being an architect of national repute, Tite also worked occasionally for railways unconnected with Locke, although this was generally rare. The Stephensons had more flexible relationships. George Stephenson worked closely with Francis Thompson on the North Midland Railway, whilst his son worked equally closely with Thompson on the Chester & Holyhead Railway. Thompson also worked with others, notably with John Braithwaite and Sancton Wood on the Eastern Counties Railway.[i] Robert Stephenson also worked frequently with John Livock, but exclusively on various independent railways that fell within the sphere of influence of the London & Birmingham Railway and its board of directors. Simultaneously the Stephensons were working with G.T. Andrews of York on several railways in the North East, but only where such railways were promoted by George Hudson. In all of these cases it seems that the choice of architect may have been dictated by the railway Chairman or the board of directors, rather than by their chosen engineer.

It is widely held that the division between architectural and engineering roles resulted in unhappy marriages between the architecture of station buildings and engineering of the train sheds behind. Given the very close working relationships between highly accomplished architects and engineers that were maintained over many years, and given the obvious prestige of these lucrative railway commissions, this seems to be an over-simplistic view. It misunderstands what can only have been a highly deliberate and intentional contrast between frontages designed to engender the solid commercial reassurance of a bank and the unashamed 'high-tech' of the overall roofs behind, which were clearly designed to excite and impress, amply demonstrating the engineering prowess that would get the passenger to journey's end at high speed, in perfect safety. That the contrast was maintained once railway companies increasingly brought station design in house under the unified command of the Chief Engineer from the 1850s onwards can only serve to reinforce the point. The contrast was extended to smaller stations once iron and glass platform canopies started to be added to lesser stations from the later 1850s. It continued unabated as frontage design moved from Tudor and Italianate, through Victorian Gothic, to Queen Anne, Baroque to Beaux-Arts, until the introduction of modernism in the 1930s redefined taste, introducing the expectation that frontage buildings should express the same excitement and modernity that station roofs had been demonstrating for almost a century.

Thereafter the finest architects and engineers of the preceding age were roundly condemned for producing 'Victorian monstrosities', fundamentally flawed by a supposed inability to resolve architecture and engineering. The initial result was some striking architecture, most particularly on the London Underground, but in the longer term the radical shift in architectural mores was disastrous for Victorian and Edwardian architecture in general and for the railway's architectural heritage in particular. It is indicative of the manner in which railway stations express the zeitgeist of their time that, as the tide turned again, of the thousands of fine buildings that were lost, it was the battles over two railway stations, Euston (fought and lost 1960-61) and St Pancras (fought and won 1962-67) that most caught the public's attention and which were arguably more responsible than any other buildings for the re-evaluation of the value of post-Georgian, pre-modernist architecture and engineering. Ironically, the majority of the stations that were built as replacements in the post-war period, particularly the new Euston and New Street stations and the 'CLASP' stations built using off-the-peg components designed for temporary classrooms, are now largely considered to be amongst the most lack-lustre public buildings constructed in the post-war era. The process has been slow and hundreds of historic railway stations and structures continued to be lost through the 1970s, 80s and 90s. There is nevertheless a growing realisation that railway structures, and railway stations in particular, are amongst the most expressive buildings of the times that produced them, both for better and for worse.

A key feature of station design that is too easily overlooked is the manner in which stations evolution solved issues of layout, organisation and people management that we take for granted today. The very earliest passenger railways, such as the Swansea & Mumbles Railway (1807), picked up passengers at set points on the lineside, tickets usually being purchased at a nearby inn, in the manner of stage coaches. The first proper railway stations, the respective termini at the two ends of the Liverpool & Manchester Railway (1830), indicated the way forward, with separate arrivals and departures platforms. The arrivals side needed no facilities. The departures side required a booking office, space for the wealthier passengers to wait under cover and a covered area where passengers boarded the trains. Waiting facilities remained remote from the platforms a number of years, passengers being called for boarding only as soon as a train was ready for departure. This prevented passengers boarding the wrong train, as even into the 1870s the very largest stations seldom had more than a single departure platform.

At intermediate stations, platforms necessarily served trains that both arrived and departed. A two-sided arrangement tended to be adopted, albeit normally with the main buildings grouped on one side only, with a simple shelter on the opposite platform, passengers crossing to the opposite side by walking across the tracks. The positioning of the two platforms opposite each other took a while to become established as many designers opted instead for staggered platforms, as this was felt to be the safer arrangement where passengers had to cross from one platform to the other when a train was in the station. In order to avoid unnecessary danger it was considered safer to adopt a one-side plan-form at more important stations, with one very long platform serving trains in both directions.

As services became more complex, particularly at busy junction stations where trains arrived from, and departed to many different destinations, methods had to be evolved to ensure that passengers could safely identify and access the right platform at the right time. Clear signage, fingerboards and elevated walkways for safe platform access had clearly been evolved by the time the World's first very large junction station was completed; the Grand Junction station in Birmingham (today's New Street station), opened in 1854. By the 1860s the concept of a long concourse spanning the tracks, rather than just a footbridge, had been devised. The modern destination board seems to have evolved at about the same time.

These aspects of signage, concourses and dedicated elevated walkways (or subways) are feature we now take for granted anywhere that large numbers of people need to be organised, in airports, exhibition centres and sports stadia. These are aspects of layout and function that need to be understood in order to understand the significance of historic stations and their component elements.

Overall Analysis of the Designation Base

Excluding a small number of crossing keepers' cottages that appear to have originally been built as station houses, data supplied by EH indicates that there are around 510 listed stations or stations with listed elements (excluding stations built for the London Underground and its constituents). As such, station buildings represent some 25% of the designation base.

Four listed stations have been entirely demolished since designation (Gainsborough Central, Kidlington, South Shields and Ravensthorpe). At least three have lost their trainsheds since designation (Malton, Fenchurch Street and Blackburn), although in the latter two cases the train sheds were described in the statutory listings as being 'not of special interest'. York Old Station, a unique Grade II* large city terminus of 1841 and the earliest city terminus to retain an iron trainshed roof, has had its train shed translocated to become a cycle store, the vacated area between the historic station buildings having been infilled with Council offices. In at least three instances (Little Sutton, Ridgemont and Millbrook), offside platform shelters that were amongst the very few that were included in statutory descriptions have been lost. In many, many instances, complementary features that existed at the time of designation, but which were not listed separately or included in the statutory description (or which were described as being 'not of special interest'), have subsequently been removed. Undesignated platform shelters have been particularly vulnerable in this respect.

Of the 510 listed stations, 99 are closed stations on closed railways and 49 are closed stations on or beside the national network, almost all in private ownership. Very few of these 148 retain platforms or other associated features. A number of these are now difficult to recognise as railway stations because of removal of associated features, particularly platforms. Of the remainder, 34 are heritage museums or on heritage railways, whilst 303 are at current or former main-line stations that remain open as part of the national network (mostly on Network Rail, with a small number on London Underground or Manchester Metrolink routes). All of these retain platforms. At a substantial number of these latter sites, the listed element(s) are no longer in railway use, being either boarded up or having been sold or leased for other uses. In a number of such cases, the listed buildings are now fenced off from the railway platforms A further 53 purpose-built Underground (mostly 'tube') stations are also designated, three of which are tube stations built by a main-line railway company (GWR (2), LNER (1)). With only one exception, all designated Underground stations remain in use as part of the operational LUL network.

Temporally, the main-line or former main-line railway stations divide thus:

Date	**Number by Decade**	**Number by Epoch**
To 1830	4 (0.8%)	**To c.1840**
1831-40	28 (5.7%)	**34 (6.9%)**
1841-50	183 (37%)	**c.1841-1852** **177 (36%)**
1851-60	64 (13%)	**c.1853-1876**
1861-70	92 (18.7%)	**172 (35%)**
1871-80	50 (10%)	
1881-90	36 (7.3%)	**c.1877-1914**
1891-1900	16 (3.2%)	**97 (19.7%)**
1901-1910	13 (2.6%)	
1911-20	7 (1.4%)	**c.1915-1947**
1921-30	6 (1.2%)	**14 (2.8%)**
1931-40	7 (1.4%)	
1941-50	0	

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Date	Number by Decade	Number by Epoch
1951-60	0	**c.1948 to present** **5 (1%)**
1961 to present	5 (1%)	

Thus, the earliest years of station development (to c.1842) are very poorly represented. This is unsurprising and very few further undesignated examples are likely to come to light. The number of listed stations post-1881 is also very low, particularly after 1910. Almost all are major stations. Again, this falling off in the number of designated stations post-1881 is unsurprising, given previous designation criteria. Other station types that are strongly under-represented include narrow-gauge railway stations (none, the outstanding example being Woody Bay station, Lynmouth), light railway stations (none), halts (one designated example, Denham Golf Club), timber-built stations (eight designated examples) and suburban stations outside of London (ten at the widest definition, all on the Liverpool and Manchester, Cheshire Lines Committee and Manchester, South Junction & Altringham routes).

An analysis has also been carried out to determine how many stations are in fact listed station houses (a single building, sometimes with an attached canopy) and how many stations (including termini) comprise listed buildings on both sides of the tracks, sometimes with additional listed elements (station master’s house, footbridge, goods shed etc). It transpires that 58% of the listed stations comprise only a surviving station house, whilst only 42% are for what might be fairly termed a station with other features extant, even if they are not described in the statutory description.

General comment on designations

Probably the most troubling aspect of station designation has been the tendency to list only frontage buildings, or to only list station buildings that are readily visible from the road, rather than those that are visible from the platforms. Sometimes this may have been because the frontage building or station house is the earliest building at a station, but in many such cases later elements such as platform canopies, footbridges water towers and goods sheds can contribute towards the creation of a harmonious group and be a major contributor to significance. Thus, at Southampton Terminus, Tite’s 1839 entrance building is listed, but not the 1920s ridge-and-furrow-roofed concourse behind, which formerly accessed the platforms and still connects the station frontage to the (Grade II-listed) South Western Hotel. As the railway platforms have been removed, the loss of the concourse would remove all railway context from the surviving listed buildings, leaving the station frontage looking simply like a casino (its current use).

In many instances the parts not included in the description date to the original build and in such circumstances the exclusion of all other elements seems extraordinary, but some of the Listings probably date to the re-Listing surveys of the 1980s, which were rapid and car-based. The lack of acknowledgement of such structures in the statutory descriptions is nevertheless a major concern and potentially misleading to owners and decision-makers.

During the course of this survey it has thus been noted that substantial historic island or offside buildings and extensive historic canopies are ignored by the designations for Tunbridge Wells Central, Eastleigh, Barnes, Stamford Town, Wellingborough, Great Malvern, Barkingside, Letchworth, Doncaster, Surbiton, Holylake, Horsham, Broxbourne, Taunton, Thetford, Ingatestone, Andover, Chippenham and Berwick on Tweed.

Substantial historic platform canopies that are attached to Listed station houses are not included in their statutory descriptions include those at Downham Market, Tunbridge Wells Central, Felixstowe (now partially demolished), Bury St Edmunds, Stamford Town, Gravesend, Rye, Battle, St Denys, Barkingside, Hatch End, Letchworth, Bromley North, Ramsgate, Margate, Doncaster, Bishopstone, Horsham, Thetford, Andover, Chippenham and Berwick on Tweed. At Ashbee's marvellous 1886 Norwich station the airy main passenger concourse and extensive platform canopies are not included in the description, whilst at Eastbourne neither the platform canopies nor the enormous porte-cochere at the side of the station are described.

Smaller offside waiting shelters are not included in the descriptions of the stations at Cottingham, Downham Market, Grosmont, Chathill, Acklington, Codsall, Stowmarket, Frant, Rye, Hamstreet & Orlestone, Rowlands Castle, Bridgnorth, Goathland, Hadlow Road, St Denys, Chertsey, Kew Gardens, Hough Green, Portslade, Keighley (Network Rail side), Swaythling and Corfe Castle.

Statutory descriptions for the following stations are noted to omit historic station footbridges: Eastleigh, Pickering, Cottingham, Stamford Town, Gravesend (demolished early 2014), Rye, Battle, Etchingham, Rowlands Castle, Bridgnorth, St Denys, Chertsey, Mexborough, Cressington, Surbiton, Horsham, West Malling, Embsay, Barkingside, Hatch End, Doncaster, Holylake and Rainhill.

A number of stations that have other undesignated features that may merit consideration for designation in order to produce more holistic listings. Thus, the following designated stations have undesignated goods sheds, many of which are contemporary with the Listed station building: Kirton in Lindsey, Frodsham, Frant, Crewkerne, North Tawton, Hatch Beauchamp, Ilminster, Bridlington, Bovey Tracey, Grange over Sands, Hale, Beckingham, Leadenham, Haworth, Oakworth, Nailsworth, Appleby, Corfe Castle, Whittingham, Wadebridge, Thetford, Romsey and Bucknell. Undesignated weighbridge houses have been noted at Cottingham, Haworth, Oakworth, Romsey and Bucknell. Unlisted weighbridges or weigh houses have

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been noted at the listed Romsey, Bucknell, Haworth and Oakworth stations. There are unlisted coal drops at Bridgnorth, an unlisted carriage shed at Grange over Sands and an unlisted engine shed at Tunbridge Wells West.

There are undesignated water towers at Crewkerne, Appleby and Romsey and undesignated water cranes at Bridgnorth and Appleby. The stations at Appledore, Ingatestone and Plumpton have undesignated crossing keeper's cottages at the platform ends. There are undesignated wooden level crossing gates at Grosmont, Woodhall Junction, Goxhill, Appledore, Hadlow Road and Elsenham. There are undesignated signal boxes at the following listed stations: Grosmont, Goxhill, Stamford Town, Stowmarket, Hadlow Road, Hellifield, Thetford and Eastbourne. Unlisted station master's houses have been noted at Dent, Pickering and Whittingham and undesignated railway workers' cottages noted at Glazebrook and Whittingham stations. The flint-built 1845 Railway Hotel at Thetford is undesignated. Numerous stations have undesignated historic road-overbridges that have strong group value with the adjacent station buildings. Two with particularly strong group value have been noted, one at Wolsingham (a fine skew bridge) and the other on the platform end at Crewkerne.

It may be helpful to append a caveat to all historic station designations noting that it should not be assumed that features not mentioned in the statutory description are not important contributors to significance. A Guidance Note on station curtilage, curtilage structures and on structures that are physically annexed to listed station buildings, principally canopies, would be very helpful for the owners of Listed station buildings, planners and statutory and non-statutory consultees.

Stations to 1852

The very earliest passenger railways, such as the Swansea & Mumbles Railway (1807), picked up passengers at set points on the lineside, tickets usually being purchased at a nearby inn, in the manner of stage coaches. Such arrangements persisted for a surprisingly long time. Thus the Liverpool & Manchester Railway built no structures at any of its wayside stations before 1842, twelve years after it was opened. The lack of any precedent for a terminal station resulted in the first purpose-built 'terminus' structure, built at Stockton for the opening of the Stockton & Darlington Railway in 1825, having more in common with a toll house than a railway station.

The first proper main line railway stations, the respective termini at the two ends of the Liverpool & Manchester Railway (1830), indicated the way forward, with accommodation for the station agent, a booking office (where passengers names were entered in a ledger), space for the wealthier passengers to wait under cover and, a new innovation, a covered area where passengers boarded the trains (a canopy at Manchester and an open-sided, timber truss, overall roof at Liverpool). The timber-truss train shed was applied again (and at greater scale) at both ends of the Leeds & Selby Railway (1834), although the walled, platformless buildings themselves looked more like large goods sheds than passenger termini. Waiting facilities remained remote from the platforms for many years, passengers being called for boarding only as soon as a train was ready for departure. At Manchester the new booking office and pre-existing station agent's house resembled a terrace of smart town houses. At Liverpool the booking office and agent's house was a relatively modest, two-storey classical building. Apart from the train shed, the only other building at the Selby terminus of the Leeds & Selby railway was a pre-existing cottage, purchased by the railway as their station agent's house.

From the mid 1830s, urban and terminal stations were built on an increasingly lavish scale, with extensive frontages screening increasingly massive overall roofs behind, all expressing the railway's capital value and social and commercial importance. In the architectural vocabulary of the time, this required substantial classical architecture for the major termini. No attempt was made to resolve the classical frontage with the architecture of the train shed. Thus at the world's first major metropolitan terminus (Lime Street Liverpool, 1833-7) John Foster Snr. provided a massive Roman screen on the street frontage, physically separate from the train shed behind. A similar long, arched screen was also used by Joseph Franklyn of Liverpool at the Grand Junction Railway's Curzon Street terminus in Birmingham (i1837-9). More famous is the screen of Greek lodges and wrought iron gates flanking the giant Doric propyleum built 1835-7 at London Euston by Philip Hardwick. The purpose of the screens appears to have been was to provide an imposing ‘gateway’ feature, rather than to screen the station behind. This was most clearly evident at Euston, where the open-work gates and small lodges flanking the propyleum were clearly hopeless in any ability to screen Stephenson and Fox's revolutionary iron train sheds behind.

After about 1838 it became the norm for the railway builders to express the railway's importance via substantial classical frontage buildings more closely reflecting contemporary civic and public buildings such as town halls. The London & Birmingham Railway showed the way with its Curzon Street terminus in Birmingham, particularly after the world's first railway hotel had been added as an extension to Hardwick's original entrance in 1840. Undoubtedly the most notable examples of the classical approach are J.P. Pritchett's massive frontage to the joint station at Huddersfield (1846-50) and Dobson's even larger 600-ft long frontage of Newcastle Central station (1848-50). Arcaded Renaissance or Italianate frontages, apparently pioneered by Tite at either end of the London & Southampton Railway c.1837-8, had a particularly strong and lasting international influence, doubtless through the influence of Locke and the contractor Brassey, both of whom worked closely with Tite.

The opening of London Euston and Birmingham Curzon Street in 1837 saw the introduction of expansive pitched-roofed train sheds with wrought-iron and glass roofs carried on cast-iron arcades. Such roofs were quickly taken up in the UK (notably Derby (1840), Manchester Victoria (1844) and Liverpool Edge Hill (1848)) and soon spread to the Continent. Timber pitched-roofed train sheds continued to be built at metropolitan termini through to 1840 (e.g. Nine Elms (1837-8) and London Bridge (2) (1839)) and at lesser stations (e,g. Lowestoft Central (1847) to about 1850. The period 1839-1852 also saw a brief fad for laminated timber arched roofs (North Shields (1839), Lytham and Blackpool (1846) and King's Cross (1852)), but the real innovation of the later 1840s was the great arched iron train shed. The first were those at Liverpool Lime Street (2) (R. Turner for the London & North Western Railway, completed 1849) and at Newcastle (J. Dobson for the York Newcastle & Berwick and the Newcastle & Carlisle railways, completed 1850).

Station facilities at intermediate stopping places on the early main line railways were initially very primitive. No station buildings as such were provided at any of the intermediate stations on the Liverpool & Manchester, for example. A more formal two-sided arrangement, with two low platforms but with buildings grouped on one side only, appears to have been established by 1838, but the positioning of the two platforms opposite each other took a while to become established as many designers opted instead for staggered platforms, as this was felt to be the safer arrangement where passengers had to cross from one platform to the other by a level crossing. Apart from at Berkhamsted, where a well-appointed Tudor Gothic station house and offside waiting shelter were provided, the buildings at the larger intermediate stations on the London & Birmingham Railway (e.g. Watford and Coventry, were remarkably modest single-storey brick boxes, the principal architectural embellishment being grand stairs connecting the booking office to the platforms. The intermediate stations on the Grand Junction Railway (1836-7), Birmingham & Derby Junction Railway (1838-9) and Midland Counties Railway (1838-40) were little better.

The employment of Francis Thompson by the North Midland Railway saw a succession of attractive Italianate, Tudor, Jacobean pavilions built as intermediate wayside stations prior to the line's opening in 1840. Brunel did the same on the Great Western Railway at about the same time, also providing for the first time high platforms, offside waiting shelters and projecting canopies. Thompson and Brunel's intermediate stations immediately set a trend for wayside stations and stations in provincial and market towns to demonstrate architectural quality and stylistic variety, with the railway builders seeking to emulate estate architecture in the shires in the same way they had emulated civic and public architecture in their early termini. With lavish capital available, the railway builders of the 1840s embarked on an architectural fiesta, building intermediate stations in clapperboard, brick, flint, stone and stucco in classical, gothic and Tudor-gothic styles, often varying materials and styles along a single route. Increasingly popular from the mid-1840s was the new Italianate style, a style so inseparably associated with the railway that contemporaries referred to it simply as 'the railway style'.

Stations and other buildings tended to be individually designed to a high specification, albeit usually with a similar plan-form and massing of station buildings on a given route. Materials would reflect local availability, both for practical and artistic purposes. Within these constraints, designers often chose to vary the external expression of the buildings along a given route by applying a variety of architectural styles to the stations. At other times a 'line style' might be used to give a homogenous appearance to stations with varying plan-forms. Because many of the engineers and a number of the architects involved worked across the country for a number of independent railway companies, very similar stations could turn up on completely independent railways, sometimes on opposite sides of the country.

As the concept of the intermediate railway station became established, a number of plan-forms were essayed, the main variable being whether accommodation for the station master was provided integrally, separately or not at all, leading to one-storey designs with no accommodation, two-storey designs with accommodation over, or to structures with single-storey public parts attached to a two-storey station house. In many cases the resultant buildings were so closely based on non-railway precedents that they may be difficult to recognise as railway stations at all when the associated tracks and platforms have disappeared. The intermediate railway station as a distinct building type is reliant very largely on the provision of platform canopies. A number of designers had a preference for overall train shed roofs, even at relatively minor stations. G.T. Andrews, working for Hudson, and Brunel and his assistants are particularly notable in this respect. Buildings with integral, projecting timber canopies emerged almost concurrently c.1839, both Brunel on the Great Western and Tite on the London & Southampton evolving relatively shallow cantelevered timber structures projecting from all four sides of both the main station building and a smaller but matching waiting shelter on the opposite platform. Again, Tite's two-storey design had a particularly profound international influence. The platform canopy was soon adopted by others, sometimes as a relatively shallow affair between projecting bays, or as a deeper structure supported on columns close to the platform edge. As soon as stations started to routinely include residential accommodation, it was logical to provide facilities at the same spot for local goods. Thus by the mid 1840s the classic arrangement of station and goods yard, the latter often with a short loading platform, crane and small goods shed, had become established as a common feature of the English landscape.

The closing years of this period were years of enormous vitality, including as they did the Second Railway Mania and the collapse of the mania bubble in 1848. The ease of raising capital before the bursting of the Mania bubble resulted in lavish spending, with stations designed to impress the public and to express corporate pride. The collapse of the bubble seems to have done little to dampen the enthusiasm for decorative stations, although the sheer quantity of work led to some repetition of existing designs and an increasing reliance on timber, particularly with the Brunel camp. Generally the pattern remained a profusion of individualistic and decorative designs, by a variety of engineers and architects. The closing years of the period saw the completion of the largest and most expensive major stations built to date, for example Huddersfield and Newcastle Central (both 1850, the latter having the first iron-arched train shed) and King’s Cross station.

Stations 1853 to 1876

This period spans from the completion of the Great Northern Railway through to the completion of the Midland Railway's trans-Pennine Settle to Carlisle route, completing a third Anglo-Scottish route.

The 1850s and 1860s saw the railways beset by financial crises. Notwithstanding the deflation of the Railway Mania bubble in 1848 this period saw railways in Britain continuing their phenomenal growth, with new routes being added at a rate of around 400 new route miles per year. These opened up many areas on the periphery, including Cornwall and the hinterlands of Wales and Scotland. Many of the greatest structures of the so-called 'heroic' period of railway building were constructed or completed in the straightened circumstances of the 1850s. Investor confidence had returned by the early 1860s, but the collapse of the bank Overend & Gurney in 1866, due specifically to their over-exposure to railway stocks, hit railway stocks particularly hard. Financial stringency sometimes led to some locally-promoted railways being designed and built by railway contracting firms, in return for shares.

The period saw the rise to prominence of a new generation of more or less scrupulous railway managers running huge and increasingly competitive businesses. As a result, many new lines were unnecessary duplicate routes, built as the emerging combines each competed to tap the more lucrative parts of the country and their sources of traffic. One of the fiercest rivalries was in the South East, where the territory of the South Eastern Railway was comprehensively invaded by the East Kent Railway (later the London Chatham & Dover).

During this period railway traffic soared. Thus between 1853 and 1876, passenger journeys grew from 82.4 million at the end of 1852 to 517 million at the end of 1876.[ii] Two areas of very rapid growth were suburban and leisure traffic, the railways being particularly instrumental in the development of both. This huge expansion in traffic, coupled with increased competition and price-cutting, placed an enormous strain on the railway network. Many stations and junctions became increasingly chaotic as traffic grew, with the public growing increasingly dissatisfied with slow trains, poor punctuality and appalling safety standards. A number of large new termini and central railway stations were built to increasingly sophisticated designs. To add to the complexity, social mores and the increased carriage of the poorer classes meant that stations had to achieve greater efficiency whilst providing separate accommodation for three classes of traveller and two sexes, plus refreshment and (often) hotel facilities.

The intense competition of the period, coupled with growth of the larger combines through amalgamation and merger, saw the railways emerge as pioneers of corporate design. The quality of build and the degree of standardisation varied enormously, depending on local circumstances, the prestige or otherwise of traffic being tapped and the particular views of the of boards of directors and / or general managers on the importance of design. Thus, the largest of all the concerns, the London & North Western Railway, was noted for its parsimony and reliance on functional, 'standard' designs wherever possible thanks to the influence of its Chairman, Sir Richard Moon. In contrast, the thrusting Midland Railway under its General manager, James Alport, was noted for the exceptional design quality of everything it built, particularly as it thrust southward from Leicester to St Pancras and then northward, first to Manchester through the Peak District, then over the Pennines to Carlisle via Settle. Other railways (of which there were several hundred, large and small) filled the design spectrum in between. Large glass and iron roofs were an increasingly important element of station design, both at termini and larger stations, important developments being the crescent truss roof (an almost uniquely railway phenomenon) and large transverse ridge-and-furrow roofs (developing Paxton's Crystal palace theme). Prefabricated iron and glass platform canopies started to appear at some lesser stations, the Midland Railway (of which Paxton was a Director) being a particular pioneer in this respect.

Many of the railways that were built in the aftermath of the second Railway Mania of 1847-8 found themselves under-capitalised and, as stations tended to be the last call on depleted capital, excessive spending on architectural variety was generally more restrained than in the previous era. The architectural expression of major metropolitan stations remained outwardly classical through the 1850s, the principal exception being Cubitt's stripped-down 'engineer's Italianate' at London King's Cross station, completed in 1852. Large iron roofs had already become an established 'must have' for major stations by 1850 and the principal innovation in the early part of this period was to incorporate a grand hotel into the overall scheme. Amongst the first were the Great Northern Hotel, Kings Cross (completed 1854, L. Cubitt), the Queen's and North Western Hotel at New Street, Birmingham (completed 1854, W. Livock) and the Great Western Hotel, Paddington (1854, C.P. Hardwick, for the Great Western Railway). The first two were Italianate buildings, physically separated from the stations proper across a public road. The influence of the Paddington hotel was longer lasting, both by being constructed across the station end, concealing the train shed, but also because it was the first grand hotel to be constructed in the newly fashionable French Renaissance style, which then remained 'de riguer' for major hotels all over the World for the next 40 years.

Financial stringency did not affect the pace of railway-building, but 'named' external architects were employed less and increasingly the busy railway engineers tended to delegate the design of station buildings to skilled assistants. The design of smaller stations tended towards four-square two-storey blocks with residential accommodation above, single-storey buildings with terminal (and sometimes intermediate) pavilions or two-storey house with attached single storey booking office and waiting room. Platform canopies generally remained very small, normally cantilevered from the station building itself. If more generous covered accommodation was needed, it tended to be provided by a small train shed.

Possibly to compensate for the higher build cost of broad-gauge railways, economy became a particular byword for Brunel and his assistants and from 1850 to 1870 Brunel and / or his assistants perpetuated timber-built variants of designs evolved on the Great Western across hundreds of miles of new routes built for the Great Western and for many other more or less independent concerns. The South Eastern Railway had previously employed clapperboard at a number of locations on its Dover route in deference to local building traditions. Whereas these had previously been leavened with stations in other materials and architectural styles,

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from the 1850s to the 1880s they built little else, for strictly financial reasons. The Great Northern Railway had already established an austere Italianate brick vernacular for its stations, a style was ideal for further extensions built in financially straightened times.

These economies of design were nevertheless architecturally significant. The post-Railway Mania crash saw a number existing railways merging into larger combines, for whom many of the newly-built but undercapitalised lines were easy pickings. These confident larger concerns were amongst the very first corporate bodies anywhere to see the value of ‘corporate image’ and each sought to develop station designs that were recognisable as their own. The Great Northern thus perpetuated Cubitt's stripped-back Italianate style. The London & South Western remained loyal to Tite (latterly assisted by E.N. Clifton), so Tite's Italianate and Tudor-gothic station designs spread ever-westward with the company's expanding network. The Midland was one of the most progressive of railway companies. It was proudly provincial and highly expansionist. In the 1850s it turned the diamond and lozenge pattern iron windows and elaborate openwork bargeboards (both used previously by one of its constituents, the Midland Counties Railway) into a corporate brand, using them extensively for nearly forty years on everything from waiting shelters to engine sheds, in Italianate and Gothic buildings. For their well-appointed stations they combined these motifs with long, single-storey buildings with terminal (and sometimes intermediate) pavilions and, from 1857, with delicate but extensive ridge-and-furrow platform canopies probably inspired by Joseph Paxton, who was a company director. These Midland stations maintained previous traditions of individual design and quality of build using local materials, but set new standards in passenger accommodation and comfort. Their introduction of generous iron and glass platform canopies in 1857 turned out to be as important to intermediate station design as train sheds had been to the design of termini.

From the later 1850s railway stations increasingly looked quite different to their predecessors. Previously railway stations had tended to be purposefully designed to have the outward appearance of banks, gentlemen’s clubs, town halls, villas or estate lodges. By the later 1850s, terminal and intermediate railway stations were emerging as specific building types. The great stations had their large hotels and big train sheds. Smaller stations started to evolved into two main forms, either low, symmetrical single storey structures with separate residential accommodation for the station master, or, more commonly, asymmetric buildings with two-storey accommodation for the station master and station master’s office and a single-storey part for the waiting rooms, porter’s office, lamp room etc. The latter type proved particularly popular as it was cheaper to build, allowing scope for spending on decoration. In the spirit of the times, decoration meant Gothic, occasionally ‘real’ Gothic (Tudor Gothic, High Gothic or Gothic Revival, notably St Pancras), but more normally ‘Victorian Gothic’, meaning anything from a steep gables and a bit of polychromy (e.g. the London Chatham & Dover railway’s ‘Gothic Light’, through to wild and heady Baroque eclecticism that married, say, Lombardic Gothic and Second Empire French Renaissance (notably London Broad Street). Each railway company, of which there were many, increasing developed their own ‘look’. One of the most distinctive was the flamboyant Franco-Italianate polychromatic style that C.H.

Driver had created for the London Brighton & South Coast Railway at Denmark Hill station in 1865. It served the company well for some 20 years.

Stations 1877 to 1914

The period from the mid 1870s to the start of the First World War saw the railways at the height of their powers, with a near complete monopoly of land carriage in late Victorian and Edwardian Britain, as well as very extensive interests in ports and shipping.

In the previous era most railways had enjoyed atrocious public reputations for cut-throat competition and for trains that were antiquated, crowded, unpunctual, very slow and, worst of all, dangerous. The railways underwent a renaissance from the mid 1870s onwards, lasting until the outbreak of the First World War. Throughout the period many substantial project were launched. These included the four-tracking of the busiest existing railways, principally those extending out from London, and the construction of the last trunk main lines, notably the Great Central main line from Sheffield to Marylebone and the Great Western Railways high-speed 'cut-off' lines, which greatly reduced journey times between their main centres of London, Birmingham, South Wales and the West Country. These major projects, together with the reconstruction of other inadequate and chaotic stations resulted in many new stations being built or rebuilt on modern principles, usually with island platforms and extensive canopies, with lavish provision of buildings in up-to-date styles both at entrances and on the platforms. At lesser stations platforms were raised and, at many, the railway companies added their own individual designs of decorative lamp standards, footbridges and platform canopies with fretted valances, completing the characteristic appearance of the classic British railway station. The period saw the railway continue to develop their own individual corporate images as a way of garnering brand-loyalty amongst the travelling public, both with bright and distinctive liveries for their locomotives and carriages and increasingly distinct house-styles for stations and platform furniture.

Many completely new stations were required, as suburbs expanded and as railways sought to build new lines into each others territory. Many railways, such as the Midland and London & South Western railways, recognised the importance of good station architecture and generous provision of station facilities in such ventures. Other railways, particularly where they were competing principally for minerals traffic, opted for more standardised solutions, often of timber. The London & North Western, Great Northern and Manchester Sheffield & Lincolnshire railways enjoyed poor reputations in this respect. Apart from city termini and major junction stations, the best opportunities for making architectural statements were on the new, rival trunk routes built during this period (e.g. the Midland Railway’s Peak Forest and Settle-Carlisle routes and the London & South Western Railway’s thrust into Devon and Cornwall) and on the high-speed 'cut off' lines built to reduce mileages on existing routes between London, Birmingham, South Wales and the West Country. At the opposite end of the scale were the minimum-cost stations built on the *Light Railways* that were promoted to take railheads into ever remoter and sparsely populated areas. Towards the end of the period, competition street tramways and deep-level tube railways induced railways to introduce

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electric trains, although during this period it was principally only on North Tyneside that such schemes involved much in the way of new station building. Tram competition nevertheless induced a number of railways, particularly the Great Western, to introduce railmotor services serving additional ‘halts’ on their routes, these being timber-built platforms with standardised, curved-roofed corrugated iron ‘pagoda’ waiting shelters.

In terms of station layouts, island platforms (platforms with tracks on both sides) were used increasing, particularly at busy junction stations. From the late 1890s island platforms were used by some railways for more general applications. The Great Central Railway’s London Extension (Nottingham to London Marylebone, opened 1899) used the layout almost universally. Concurrently station layouts with transverse concourses above the tracks became increasingly popular, particularly at busy junction and more modern suburban stations. There was an increasing separation between station facilities and station master’s houses. Ultimately station master’s houses became wholly separate structures, allowing at all but the largest stations to become symmetrical, single-storey structures that were a complete break with the old-fashioned irregular Gothic forms of the previous generation.

Architecturally, the period initially saw a general continuation of styles established during the later 1860s and 1870s, generally with buildings that were ‘Victorian Gothic’ in character, even where the detailing highly eclectic. Digby Wyatt and Francis Fox’s High Tudor-Gothic extensions to Bristol Temple Meads station were completed in 1878. The London Brighton & South Coast Railway continued its eclectic ‘Denmark Hill’ mix of strong polychromatic Italianate brickwork, turrets and French Renaissance roofs, culminating with Eastbourne (1886) and Lewes (1889). The North Eastern pursued increasingly High Gothic for a few more years, notably with Middlesbrough (1877) and Sunderland (1879). The London Chatham and Dover also continued with its ‘Gothic-light’ for some years more. Initially modernity was expressed through the increasingly light and airy iron and glass structures behind. Companies who had developed more symmetrical, less fussy, single-storey house-styles found themselves able to continue to develop and apply them to increasingly modern stations for many more years, as tastes moved away from heavy Gothic. The Midland Railways’ single-storey variegated pavilion stations were cases in point, as were the new stations built from 1870 by the Great Western Railway for its four-tracking of the main line out of Paddington. Thus by 1870 both companies had developed house styles that proved to be capable of development into the 1890s. These were all house-styles that would have been instantly recognisable to the travelling public. The real improvements, pretty well across the board, were in the improved accommodation and facilities and in the increasingly generous provision of expansive and airy platform canopies, sometimes of extraordinary extent.

Signs of changing architectural tastes were becoming apparent in large stations the 1880s, in stations such as Slough (1882) and Norwich Thorpe (1886), with symmetrical frontages, convex mansard roofs and styling variously described as Free Renaissance or Second Empire. Whilst still rather heavy in external character, these had fine ironwork, Norwich in particular having an outstanding concourse roof, high, bright and unencumbered by superfluous decoration. Slough was a one-off for the Great Western, but Ashbee’s Free

Renaissance ‘Norwich’ style became a feature of a number of the Great Eastern’s better stations thereafter. As the 1880s progressed, the London Brighton & South Coast Railway found its Denmark Hill style to be old-fashioned and adopted an attractive Domestic Revival style in a number of smaller stations designed by the architect T.H. Myres. In the company’s own hand this became more loosely Queen Anne towards the turn of the century. Similarly, the Great Eastern Railway also adopted an attractive Domestic Revival style in East Anglia from the 1880s. The London & South Western moved from a rather bland brick interpretation of the Italianate to an attractive Queen Anne house-style at about the same time. This was used to particularly good effect in the astonishingly modern Bournemouth Central station, completed in 1886.

The early 1890s saw the introduction of Edwardian Baroque, usually with abundant terracotta detailing. Charles Trubshaw on the Midland Railway had already used terracotta on stations rebuilt in stripped Tudor and Jacobean styles between Bingley & Skipton between 1883-92 and in 1892 used it to greatest effect in the Baroque rebuilding of Nottingham London Road. Terracotta Baroque was subsequently used to good effect at Leicester Central (1899), Nottingham Victoria (1900) and Nottingham Midland (1904), and in more restrained fashion at Leicester Central and London Marylebone (1899) and Manchester Victoria (1909). The Edwardian Baroque as used by the railways after 1900 can have a tendency to look rather pompous (e.g. Sir Charles Morgan’s frontage to London Victoria (1908)), but by this time it was transmuting into a robust Beaux-Arts style. Early examples are A.W. Blomfield’s contemporary ‘Chatham side’ frontage at Victoria (1908) and his 1911 entrance block at Tunbridge Wells Central, which set a more restrained style used so successfully after the First World War by J.R. Scott at Ramsgate and Margate. London Waterloo, commenced in 1900 and completed in 1922 has Beaux-Arts detailing (e.g. the Victory Arch), but the best exemplar is Percy Tempest’s Dover Marine station, complete just in time to handle countless troop and ambulance trains during the First World War.

Stations 1915 to 1948

The period from the commencement of the First World War to Nationalisation includes the grouping into four large companies, which took place in 1923. In comparison to earlier periods, this period saw relatively little in the way of new main-line station building, largely on account of two world wars and a Great Depression.

The period commenced with the completion of major pre-war station projects, either during the war (e.g. Birmingham Moor Street (Great Western Railway, 1916) or after (e.g. London Waterloo (London & South Western Railway, completed 1922). In some cases pre-war projects that has not been started before the Grouping of 1923 were built to pre-war designs (e.g. Berwick on Tweed (London & North Eastern Railway to North British Railway plans, 1924-7).

Following the Grouping the newly amalgamated ‘Big Four’ railways (the Southern, London Midland & Scottish, London & North Eastern and an enlarged Great Western Railway) each embarked on limited station construction programmes, generally in restrained Beaux-Arts, Baroque or neo-Georgian styles (e.g. Bromley North, Margate, Ramsgate and Exeter Central (Southern Railway, 1926, 1926, 1930 and 1933), Welwyn Garden City and Aylesbury (London & North Eastern Railway, both 1926), Tilbury Riverside (1930, for the London Midland & Scottish Railway) and Newton Abbot, Newport (S Wales) and Cardiff (1927, 1928 and 1935, for the Great Western Railway). At all of these stations the canopies and platform building were generally unpretentious. Platform canopies were generally functional steel structures, stripped of fussy detailing such as decorated spandrels and (often) decorative valances.

Modernist styles were adopted in the 1930s, with varying degrees of success, although the ‘Company’ designs seldom approached the exceptional contemporary designs produced by Charles Holden for the newly formed London Transport. In many cases the unity that Holden produced between the frontage buildings and the platforms structures was lacking, canopies often being functional steel structures. For a period Portland stone was favoured as a facing material for some of the more restrained art-deco designs (Richmond and Wimbledon 1937 and 1939 for the Southern Railway, Leeds City (concourse and hotel only) (1939, for the London Midland and Scottish Railway and Taunton (north side) and Leamington Spa (1932 and 1939, for the Great Western Railway). Like Leeds, Portland stone would have been the material for the rebuilding of Euston, proposed in 1938, but not realised because of the outbreak of war. Brick was also widely used, albeit often less successfully to modern eyes, for example Doncaster station frontage and Longbenton station (1933 and 1948, for the London & North Eastern Railway), Kingston upon Thames (1935, for the Southern Railway) and a series of stations provided by the London Midland & Scottish Railway 1932-35 for the extension of District line electric trains to Upminster (Elm Park, Beccontree, Dagenham East, Hornchurch and Upminster Bridge). To these may be added Chalkwell (Southend), Leigh-on-Sea, South Kenton, Luton and Apsley (1933, 1933, 1937 and 1938, also for the LMS). The London & North Eastern adopted tile-clad facades for a period in East London (e.g. Maryland, possibly 1940).

The inter-war stations that are generally most admired today are those that projected a ‘streamlined’ aesthetic (Southampton Central, Woking, Bishopstone and Horsham (1935, 1937, 1938 and 1938 for the Southern Railway), or those that strongly express a concrete aesthetic. In the latter category are Surbiton (1938, for the Southern Railway), the Leeds City station concourse, Blackpool North station concourse and Hoylake station (all 1938, for the London Midland & Scottish Railway) and some of the ‘tube’ extension stations built by the main line railway companies, notably Loughton (1940, for the London & North Eastern Railway) and Perivale and West Acton (1938-47 and 1940, for the Great Western Railway). To these may be added the streamlined stations with very fine reinforced concrete canopies on the Southern Railway’s Chessington branch (Chessington South, Chessington North, Tolworth and Malden Manor, all 1938-9).

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Stations 1948 to the present

Whilst many of Britain's railway stations were in an appalling state after the Second World War, Nationalisation and immediate post-war investment did not result in a renaissance of station reconstruction. The main preoccupation of the newly nationalised railway was rehabilitation of appallingly run-down infrastructure, repair and replacement of rolling stock and the improvement, where possible, of working conditions, particularly at engine sheds. Attention had not yet turned to rationalisation of duplicate lines and stations, nor to de-staffing. Such matters had not been in the nationalisation 'manifesto'.

Between 1948 and the announcement of the 1955 Modernisation Plan, work on Britain's railway stations was substantially a case of 'make do and mend'. A number of stations, most notably Plymouth, York, Middleborough, London Cannon Street, Barrow Central, Sunderland and Birmingham New Street, had severe bomb damage to their roofs. A number of smaller stations had also suffered extensive damage. Of more concern was the backlog of maintenance arrears and failing roofs. In most cases investment in stations was limited to applying corporate signage, patching up bomb- and blast-damaged damaged train sheds and canopies and, where necessary, replacing the most damaged or rotten with functional steel platform canopies to standardised designs. Where necessary, the remains of bombed-out entrance buildings were subject to ad-hoc repairs until funds and materials for more thorough reconstruction became available, such temporary repairs often lasting well into the 1960s.

Generally new early-nationalisation station buildings were provided because of non war-related causes. Girvan station, burned down in 1946, was rebuilt by the newly-formed British Railways in 1948 to a pre-war LMS 'streamlined' design. One of the very first post-nationalisation designs was for Bury (Bolton Street), where the street frontage had burnt down after the war. It was replaced in 1952 with a bespoke new brick and reinforced concrete Modernist entrance building, with brick clock tower and covered footbridge. The reconstruction of Twickenham station, demolished immediately pre-war for the construction of Southern Railway streamlined station, was finally completed in 1954, with new platform structures and a rather charming entrance pavilion, with coloured mosaic panels and flat concrete roof cantilevered out as a canopy. A similar form was used for the platform shelters at the bombed-out Wallasey Village station and at Cheddington (possibly 1955). Grays station (Essex) and Potters Bar may have been rebuilt at a similar time. The remains of Middlesbrough station were rebuilt at about the same time, producing what still seems like a skilful hybrid of Victorian gothic and Festival of Britain concrete. All of these early nationalisation stations have a definite charm, redolent of an age of optimism, equality and chronic materials shortages.

The period 1955-63 marks the architectural high-watermark of the nationalised railway industry. It spans from the 1955 British Railways Modernisation Plan, through to the abolition of the British Transport Commission under Harold Macmillan and Ernest Marples' 1962 Transport Act. British Railways retained a regional structure, each region retaining individual responsibility for architectural design. Materials shortages were becoming a thing of the past and Government finance for railway investment and operation was available in spades. The bombed-out York station, which could so easily have been lost, was carefully and sympathetically repaired. The decision to electrify the West Coast Main Line from London to Manchester and Liverpool saw the concept of ‘total route modernisation’ emerge, with stations, track, signalling and rolling stock all being renewed simultaneously. Elsewhere station renewals were based almost exclusively on condition and urgency. Harlow got a completely new station to serve the new town. Cost-cutting and the projection of corporate image were seemingly unimportant. The new stations were normally at least as well provided as their pre-war predecessors. Each new or rebuilt station seemed to demand its own, individual design response and inventiveness was encouraged.

The early Modernisation Plan stations, Banbury (1958), Chichester and Barrow (1959) still reflected something of the early post-Nationalisation stations in their use of brick, reinforced concrete and mosaic panels. Banbury had reinforced concrete platform canopies. Barrow, utilitarian steel. The best stations, Manchester London Road, Harlow, Broxbourne, Barking and Coventry (all 1960-61) were each unique and distinct, with highly varied forms and materials. Probably the very best was Oxford Road, Manchester (1959-60), its dramatic laminated timber roof of three conoid shells and laminated timber platform canopies reflecting the structural boldness of Victorian train sheds. Despite the huge investment in the 1955 Modernisation Plan (initially costed at £1.2 billion), the railways continued to hemorrhage money, losses rising from £15.6m in 1956 to £42m in 1960.

The appointment of Richard Beeching as Chairman in 1961, the dissolution of the British Transport Commission under the 1962 Transport Act and the publication of Beeching’s 1963 report "The Reshaping of British Railways", brought a radical change of focus. One-third of the country's 7,000 railway stations would close. The remainder would be modernised, cut back, replaced or simply removed, to require less maintenance and fewer staff. The results were compounded by the ‘British Rail’ rebranding in 1965, seeing the introduction of a new black and white corporate image, to be applied universally across the network. The result was a miserable downturn in architectural quality. Where new buildings had to be provided, traditional individual rebuilding projects were generall abandoned in favour of mass-produced solutions, using factory-made parts. The Southern Region, and to an extent the Western Region, adopted the CLASP method for their reconstructed stations, used since the 1950s by local authorities for classrooms and other no-frills public buildings. The flat-roofed prefabricated buildings were made of steel and concrete, with a large water tank mounted on the roof. Windows were small and placed high up, immediately below the eaves. Evenly spaced wooden or metal pillars held up flat-roofed canopies which were usually wood-panelled underneath. Pre-formed panels of aggregate-coated concrete formed the outer walls. They proved to be prone to rot and a number were short-lived.

The first CLASP stations were built in 1965, the last in 1977. CLASP stations were built at Sunbury, Fleet, Crewley, Ashtead, Aylesham, Belmont, Belvedere, Charlton, Crayford, New Eltham, Slade Green, Berrylands, Hampton Wick, Catford, Poole, Oxford, Longfield, Meopham, Bristol Parkway, Kidbrook, Rainham, East Grinstead, Hassocks, Sunningdale, Virginia Water, Wokingham, Gloucester, Lower Sydenham, Strood, Forrest Hill, Brockley, Wool. British Rail used also twice used the SCOLA (Second Consortium of Local Authorities) scheme, similar to CLASP, when Newington and Teynham stations were rebuilt in the late 1970s to suit one-man operation.[iii] A few larger stations were rebuilt (e.g. Leeds in 1967), whilst 1971 saw the opening of Bristol Parkway, the first in a new generation of park-and-ride stations. Such stations were dismally utilitarian. In 1973 a dreadful expanse of a single-storey travel centre was erected in front of King's Cross station. Bristol Parkway and Leeds have subsequently been completely rebuilt post-Privatisation and the King's Cross travel centre removed. Somewhat better were Basildon (1974), Birmingham International (1976) and Milton Keynes (1982). Beeching and Marples' greatest architectural memorial were the new Birmingham New Street station (1964-67, Kenneth J. Davies, for British Rail, currently being redeveloped) and Euston station, opened in 1968 after six years of reconstruction, to designs by the British Rail architect's department in consultation with Richard Seifert & Partners. Neither station had any connection with railway design and both had dark, dismal platform areas. Euston's concourse was clearly based on airport terminal principles, whilst its external expression was that of a CLASP station on steroids. Euston will be reconstructed for HS2. Unlike the loss of its predecessor, there has been no public outrage.

From 1980 into the 1990s, British Rail adopted a new system of brick buildings with apex roofs, smaller examples resembling a 'chalet'. The sectorisation of British Rail in 1982 as a prelude to privatisation brought control of stations under individual sector managers, with greater autonomy for station budgets and design. Network SouthEast, under its head Chris Green, and ScotRail led an increased appreciation of station heritage as a key to delivering customer satisfaction, although the brightening up of rundown stations and the application of new sectoral branding did lead to some loss of heritage features, such as old-fashioned ticket windows. Nevertheless, when the London – Aylesbury / Banbury route was subject to total route modernisation 1988-92, no stations were demolished. Waiting rooms were brought back into use and buildings restored. An encouraging post-Privatisation trend has been a move away from unifying 'corporate-image' branding, with many stations, both designated and undesignated, now receiving authentic heritage colour schemes and signage and sympathetic lighting. The restoration of Birmingham Moor Street station in 2002 by Chiltern Railways and the Birmingham Alliance seems to have been an early pioneer of this.

Undoubtedly the greatest architectural legacy of the Sectorisation era to the privatised Railtrack was the reconstruction and extension of Liverpool Street Station (1985-91, Nick Derbyshire, for British Rail and Network SouthEast). Unlike Euston and New Street and the schemes proposed for St Pancras and Kings Cross, the station was not demolished. Instead it was cleaned, restored and carefully extended in facsimile, to wide professional and public acclaim. Similar work in facsimile has been carried out in the extension of Moor Streetr station. One of the last major Network SouthEast stations was a new-build however, this being Norman Foster's station at Stansted Airport.

2 TRAIN SHEDS

A train shed is a timber or metal large-span roof adjacent to a station building, spanning both the tracks and the platforms. It is also known as an overall roof. Whilst large clear-span roofs and metal roofs have a history that pre-dates that of the main-line railway, and whilst such roofs were built for other applications such as market and exhibition halls throughout the 19th Century and after, from 1830 to 1930 the railways were the principal customers for such roofs and at the forefront of the technological development of large clear-span roofs. The overall roofs built for the railways during this period developed solutions which continue to be widely employed in today's clear span buildings.

The late 20th Century saw a revival in interest in train sheds as a key component of modern stations, starting with Nick Derbyshire's highly praised facsimile extensions to the Victorian train sheds at London Liverpool Street (1992, Nick Derbyshire, for British Rail), followed by the first brand new large train sheds for nearly a century: the appropriately high-tech Waterloo International (1994, Nicholas Grimshaw and Sir Alexander Gibb & Partners, for CTRL / Union Railways) and Leeds (former Leeds New) (2002, for Railtrack). These later structures, arguably all worthy of statutory recognition 'straight out of the box', fall outside of the temporal scope of this study.

(Note: in this chapter, surviving structures are shown in **bold**.)

Timber train sheds

The first railway train shed was a relatively conventional queen post timber truss structure built by George Stephenson at Crown Street station, Liverpool, opened in 1830. It covered three tracks and spanned between a platform canopy on the departure platform and a retaining wall opposite. Whilst its main function appears to have been as a carriage shed, it established the convention of a train shed being a major component of any self-respecting railway terminus. It was thus followed by similar roofs of increasing dimensions at **Selby** and Marsh Lane, Leeds (1834, James Walker, for the Leeds & Selby Railway, three spans on plain cast iron columns), Liverpool Lime Street (1) (1836, John Cunningham and Arthur Holme, for the Liverpool & Manchester Railway, three spans on decorative cast iron arcading, 55 foot span), London Bridge (1) (1836, for the London & Greenwich Railway, 56 foot span), Nine Elms (1838, William Tite, for the London & Southampton Railway, 74 foot span), Preston (1) (1838), London Bridge (2) (1839, J.U. Rastrick, for the London & Croydon Railway),[iv] Southampton and Gosport (1840 and 1841, William Tite, for the London & Southampton Railway) and Middlesborough (1) and Redcar (1) (1840 and 1846, John Middleton, for the Middlesborough & Redcar Railway). The opening of the Great Western Railway in 1840 saw the completion of the first timber train sheds built on a heroic scale, at Bath and **Bristol (Temple Meads)** (Grade I), the latter with a clear span of 72 feet, rivaling the giant timber and composite slipway covers built in the Royal Navy's dockyards. To achieve this with lightness, artistry and economy of materials, Brunel laminated his timber principal rafters between wrought iron plates and extended them beyond the cast iron supporting columns, to cover circulation 'aisles' to each side, so that the principal rafters were partially cantilevered. It is claimed that Brunel's Bristol roof was the largest single-span building constructed to date, although in 1844 it was clearly surpassed by the composite wood and iron trusses of Charles Fox's 80 foot span roofs over the slipways at Pembroke Dock.[v]

After 1840 timber trussed overall roofs were generally only employed on smaller, single-platform stations, spanning over the platform and one line of rails. Examples included **Darlington North Road** (3) (1842, Grade II*), Guildford (1845), Burnham on Sea (1858), Aldeburgh (1860) and the remarkably late **Thurso** and **Wick** (1874). The format was doubled by Mocatta at Reigate (1841), leaving space for two uncovered through tracks in between matching stations facing each other. Timber trussed roofs were used over concourses only at Lowestoft Central (1847) and Littlehampton (1863).[vi]

Brunel and his assistants provided the exception, remaining firmly wedded to wide-span trussed timber train shed roofs on most of the railways with which they were associated, building them at Slough (1840), Taunton (1842), Oxford (1) (1844), Exeter (1844), Exeter (St Thomas) (1) (1847), Basingstoke (1848), Westbury (1848), Newton Abbot (1848 and 1861, Dawlish (1848), Plymouth Millbay (1849), Windsor (1850), Swansea (1850), Wolverhampton (1854), **High Wycombe** (1854), Truro (1855), Salisbury (1856) and Thame (1862).

Alongside these, Brunel and his assistants also essayed timber train shed roofs with wrought iron ties and struts. A pair of such roofs had been built in 1839 at the Grand Junction Railway station at Birmingham Curzon Street. Brunel and his assistants built them at Clevedon (1847), **Frome** (1850, Grade II), Banbury (1850), Birmingham Snow Hill (1) (1852), Penzance (1852), Salisbury (1856), Henley on Thames (1857), Tavistock South (1859), Exeter St Thomas (2) (1861), Falmouth (1863), **Kingswear** (1864, Grade II), **Chard Central** (1866, Grade II), Taunton (1868), Mortonhampstead (1869), Cheddar (1869) and **Ashburton** (1872, undesignated).[vii] By far the finest roof in this tradition was Francis Fox's **extension to Brunel's train shed at Bristol Temple Meads** station (1871-78). An exceptionally long roof of this type was provided by Tite at the royal **Windsor & Eton Riverside** station, completed in 1851 (London & South Western Railway). Coniston station (1859, E.G. Paley, for the Furness Railway) and **Kirkby Stephen East** (1862, Thomas Bouch, for the South Durham & Lancashire Union Railway, Grade II) were other examples.

The Stockton & Darlington Railway has a tradition of providing its medium-sized stations with a train shed spanning a pair of tracks, one serving a platform, the other serving as a carriage siding and one platform. This tradition dated back at least as far as the 1842 rebuilding of Darlington North Road Station. There was a strong Andrews influence on John Middleton's hipped-roofed timber and iron train sheds at Middlesbrough (1) and Redcar (1) (both 1847). At **Redcar** (2) (1861, J.P. Pritchett Jnr. and William Cudworth) provided a replacement hipped train shed with timber principal rafters, wrought iron ties and cast iron struts. The roof was repeated in 1862 at Saltburn by William Peachey, for the same company. Guiseborough (1854) and Bishop Auckland (2) and (3) (1857 and 1867) were similar, but with wrought iron struts.

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Ultimately the timber roof was not well suited to steam railway locomotion and was an evolutionary dead end. An attempt to better adapt the material to train shed use was to form high laminated timber arches, experiments that generally ran in parallel with the development of laminated timber bridges. The earliest example was the triple arched train shed built by John and Benjamin Green at North Shields (1839, for the Newcastle & North Shields Railway). Its wider bay over the tracks spanned 25 feet, with the arches tied with wrought iron bars. The narrower arches over the platforms were conventionally tied using timber. This was followed in 1848 by the original Blackburn station (for the Bolton, Blackburn, Clitheroe & West Yorkshire Railway), which had a 66-foot span, 300-foot long train shed, with laminated wrought iron and timber arches that also required no ties. The last major laminated timber train shed roof were the twin vaults of Kings Cross station (1852, Lewis Cubitt, for the Great Northern Railway). These spanned 105 feet and were braced by substantial arcaded side and centre walls. The laminated timber arches proved insufficiently durable and were replaced in iron in 1869 (east side) and 1887 (west side). The replacement iron arches were carefully designed to preserve the form of the original roof.[viii]

Similar to the high arched laminated roofs were others with arches of bolted solid section, notably the 53-foot wide arched train shed at the Lytham terminus of the Preston & Wyre Railway (1846), where the arches sprang directly from ground level, requiring no visible ties. Brune’s assistants produced similar arched roofs based on the aisled, cantilevered Bath / Temple Meads format at Oxford (2) (1851), Leamington (1852), Merthyr Tydfil (1856), and Weymouth Town (1857).

Pitched Roofed Iron Train Sheds on Columns (‘Euston Roofs’)

Whilst the timber-trussed 1836 Lime Street (1) roof was undoubtedly an impressive structure, prior to 1838 railway train sheds were structurally and technically unambitious, employing simple, tried-and-tested methods. The great leap forward came in 1838, with the opening of the London & Birmingham Railway and the completion of its termini at Euston and Curzon Street. These stations included two of the project’s many marvels, the all-metal trainsheds designed by Charles Fox, working under Robert Stephenson. These comprised two parallel ranges of open-sided, pitched-roofed sheds, comprising wrought iron transverse trusses, supported on longitudinal arcades of cast-iron columns and cast iron arched girders decorated with circles. The trusses were made using rolled iron T sections for the rafters and compression members, and rolled bar for the tension members. The connections were made by forging and drilling the ends to the bars, which were bolted together. Final adjustment was by wedged connectors. The two roofs were different in a number of respects. The Euston train sheds were 200 foot long, with 40-foot trusses. It was fully fireproof, with a cladding of slate, fixed directly to angle-iron laths with copper wire. The train sheds at Curzon Street were each 217 feet long, with 56½foot trusses and slate cladding fixed to timber sarking.

The roofs were a sensation and the progenitors of all subsequent all-metal roofs, both on the railways and in multiple other applications. They were not the first all-metal roof structures, as cast-iron trusses had been used to a limited extent in the ‘fireproof’ roofs of some British textile mills and in naval dockyards during the first decades of the 19th Century. By the 1820s British engineers were experimenting with trusses with cast iron struts and wrought iron ties. Similarly, largely unknown in Britain, wholly wrought iron trusses had been built to a limited extent by French engineers, generally working out of the spotlight in palaces and monasteries in Imperial Russia, where serf labour allowed the profligate use of what was in Russia still a craft product. The Euston and Curzon Street train sheds were nevertheless the first buildings to combine wrought iron trusses and cast iron colonnades into a single very large, prefabricated structure devoid of any masonry or timber. The use of wrought iron rolled T sections for compression members appears to have been wholly novel. More importantly, the roofs were lightweight, airy and quick and cheap to erect. Whilst timber remained in use as a medium for composite trussed in pitched roofed train sheds as late as the 1870s, the ‘Euston roof’ was widely and rapidly copied and became the most common form of train shed, both in Britain and throughout the world.

In Britain the Euston and Curzon Street roofs were immediately repeated, but in a more expansive form but simpler arcading with straight iron girders at the Derby tri-junct station (1840, Francis Thompson and Robert Stephenson), which whilst only having one very long platform, had a large, 3-span train shed 140-foot wide covering the station platform and seven roads for stabling carriages. The original form was also taken up immediately by G.T. Andrews, who built Euston roofs at York (1840, two 40-foot spans), Gateshead (1844, two 44 foot spans), **Durham Gilesgate** (1844) (two 27 foot spans), **Scarborough** (1845, two 44 foot spans), Whitby (1847, two unequal spans and Hull (1848, three 44 foot spans). These all had hipped ends. Andrews adapted the form for his Gothic **Richmond** station (1846), with two steeply pitched, gable-ended roofs and decorative cast-iron arcading. Similar roofs on similarly decorative arcading were built by Weightman and Hadfield of Sheffield at Boston, Alford, Firsby and Louth (all 1848, for the East Lincolnshire Railway). At **Edinburgh Haymarket** (1842) John Miller provided a 12-bay, variant Euston-type roof with cast iron struts, set on foliated arcading, with fluted columns with capitals.

More ambitious versions of the Euston roof were built at Manchester Victoria (1) (1844, George Stephenson), with three spans of 60 feet, London Maiden Lane (1850, later the Midland Goods Shed, King’s Cross, two spans) and Liverpool Tithebarn Street (later Liverpool Exchange) (1850, John Hawkshaw) with two spans, the larger shed being 136 foot at its widest point, with a lightweight cladding of galvanised iron sheet. Tithebarn Street station was considered remarkable in that it took only six months to build. A single-span Euston roof was also erected at Liverpool Edge Hill station in 1847 and the Euston roof was repeated again at Rugby (2) in 1850. Remarkably Peterborough East station (1845) had six parallel narrow spans, forming a roof 410 feet long and 228 feet wide, approaching twice the overall width of the Derby train sheds. The single-span York Excursion station (1846) was notable for its length. Small versions of the Euston roof spanning just a narrow platform and a single track were built at Redhill (1844, two spans), Canterbury West (1846, two spans) and St Albans Abbey (1858, one span). The last true Euston roofs were additional matching span added alongside the originals at Euston itself in 1873 and an additional span added to what was by then the **Midland Goods Shed** at King's Cross in 1888, possibly incorporating elements of the 1850 Maiden Lane roof.

By the 1850s engineers were seeking to increase the distance between the supporting columns and the Euston-type arched cast-iron girders gave way to straight girders of various forms. Amongst the first of these was the train shed at T.C. Hine's **London Road station, Nottingham** (1857, three spans), which has unadorned columns connected by heavy cast iron girders, in the manner of the Thompson and Stephenson's Derby station. Similar was Buxton (1863, two separate spans), where the cast iron girders were open and infilled with circles. In the 1850s (possibly as early as 1850), the London & North Western Railway substituted fabricated wrought iron Pratt truss girders at Rugby (2), in this instance light 3-panel girders of a form repeated at Stafford (2) (1861, two spans, for the London & North Western Railway), **Crewe** (2) (1867, two spans), Holyhead (2) (1880, 2 spans) and **Huddersfield** (1886, two unequal spans), all for the London & North Western Railway). This form of Euston roof, but with increasingly long and heavy girders, became the 'house style' of the London & North Western Railway for the next three decades, being repeated at Swansea Victoria (1867?, two spans), Rugby (3) (1886, two spans), **Chester (additional spans)** (1890, two spans), Llandudno (1892, four spans) and Crewe (additional spans) (1906, two spans). The same general pattern with long and heavy trussed supporting girders was used by others, including at Chester Northgate (1875, two spans, for the Cheshire Lines Committee), Manchester Victoria (1877-1904, three unequal spans, for the Lancashire & Yorkshire Railway), Cardiff Queen Street (1887, two spans, for the Taff Vale Railway) and Liverpool Exchange (2) (1888, four spans, for the Lancashire & Yorkshire Railway).

Curved supporting girders made their final appearances in lengthened form, probably of wrought iron, at London Broad Street (1865, two spans, for the North London Railway) and in more decorative form at **Preston** station (three unequal spans), built jointly by the London & North Western Railway and the Lancashire & Yorkshire Railway between 1876 and 1903, the latter being undoubtedly the most spacious and decorative of all the traditional Euston-type train sheds.

The introduction of steel saw the form transmute one last time, with large-span trusses made of increasingly standard rolled sections, supported on lengthy arched trussed girders and heavy riveted columns. The effect in combination with the increased height and spans permitted was not displeasing however, much the best British example being Nottingham Victoria station (1900, Albert Edward Lambert Douglas and Francis Fox, for the Great Central Railway). With five fully-glazed spans, columns over 42 feet tall and a centre span of over 82 feet, it was well lit and spacious, combining the height of an arched train shed with the ample glazing of a ridge and furrow roof. Other examples of slightly lesser note were London **Marylebone** (1899, Douglas and Francis Fox, for the Great Central Railway, three spans) and **London Victoria** (Brighton side (2)) (1908, Sir Charles Morgan, for the London Brighton & South Coast Railway, five spans). The latter was of note for its exceptional length, each platform being able to accommodate two trains end-to-end.

Pitched Roofed Iron Train Sheds on Walls

As Brunel and his assistants were enthusiasts for single-span timber train sheds at terminal and through stations large and small in the western counties, a similar strain of development took place, initially in the East and North East of England, using ‘Euston-type’ wrought iron trusses on masonry walls. One of the most enthusiastic early exponents was G.T. Andrews, who built a series of similar 44-foot span iron-trussed train sheds on masonry curtain walls at a number of small-town stations in the East and North Ridings of Yorkshire on lines under the control of George Hudson. Most were at through stations with two tracks and two platforms, where the overall roofs were provided exclusively in the interests of passenger comfort. Andrew’s train sheds at his through stations were generally hipped-roofed, with the end openings spanned by straight open-truss girders, usually of the lenticular pattern. Such train sheds were provided at Malton (1845, Grade II), Bridlington (1) (1846), **Filey** (1846, Grade II*), Driffield (1846), Pickering (1846, Grade II), Beverley (1846, Grade II), **Pocklington** (1847, Grade II), Market Weighton (1847) and Boroughbridge (1847). Tadcaster (1847) was similar, but the train shed had gabled ends. Of these stations Driffield station survives, but its roof was removed in 1949. Beverley (Grade II) had its roof replaced in 1908. Filey’s roof was truncated at both ends in the 1950s, but was fully restored in 1990. Malton’s roof (one of only two to have survived intact) was included in the station’s Grade II listing, but was demolished, along with much of the remainder of the station, in 1989. Pickering lost its roof in 1952, but it was replaced with a replica of the original in 2011.

An isolated example of a two-track, single-platform, walled train shed with iron trusses was Stamford Water Street (later Stamford East) (1856, William Hurst, for the Stamford & Essendine Railway), which had iron trusses and gabled ends.

Other railways also built side-walled, twin-platform train sheds with ‘Euston-type’ wrought iron trusses, initially closely based on Andrews’ stations, but with gabled ends. These included Market Rasen and Brigg stations (1848, Weightman and Hadfield of Sheffield, for the Great Grimsby & Sheffield Junction Railway), Gainsborough station (1849, Weightman and Hadfield of Sheffield, for the Manchester Sheffield & Lincolnshire Railway) and Sittingbourne, Canterbury, Dover Priory and **Margate (East Kent Railway)** (1858, 1860, 1861 and 1863, for the London, Chatham & Dover Railway). Increasingly large versions, spanning two platforms and three or four tracks (or two tracks and an island platform), were also constructed, included Lincoln St Marks station (1846, Midland Railway), **Chester General**, with two parallel train sheds separated by a brick arcade (1848, Francis Thompson and C.H. Wild, for the Chester & Holyhead Railway), Sheffield Victoria (1851, John Fowler, for the Manchester Sheffield & Lincolnshire Railway), Wolverhampton High Level (1852, for the Shrewsbury and Birmingham Railway), Wakefield Kirkgate station (1854), Dover Harbour (1863, for the London, Chatham & Dover Railway), Exeter St David’s (2), the largest span example with a span of 132 feet (1864, Francis Fox, for the Bristol & Exeter Railway), Mirfield (1866), South Shields (1871), Southport Central (1883, C.H. Driver, J. Brunlees and Charles Douglas Fox, for the West Lancashire Railway), Blackburn (1888, W Hunt and H Shelmerdine(?), for the Lancashire & Yorkshire Railway) and, last of all, Liverpool Riverside (1895, for the London & North Western Railway).

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Tied segmental train sheds

Amongst the World's most celebrated train sheds is Dobson's gracefully curved three-span train shed at **Newcastle Central**, completed in 1849 for the York Newcastle & Berwick and Newcastle & Carlisle railways. With its three parallel 60-foot span roofs of segmental wrought iron ribs, the roof had precedents in the untied roofs of Paxton's Chatsworth greenhouse (1836-40) and Turner and Burton's Kew Palm House (1844-8). These sprang from ground level however, and Dobson wished his roof to spring from colonnaded cast iron arcades in the manner of the Euston and Curzon Street train sheds. To resist the outward thrust of the curved ribs, Dobson provided simple horizontal wrought iron ties between their feet, suspended from the crown of each arch by a single vertical strut. Nobody had previously attempted to build a multi-span arched structure on such a scale, particularly one perched on top of cast iron arcades. Nobody had ever tried to build such a structure on a curve. The train shed was a sensation. Fortunately it survives to this day and has recently been upgraded to a Grade I listed building.

Dobson's simple tied arch was adopted in later years as part of its house style by the North Eastern Railway, successor to the York Newcastle & Berwick and Newcastle & Carlisle railways. First was **Darlington Bank Top** station (1887, William Bell), which had three roofs of 62-foot to 66-foot span in which the intermediate ribs between the columns were dispensed with in favour of longer purlins. The ribs were pieced, with latticed ends that visually extended the segmental ribs into semi-ellipses. At **Alnwick**, opened the same year, Bell reverted to simple segmental ribs, producing a cleaner look closer to the original Dobson aesthetic, repeated later at Hull and Monseaton (below).

In 1893 Bell completed the new Stockton station, with two roofs of a larger span, requiring an upwardly-arched tie suspended with multiple struts. It is more correctly classified as a crescent arch and is considered below. Bell reverted to the simple tied arch in his last major roof, at **Hull Paragon** (1904), which had five spans (one of 70 feet, three of 64 to 65 feet and one of 58 feet). This repeated the Alnwick formula, but with the roofs supported on an arcade of cast iron columns and fabricated open truss girders.

The last roofs of the type were an additional span at South Shields (1905), a roof over the concourse at **Bridlington** (1912) and a platform canopy at **Monkseaton** station (1915), built for the Tyneside electrification project. Whilst the Monkseaton canopy is unique in the UK, it is reminiscent of Berlin or Viennese S-Bahn suburban station of the period.

Metal Crescent Trussed Roofs

An accident at Euston in the mid 1840s brought down a column and part of the roof. The accident demonstrated a need for very large clear-span train sheds, uncluttered by supporting columns. To achieve this Richard Turner (designer of the Kew Palm House, built 1844-8), in collaboration with Joseph Locke and William Fairbairn, designed a new form of roof combining the truss and the tied arch. This comprised an arched top chord formed of rolled deck beams, tied with an arched rod. To keep the truss in a crescent shape, vertical cast iron struts and diagonal wrought iron ties were set between the two chords. Sliding joints were provided at the supports to prevent any outward thrust being transferred to the supports.

Turner had in effect invented the lightweight space-frame and found that it could span unprecedented distances. An extension of Liverpool Lime Street station was urgently needed and, following a series of tests on a full scale arch, Turner designed a crescent trussed roof that would cover the entire station in a single span of 153 ft. 6 in., more than twice the span of any iron roof built up to that time.

Turner's Lime Street roof, completed in 1849 (the same year as Dobson's 60-foot spans at Newcastle) rapidly became the template for a new breed of exceptionally wide-span roofs, built at a time of exceptionally aggressive railway expansion and competition. Indeed, the next built, at Birmingham Grand Central Station (New Street) in 1854, by A.E. Cowper, had a length of 1,100 foot and a span of 212-foot, which remained a world record for the next 20 years, until finally eclipsed by Barlow's St Pancras train shed. Contemporary with Birmingham was London Fenchurch Street (1854, George Berkeley, 101-foot span) and Wolverhampton Low Level (1854, John Fowler and I.K. Brunel, 115-foot span). Birmingham New Street, Wolverhampton Low Level and Fenchurch Street were followed in turn by a series of similar wide-span roofs London Charring Cross (1864, Sir John Hawkshaw, 164-foot span), London Cannon Street (1866, Sir John Hawkshaw, 190-foot span), **Manchester London Road (2)** (Piccadilly) (1866, William Baker, two 95-foot spans), Birmingham Snow Hill (2) (1871, two spans) and **Manchester London Road (3)** (Piccadilly) (1881, L.H. Moorson, 100-foot span and 78-ft span). Smaller versions were built at Ramsgate Harbour (1863, Sir John Fowler), Worcester Shrub Hill (1865), and London Bridge (1867, C.H. Driver and F.D. Banister, 88-foot span).

Three main variant's of Turner's classic form were evolved in the 1860s. The first of these were built wholly of wrought iron rolled sections, but again with vertical struts and diagonal ties. The type drew heavily on Berkeley's Fenchurch Street roof. Short span roofs of this type were built with horizontal lower ties at London **Farringdon** and **West Brompton** (1865 and 1869, Sir John Fowler). More ambitious, with wider spans and high arched lower ties, were the roofs at Leicester Belgrave Road (1883). Like Turner's original structure, these were effectively bowstring or crescent Pratt trusses

A parallel development was to dispense with the vertical compression members and to use only diagonal struts that could be in tension or compression, depending on wind loads. These were effectively crescent Warren trusses. Such roofs were built at **Liverpool Lime Street (3)** (1867, William Baker, 212-foot north span), Birkenhead Woodside (1878, two spans), **Liverpool Lime Street (4)** (1879, Francis Stephenson and E.E. Ives, 191-foot south span), **Penzance** (1879, 80-foot span, crescent Pratt truss), Manchester Exchange (1882, three spans) and Birmingham New Street (Midland side) (1885, F. Stephenson, two spans, 58-foot and 67-foot, 6 inches span).

A third variant reduced the struts and ties to all but non existence through the use of deep I-beam or latticed principal ribs, becoming effectively a wide-span tied segmental arch crescent arch with an upwardly-arched tie suspended on radial struts. The earliest was the two-span roof at **London Victoria (Chatham side)** (1862, Sir John Fowler, 127-foot span and 129-foot span). Francis Fox's gothic roof at **Bristol Temple Meads** utilised the same principles, albeit with a shallow pointed arch to harmonise with Brunel's original station (1871-78, 125-foot span). Others were Liverpool Central (1874), Glasgow St Enoch (smaller 1876 roof), **Glasgow Queen Street** (James Carswell, 1878-80, one span) and Bradford Exchange (1880, two spans). The last extended the ribs with tapering cast iron spandrels, to give the roofs the appearance of having semi-circular ribs. Amongst the last of the type were William Bell's Stockton station (1893, two spans) and Blackpool Talbot Road (1898, two spans), which were similar to Bradford. The last of all was **Span 4 at Paddington station** (1906-15) which is unique in having high semi-eliptical form with cross- and radial ties.

These roofs have had a chequered history. Part of the roof at Charring Cross famously collapsed in December 1905, killing six people and leading to the replacement of the entire roof with a transverse ridge-and-furrow roof on columns. A.E. Cowper's fabulous roof 1854 roof Birmingham New Street and Hawkshaw's fine Cannon Street station roofs were removed in 1946 and 1958 respectively because of war-time bomb damage. The 'Midland side' roofs at New Street were removed for the reconstruction of New Street station between 1964 and 1967. A number of the roofs were simply a victim of having been built at a time of rapid expansion. Many were born or railway rivalry and were erected at what were later regarded as 'duplicate' stations, Leicester Belgrave Road, Birkenhead Woodside, Manchester Exchange, Bradford Exchange and Blackpool Talbot Road all succumbing to closure and demolition in the 1960s and 70s. Others were simply outgrown. Thus Turner's original Lime Street Station roof of 1849 was replaced with a similar but larger roof in 1867. The 1871 roofs at Birmingham Snow Hill were lost when the station was enlarged and rebuilt from 1906 onwards. Driver and Bannister's roof at London Bridge station (listed Grade II) was removed in 2013 to allow the station to be completely rebuilt to handle greater traffic. The roofs at Worcester Shrub Hill (1865) and at Stockton (1893) were removed to save on maintenance in the 1930s and 1970s respectively. Two have been lost through a lack of appreciation of significance. Ramsgate Harbour station (1863, Sir John Fowler) closed in 1926, but survived as an amusement arcade until demolished in 1997. George Berkeley's roof at the Grade II London Fenchurch Street (Betjeman's 'delightful hidden old terminus') was demolished in 1987 for an 'air-space' office development. It was described in the station's statutory listing as being 'not of special interest', notwithstanding that the station was lauded as the only British terminus where the train shed and entrance block formed a single harmonious whole. Dating to 1854, the Fenchurch Street train shed was also the world's oldest surviving crescent truss roof.

<u>Arched train sheds with no visible ties</u>

Of the two great train sheds completed in 1849, Dobson's Newcastle Central roof was a sensation for its beauty, whist Turner's Lime Street roof was a sensation for its exceptional span, engineers immediately aspired to build high arched train sheds that were completely devoid of visible ties. The first such roof was Paxton's 72-foot span barrel vault over the great transept of the 1851 Great Exhibition building, with its crown standing a full 168 feet above the ground.

Concurrently with the planning and construction of the Great Exhibition, Brunel and Lewis Cubitt were designing roofs for **King's Cross** and **Paddington** stations, opened respectively in 1852 and 1854. At King's Cross Cubitt proposed a pair of un-tied parallel semi-circular arched roofs, each 105 foot wide and 800 foot long. At Paddington Brunel proposed three parallel un-tied semi-eliptical roofs, each 699 foot long, spanning 68 feet, 102 feet and 70 feet. In additional, Brunel proposed two transepts connecting the three spans, creating a roof that was highly regarded for its daring and beauty. Cubitt's ribs were of laminated timber, Brunel's of wrought iron two. Brunel had the advantage that his station was in a cutting, so used the surrounding earth to resist the outward forces in his arches. Cubitt's arches were braced by substantial arcaded, brick-built, side and centre walls. The laminated timber King's Cross arches proved insufficiently durable and were replaced in iron in 1869 (east side) and 1887 (west side). The replacement iron arches replicated the form of the originals and did not require additional ties.[ix] Brunel's untied roofs did cause problems in later years, resulting in the supporting arcades being completely rebuilt in steel.

The semi-eliptical form and wrought iron construction of the Paddington roof was copied by Sir John Fowler in the construction of all of the Metropolitan District Railway stations between **Paddington (Metropolitan)** and Westminster, including **Bayswater**, **Notting Hill Gate**, Kensington High Street, **Gloucester Road**, South Kensington, Sloane Square, Victoria and St James' Park, opened 1868-9. Like Paddington, all of these were in cuttings, meaning that ties were unnecessary. These roofs have proved particularly durable.

The later 1850s and 1860s saw the attention of railway engineers and proprietors enthralled to the various forms of wide-span crescent truss roofs, but the completion in 1868 of Barlow's magnificent 245-foot wide and 105-foot high roof at St Pancras (see below) refocused attention on the aesthetic merits of high arched roofs with no visible ties.

Two roofs of this later period drew directly on the Paddington roof, these being Thomas Prosser and T.E. Harrison's magnificent curved, five-span, semi-eliptical train shed at **York**, completed 1877. With a length of 795-feet, this had a central span 81 feet wide and 48 feet high, flanked on both sides by diminishing spans of 55 feet and 43 feet. Built on a level site, it was heavily buttressed on both sides, in the manner of King's Cross. The last of the genre was William Bell's Sunderland Central, completed in 1879. Its single, semi-eliptical span echoed the largest span at York, but had the advantage, like Paddington, of being braced by the retaining walls of a cutting. Unfortunately the roof was demolished in 1953, following wartime damage. The third such roof of the 1870s was William Peachey and William Cudworth's extraordinary pointed roof at Middlesbrough, completed in 1877. The station was a gothic extravaganza and the roof was designed to match, being only 76 feet in span, but 60 feet high. Sadly demolished in 1954 following heavy wartime damage, the roof was described by Carroll Meeks as *'the Sainte-Chapelle of train sheds'*.[x] Its height to with ratio has never been surpassed. It marked a fitting culmination of a strain of roofs started by Dobson at Newcastle Central.

Two separate threads of high-arched metal train sheds with no visible ties emerged at the end of the 1860s. Slightly the earlier was the arch springing from rail height, with ties below rail level. Arches springing from ground level had of course been ket to the success of the

Chatsworth Great Stove and the Kew Palm House and had been essayed in laminated timber in 1846 in the 53-foot wide train shed at the Lytham terminus of the Preston & Wyre Railway. The first train shed of the type to be built in iron not only surpassed this by a mile, it also surpassed all existing roofs, not only in Britain, but throughout the World. This was W.H. Barlow's gothic **St Pancras** train shed, completed for the Midland Railway in 1868. With rigid, latticed ribs tied beneath rail level, a span of 245 feet and a height 105 feet were achieved, holding the World record until the Pennsylvania Railroad copied the design with an additional ten feet in width at their Jersey City station twenty years later (1888). In Britain the design was replicated by the Midland and its partners, but without the pointed crown, at Glasgow St Enoch (1877, demolished 1977) and at **Manchester Central** (1880, L.H. Moorsom, 210ft wide and 90ft high). The St Pancras roof was also copied at stations in Cologne, Berlin, New York and Boston.

The second strain of development was the externally braced arch, where the arched members are braced by external triangulation, usually within a conventional vertical sided, pitched roof envelope. The form, first used in cast iron in the roofs of fireproof mills in the 1820s and in ship-building slipway covers in the 1840s, first saw railway use in wooden form in the 1840s and 1850s, for instance in the 1846 Lytham and Blackburn laminated timber train sheds and in the 1850s in the Brunellian Oxford (2), Leamington and Merthyr Tydfil roofs. The first train shed application of the form in iron may have been William Peachey's cast iron roof trusses at Barnard Castle (3) (1864, William Peachey), then, much more spectacularly at **Bath Green Park** (1870, J.S. Crossley, 66-foot main span), where the segmental wrought iron ribs of the main span were braced to either side over the side spans. The form reached its zenith with the train sheds at **London Liverpool Street** station (1875, Edward Wilson) and **Brighton** (1883, H.E. Wallis) and the **Norwich Thorpe concourse** (1886, W.N. Ashbee and John Wilson). A small **royal train shed** in the Portsmouth Dockyard (1888) appears to have been based on naval precedents. Once steel was accepted as a medium for building train sheds, the form was simplified into a triangular truss with curved lower tie, as in the roofs at London Liverpool Street (1896 extensions), the transverse ridge-and-furrow roofs of **Glasgow Central** station, (1900-05, Donald Matheson), the roofs over the concourses and covered walkway of **Wemyss Bay** station (1903, James Miller) and Birmingham Snow Hill station (1906-12) and in the train shed at **Dover Marine** station (1914, P.C. Tempest).

Ridge and Furrow Roofs

The horizontal ridge-and-furrow train shed roof comprises multiple parallel, pitched, glazed roofs sharing common valley members so as to form a continuous corrugated roof. The roof type was remarkable for its light weight ability to cover vast areas with almost uninterrupted glazing. Ridge-and-furrow roofs may be laid longitudinally, supported on straight, open-truss cross girders, or they may be laid transversely, usually between load-bearing walls

Ridge-and-furrow glazing was developed by Joseph Paxton for cladding the Great Stove at Chatsworth (built 1836-40), where it was applied vertically to the curved sides of the arched structure. Paxton first applied it to a horizontal roof in the *Victoria Regia* Lily House at Barbrook (1850), immediately applying it in the same manner to the vast expanse of the 1851 Great Exhibition building. Paxton's longitudinally-glazed Great Exhibition roof was entirely of timber and glass, laid over Pratt truss wrought iron cross girders spanning between cast iron columns. The Crystal Palace system was used concurrently, using the same kit of parts and the same supplier (Fox & Henderson) for the Oxford Rewley Road station (1851, for the London & North Western Railway, Grade II*), which itself required speedy erection if it was to open in time to cater for the expected London excursion traffic. In the event, the Oxford station was not completed in time and had limited influence due to its temporary appearance, problematic foundations and faulty detailing. The extensive glazing permitted by Paxton's ridge-and-furrow roofing system nevertheless caught the attention of the World. Its most immediate application was for glazing the crowns of Brunel's great barrel vaults at Paddington station, whose construction was already underway at the time of the Great Exhibition. Paxton's influence as a Director of the Midland Railway saw that company pioneering lightweight iron and glass ridge-and-furrow station canopies at C.H. Driver's Kettering and Wellingborough stations in 1857. Thereafter such platform canopies rapidly became a key part of that railway's house style. The Furness Railway soon followed.

For much of the second half of the 19th Century the arched and pitched roof forms remained the engineer's choice for train sheds at larger stations. One of the first railways to adopt ridge-and-furrow roofing for large train sheds was the Furness Railway, whose better stations were designed by E.G. Paley of Lancaster. Probably the first was Paley's **Barrow-in-Furness Old Station**, built in 1863 with a transverse ridge-and-furrow roof carried between masonry side walls. This roof type became part of that company's house style, Barrow being followed by Carnforth (1867), Windermere Lakeside (1872), Barrow Ramsden Dock (1881) and Barrow Central (1882). Other early examples were the roofs to either side of the crescent truss roof at London Bridge station (1865, C.H. Driver and F.D. Banister) and **Kings Cross suburban station** (1875, extended 1895).

From the early 1880s the ridge-and-furrow form became increasingly popular for train sheds, as it permitted the construction of light and airy train sheds that were considered to be more attuned to the changing aesthetic of the age. It also had the advantage of being able to cover almost unlimited areas. The roof type was thus used in the greatest stations of the late Victorian and Edwardian era, including **Edinburgh Waverley** (1892-1900, James Bell and Blyth & Westland, Grade A), **Glasgow Central** station (1879 and 1905, Donald Matheson, Grade A) and **London's Waterloo** station (1901-22 J.W. Jacomb Hood and A.W. Szlumper, undesignated). The completion of Waterloo station marked the end of train shed construction in England, no more being built until the closing years of the 20th Century (Waterloo International, 1993, Nicholas Grimshaw and Sir Alexander Gibb & Partners) and Leeds, 2002).

Three main types of ridge-and-furrow roof evolved.

Longitudinal roofs on cross girders

Paxton's original form was exceptionally lightweight, being of timber and glass only, laid longitudinally, with iron used only for supporting transverse girders. The principle was to use the natural strength of a corrugated roof form. Its valleys were thus unsupported between the transverse girders and comprised no more than wooden gutters. It was found to be prone to decay and to be difficult to maintain. The Paxton parts of the Paddington and Oxford roofs were subsequently replaced. The principle was sound however and similar but more durable longitudinal lightweight roofs on cross girders were erected at **Bournemouth Central** station (1885, W. Jacombe, 95-foot span) and in the 1879 rebuilding of at **Glasgow Central** station, where the deep cross girders have spans of up to 213 feet. A variant used and developed by the Midland railway, with the ridge- and-furrow glazing passing through the cross girders. Such roofs were built on a small scale at **Ilkley** (1887) then on a much larger scale at Bradford Forester Square (1890) and Leicester London Road (1892).

Transverse roofs

Transverse ridge and furrow roofs were a more practical proposition, as rainwater in the valleys had a less far to travel and because supporting girders could potentially be dispensed with entirely. Lightweight transverse ridge-and-furrow roofs with minimal additional support beneath the roof valleys were built at the old **Barrow-in-Furness** station (1863, E.G. Paley), Carnforth (Furness Railway side) (1867) and **Carlisle Citadel** Station (1880). In the latter case the deep, narrow trusses of the ridge and furrow roofs were fabricated with flat bar. The potential lateral instability problem was addressed by a system at right angles to the main span, braced by rigid circular elements. The transverse ridge and furrow roofs at Rugby (1886) and **Stoke on Trent** (1893) was superficially similar when viewed from beneath, but the valleys were effectively supported on the lower flange of deep bowstring Warren bowstring trusses above that were invisible from within the station.

Roofs with trussed valley girders

The most common type of ridge-and-furrow train shed shares the general profile of the Paxton roof, but is not self-supporting, having more-or-less deep truss girders beneath each valley. The earliest was the first London Victoria station (1860), where the platforms were covered by a series of 50-foot wide transverse pitched roofs supported on deep Warren trusses. Amongst the earliest succeeding examples were the roofs on either side of the crescent truss train shed at London Bridge station (also 1865, C.H. Driver and F.D. Banister) and **Kings Cross (suburban station)** (1875, extended 1895). Later examples included Manchester Victoria (through platforms) (1881), London Euston (departure platforms) (1892), **Edinburgh Waverley** (1892-1900, James Bell and Blyth & Westland), **Marylebone station (concourse)** (1899, Douglas and Francis Fox), **Glasgow Central (Edwardian extensions)** (1900-05, Donald Matheson), **Oxford Rewley Road (replacement roof)** (1901-6), Plymouth Millbay (1902), Leith Central (1903), Shrewsbury (1903-4), London Charring Cross (1905), Birmingham Snow Hill (1909-14), **Whitley Bay** (1911, William Bell), **Birmingham Moor Street (concourse)** (1914), L**ondon Waterloo** (1901-22 J.W. Jacomb Hood and A.W. Szlumper) and **Southampton Terminus (concourse)** (1927, Grade II*). A number of ridge-and-furrow station canopies of the period were of a scale that equalled that of many train sheds. The roof at **Tynemouth** station (1882, William Bell, Grade II*) is a good example.

3 RAILWAY HOUSING

Like other industrial concerns, the railways found it often necessary to provide housing for their workers. The motives for this varied, as did the quantity and quality of housing provided. Single dwellings and small groups of houses were provided where the railways needed to provide staff in remote places where the existing housing stock was poor or non-existent. Sometimes railway companies were obliged to build substantial settlements of high-quality, low-rent housing in order to attract large numbers of skilled workers way from established industrial centres to railway works being built on greenfield sites. Sometimes housing was provided for purely paternalistic reasons, it being argued that good conditions promoted morale, good health and loyalty, thereby educing absenteeism. Workers living on site provided security for the company's property, whilst providing both a job and a home improved discipline and staff retention, as nobody wanted to lose both their job and their home.

Some companies provided housing lavishly, others were more parsimonious, notably the Great Western, which, with the exception of station-masters houses, seems to have built hardly a single worker's dwelling house between 1853 and 1907.[xi] Some railways designed and built most of their workers' housing, whilst others appear to have issued general specifications and left it to commercial builders to decide on materials, details and finish. Others relied more heavily on market forces, expecting adjoining landowners and speculative developers to provide for the housing needs of its workers.

In many cases the railway companies acquired other concerns, such as canals, with existing housing stock. Sometimes land was acquired for future expansion, with existing housing and existing sitting tenants. Latterly, railways were forced to build new homes for people that would otherwise be made homeless by railway construction projects. Nevertheless, by whatever means, in the era before municipal housing, the railways were by far the nation's largest landlords. Thus, at the end of 1913 the London & North Western Railway owned 9,022 homes, making it by far the country's largest single landlord. The next largest was the North Eastern Railway, with 6,304. A total of 56,500 railway-owned houses was reached in the 1920s. It is estimated that around 29,000 of these were purpose-built for railway workers. By 1989, only 765 remained in railway ownership, the remainder having been sold, demolished or passed into housing association or municipal ownership.[xii]

Railway housing effectively fell into two broad categories: isolated and clustered. The first type drew its inspiration from the needs of landed estates, canals, turnpikes and early railways to provide on-the-spot accommodation, often in remote locations, for gate keepers, estate workers, lock-keepers, toll collectors and incline keepers. The railway's followed suit, with dispersed cottages and lodges for level-crossing keepers, signal men ('bobbies'), track maintenance workers and station masters. Such buildings were often built along with the railways themselves, combining the (often single-storey) form and layout of the precedents with the particular architectural vernacular chosen for the more substantial buildings on the route. The results were often cottages of exceptional charm and quality, particularly on railways built before the 1860s. Even through the 1860s and into the 1870s, workers housing of very high quality was an important element of the last 'heroic' lines built, notably by the highly competitive Cheshire Lines Committee and by the Midland Railway, the latter both on its late main line railways through the High Peak and over the Pennines, between Settle and Carlisle line, the latter opened in 1876.

Some of the most attractive railway houses were the line-side cottages provided for level-crossing gate keepers. Increasingly fewer of these were built in Britain from the 1850s and 1860s, as British railway companies realised that parliamentary sanction was more likely to be forthcoming if they provided bridges for road crossings. This also coincided with the first introduction of mechanical block signalling and it was soon appreciated that locating signal boxes at level crossings meant that signalmen could double as crossing-keepers. The crossing cottage had nevertheless crossed to Ireland and continental Europe by this point and the significance of the house form has an international dimension as such cottages was very widely constructed on most European railways well into the 20th Century. In both Britain and Europe, such housing has a social significance, as it was soon realised that guarding crossings provided gainful employment for railway widows, maimed company servants and, increasingly, railway pensioners.

Because of subsequent rebuilding of busier stations as the first and second generation main line railways expanded, followed by the dramatic culling of stations and the wider network in the 1950s and 1960s and subsequent installation of automatic level-crossing barriers, there has been substantial attrition of historic crossing-keepers and station-masters houses, although a number were sold off to become private houses. Nevertheless, where they survive, the crossing-keeper's cottages and detached station houses of the earlier generation of main line railways are often the sole vestige of the original architectural vernacular of a given railway or route. Often meriting the meriting the suffix 'ornée' and usually with clear associations to architects of national importance, such buildings are clearly important.

As with other forms of railway structure, later examples tend to become increasingly standardised as companies amalgamated into large concerns with their own corporate designs which were increasingly based on more urbanised or industrial house plans. Where the occasion demanded, such houses could still be very good examples of industrial architecture, with relatively generous accommodation, good detailing and the occasional architectural flourish. The housing provided by J.S. Crossley on the Midland Railway's Settle - Carlisle route (built 1870-76) for example was built to the same exacting design standards as the line's stations and engineering works, with a quality and group value reminiscent of the earlier railways. The Cheshire Lines Committee (formed 1865-6) also provided very attractive gothic-revival cottages, often with polychromatic detailing and ornate bargeboards matching the style of their stations.

Due to location and architectural quality, such railway cottages as have survived are often relatively well cared for, but they tend to be rather small for modern living. Many have thus been extended or otherwise altered. Loss of original fenestration has been a problem, including on some listed examples. Where the railway, station or crossing such cottages once serviced have been erased, demolished or removed, it can sometimes be difficult to appreciate the building's original function or historic significance.

The second, clustered, type of railway housing comprises the terraces (and occasionally) tenements erected for railway workers at key locations, such as large locomotive sheds, junctions and railway workshops, often where there was nothing before. Both terraces and tenements were generally based on the standard forms of the time, albeit that those built by, or for the railways tended to be more generous than the norm in terms of layout, room sizes and sanitation. As with the isolated cottages, railway terraces would often be of some architectural quality, occasionally meriting the description of 'model cottages'. In the spirit of the times, settlements of more than one terrace often merited the provision of additional facilities, such as a shop, company-provided school and / or worker's institute. By accident or design, pubs, co-operative shops and non-conformist chapels of various sects often followed. Such terraces were built for a variety of reasons and possibly one of the most extraordinary is a terrace in Windermere. Windermere was essentially a creation of the railway, although most of the town was built by others. Nevertheless, located directly above Windermere station is a terrace of houses, said to have been built by the Furness Railway for three of its executives. These gothic extravagances, Furcottages, Alice Howe, Boston House and Bannerrigg were built c.1849 and are alleged to have been designed by A.W.N. Pugin.

Amongst the best known terraced clusters lie within the major railway towns and settlements built on greenfield sites. Possibly the earliest candidate would be Shildon, where the Stockton & Darlington Railway established its own works in 1826, followed by Timothy Hackworth's private works in 1833. Apart from a row of four cottages, built c.1825, there is little evidence of a planned railway village here before the mid-19th Century. Almost certainly the earliest planned railway village (and certainly the oldest surviving) is Vulcan Village, Newton le Willows, Lancashire, built in 1833-5 to accommodate the workers of the independent Vulcan Foundry, established in 1830 as Charles Tayleur and Co., to produce railway materiel following the opening of the Liverpool & Manchester Railway. Robert Stephenson was a partner from 1832-36 and the company completed its first locomotives in 1833, after which it developed into one of the world's foremost locomotive manufacturers, training a number of the foremost early locomotive engineers, including Daniel Gooch. The village comprises a school and 114 properties in six planned, uniform rows of terraces (Manchester, Liverpool, Derby, Sheffield, Chester and London Row).[xiii] Little similar seems to have been built prior to the development of communities such as Wolverton (c.1840), Swindon (from 1842), Crewe (from 1843), Ashford (from 1847) and Wolverton (New Bradwell) (from 1854), all of which were built by the railway companies themselves, as they increasingly brought locomotive, carriage and wagon construction in-house.

Such communities were provided with all necessary facilities at hand. The earliest railway-built church was the Grade II St George the Martyr Church, Church Street, Wolverton, by Wyatt & Brandon (Grade II, 1843) and Christ Church, Prince Albert Street, Crewe, (now a shell (Grade II, 1843). Indeed, Crewe had four railway-built churches. Railway-built baths, schools, mechanics' institutes, hospitals, orphanages and parks followed. The earliest railway housing in the first of these towns suffered badly from clearance schemes in the 1960s and 1970s, but housing from the later 1840s onwards has fared better, as have the attendant buildings erected for welfare and intellectual and spiritual betterment of the employees.

Important railway workers' suburbs also appeared on the edges of pre-existing towns, most notably towns housing railway works (e.g. Derby (from c.1840), Brighton, Darlington, York and London (e.g. Battersea, Romford, Stratford)), but also where there were important junctions and engine sheds (e.g. Cricklewood, Willesden, or Peterborough (New England) (1850)). Railway terraces similarly occur, singly or in larger groups with attendant facilities, at more remote locations, where there was once a key junction or locomotive shed. Sometimes railway terraces occur at locations which appear to have never had any obvious connection to a key railway facility. In such cases it would appear that the railway company simply preferred to house its workers together in a nucleated settlements, rather than dispersed along the railway, even if this meant that some workers had a longer distance to travel to their allocated place of work. Before the passing of by-laws improved the quality of industrial workers' housing, railway-built housing tends to be relatively easy to distinguish from non-railway housing stock, because of their superior detailing and more generous proportions.

Generally speaking, after the 1870s railway-built houses in railway towns tend to be increasingly difficult to distinguish from those provided by speculative builders, either independently or to railway specifications on railway-provided land. In almost all cases the railway-built houses are just that bit better-built than the norm. Outside of the railways town the architectural quality of railway cottages built after c.1870 varies between railway companies. The Midland Railway maintained earlier traditions of architectural style and quality under both J.S. Crossley (to 1879) and Charles Trubshaw (from 1874 to 1917), whilst the London Brighton & South Coast Railway appears to have commissioned some attractive tile-hung cottages in the 1880s, possibly inspired by contemporary stations designed for them by T.H. Myres. Ubiquitous, standardised designs built across a company's entire network are surprisingly rare, the best-known exception being the houses built by the London & North Western Railway under Francis Webb from c.1880 to 1904, over a thousand of which were built in between London and West Yorkshire and Cambridge and West Wales (and even in Northern Ireland) to standardised designs, using standard red bricks from the company's own Staffordshire brickworks. Otherwise, in more rural locations, later railway-built houses often tend to be distinguishable simply because their industrial appearance and terraced form is alien to the local established vernacular. This remains the case through to the Grouping of the railways into four large companies.

After the 1923 Grouping, only the Southern Railway built housing in any quantity, generally spaciously laid out estates with generous provision of allotments and recreation and sports grounds. Of the other three companies, the enlarged, post-1923 Great Western Railway attempted to make up its historic shortfall of company-provided housing by setting up co-operative housing associations. These built eleven estates up to the 1940s. The London &

North Eastern Railway did similar and indeed their Railway Housing Association (est. 1919) still owns and manages 1,340 affordable rented homes (many of them new-build), mainly in the North East and Yorkshire/Humberside areas of England. The London Midland & Scottish opted instead to provide cheap loans for house purchase. The inter-war, railway-built housing is generally similar in appearance to well-built municipal housing of the period, being semi-detached or in short terraces on spaciously laid out estates. Such housing is usually architecturally unremarkable, with no known examples of the modernist style.

A sub-type of the clustered or nucleated form is the railway tenement. Such blocks were unsurprisingly built for railway workers in Glasgow, both at Cowlairs and Cockerhill, whilst at Barrow in Furness, the Furness Railway built 564 homes in a number of outstanding sandstone tenements blocks for railway, dock and iron workers that are clearly based on Glasgow precedents. All of these are listed, some at Grade II*. Most railway tenements were built in inner-city locations, resulting from the increasing public outrage over the mass eviction of the labouring classes as the railways penetrated ever deeper into densely packed urban areas. Whilst landowners were compensated, until 1885 the only compensation offered to tenants were cheap train fares, so that they could (in theory) still commute to work from wherever they were displaced to. This changed from 1885, with the Housing of the Working Classes Act and other instruments, which effectively required railway and other major construction projects to provide replacement housing within one mile of displaced people's former homes. This form of railway housing has received very little study outside of London, but it seems that many displaced people chose to move on, leaving the railway companies with spare high-density accommodation conveniently located almost adjacent to their expanding city termini, loco shreds and goods yards. Possibly the earliest such tenements were the five-storey tenements known as Coronation Buildings, built at Vauxhall 1886-92 by the London & South Western Railway to re-house 1,041 people displaced by widening of the lines into Waterloo. Later, those displaced by extension of Waterloo station were housed in five architecturally identical blocks at Campbell Buildings, Lambeth. A further block was in nearby Stanegate Street. These six blocks were designed from the outset to provided more space than needed for the 1,750 displaced people, the remainder being allocated to railway staff from the outset. Similarly, when the Great Eastern Railway enlarged the Liverpool Street terminus c.1890, 600 displaced people were re-housed at the company's expense in four-storey tenement blocks at Quaker Street, Fieldgate Street and Winchester Street. Other examples included Culross Buildings (King's Cross, 1891), Polygon Buildings (St Pancras), and Wharncliffe Mansions (Marylebone). The London Brighton & South Coast Railway similarly built eight tenement blocks in Bermondsey in the early 1890s, again to house artisans displaced by railway widening works around London Bridge station. These blocks were referred to as the 'seaside buildings', being named after seaside resorts (Chichester, Eastbourne, Hastings, Portsmouth, Ryde, Worthing, Brighton and Arundel. All of the known London tenements have been demolished in recent years, with the exception of Brighton Buildings on Tower Bridge Road (1892) and Arundel Buildings on nearby Webb Street.[xiv] These blocks are significant, partly as privately-built tenements that compare relatively well to those provided by social reformers such as Peabody, but they are also of historic and social importance in their own right.

4 TUNNELS

Tunnels have been an essential component of railways, from the earliest beginnings as guided barrow-ways in mines, through to the present day. In modern times tunnels tend to be used to mitigate environmental effects, generally noise or visual effects, or navigation impacts where navigable rivers, estuaries or straits need to be crossed. In the earliest days, the railed way was merely a functional adjunct to the tunnel (the mine) and. where gradients in mines were steep, rope haulage was resorted to, either vertically or via inclined planes. As railways broke out into daylight and developed as a mode of surface transport, tunnels were seldom needed, as horse tramways and subsequent 'hybrid' railways could normally make use of indirect, contour-hugging formations and, if needed, inclined planes where sharp changes of level were needed.

In contrast, from the dawn of the modern railway in the 1820s, an inherent requirement of main line railways was a relatively level and relatively straight formation. Tunnels were thus an essential component of any railway needing to traverse higher ground (or a steep change in topography) whilst maintaining a relatively direct route and an acceptable gradient. Tunnels could also be used to conceal railways in the landscape, where there would otherwise be opposition from influential landowners. They could also be used to allow railways to penetrate urban areas without undue loss of developed (or developable) land, thereby avoiding opposition from municipal authorities. Generally tunnels used to overcome natural topography were bored. Generally those used to overcome opposition from opponents were created by the cut-and-cover method, effectively a roofed-over cutting created to hide the railway from view.

Tunnels had been resorted to by canal-builders for the same reasons as they were resorted to by railway builders: To overcome higher ground whilst maintaining a level formation. Some canal tunnels were very long indeed and tunnels such as the 2½-mile Sapperton tunnel and the 3-mile Standedge tunnel were considered as wonders of their age. The methods used for setting out and for excavation from headings from one or more shafts, as well as from both ends, laid the foundations for later railway tunnel construction. Canal tunnels, especially the longer ones, were nevertheless almost invariably of minimal dimensions. They were only normally experienced by working boatmen and the method by which boats were 'legged' though most of them dictated that long canal tunnels were normally only very slightly larger than the vessels they were required to accommodate. With the almost sole exception of the flamboyant east portal of the Sapperton tunnel of 1789 (decorated with rock faced and vermiculated masonry, round-headed niches and engaged Doric columns with entablature) the portals of canal tunnels were usually completely unadorned. Once a canal tunnel was completed, light and ventilation were not a consideration and construction shafts were often filled in upon completion, remaining so until barges started to be routinely motorised in the early 20th Century.

RPS

Steam-operated, passenger-carrying railways required tunnels of a completely new order, both in terms of scale and in number. By the time the last canal tunnel was completed in 1858, there were some 105 canal tunnels in the mainland Britain, varying in length from 20yds to 5,698yds.[xv] In contrast, according to Simmons & Biddle, the official total of all main line railway tunnels in Britain is ten times that number, being 1,047.[xvi] Railway tunnels were also required to be significantly wider, higher and better ventilated than canal tunnels. In a canal tunnels the ingress of water could be regarded as a positive benefit. In a railway tunnel, the reverse is the case.

Except in exceptional circumstances, early and hybrid railways, up to and including the Stockton & Darlington Railway, avoided the expense of tunnels. Where tunnels were required, early tramroad and railway tunnels employed similar construction techniques to those used on the canals, being of minimal dimensions and having relatively plain portals. Good examples are the Fritchley tunnel of 1793 on the Butterley Gangroad, the 80-yard Stodhart (or Chapel Milton) tunnel of 1796 on Outram's horse-worked Peak Forest Tramroad and Robert Stephenson's single-line, 828 yard long Tyler Hill tunnel, located on what was a rope-worked section of the Canterbury & Whitstable Railway, opened in May 1830. As this was six months before the opening of the Liverpool & Manchester Railway, this tunnel has the distinction of being the first railway tunnel through which fare-paying passengers were hauled on rails. Cable haulage was subsequently replaced by locomotive haulage. Another is Stephenson's 1mile 36 yard Glenfield tunnel on the Leicester & Swannington Railway (opened 1832). Whilst the Leicester & Swannington was essentially a mineral railway which also made extensive use of rope haulage, the Glenfield tunnel was on a locomotive-worked section. As passengers were carried on demand in the railway's only carriage, the Glenfield tunnel lays claim to the first tunnel through which passengers were hauled by a steam locomotive. Both the Tyler Hill and Glenfield tunnels subsequently caused major problems due to inadequate clearances and lack of ventilation when their respective lines were converted to main line branch railways. The Glenfield tunnel had an additional 9 ventilation shafts added to its original four.

Both the Leicester & Swannington Railway and the Canterbury & Whitstable Railway were hybrid railways, combining elements of early horse railways with locomotive and cable haulage. The Liverpool & Manchester Railway, the world's first modern main line railway, did not require any tunnels on its locomotive-worked main line, but it did require two tunnels at its Liverpool end, to overcome the steep change in slope between Edge Hill and the railway's Wapping freight terminal at the docks (downwards) and its Liverpool passenger terminal at Crown Street (upwards). Typically for early railway tunnels, the crowns of both tunnels are very shall, in places being only a few feet from the surface. The latter was single-tracked, 15ft wide and 12ft high and 291 yards long. It is claimed to be the world's first tunnel under streets. The former was 22ft wide and 16ft high, double-tracked and 2,250 yards long. It is claimed to be the world's oldest tunnel under a metropolis. Both were worked by rope haulage, obviating the need for additional ventilation. The tunnels were lined in brick, with a relatively primitive internal section, having vertical walls and a segmental arched roof. Walls and roofs were whitewashed from the start and the Wapping freight tunnel was equipped with gas lighting throughout. In the manner of canal tunnels, the portals were unadorned at the

Edge Hill end, but to reassure passengers of the solidity of the structure, a decent, rusticated portal was provided at the Crown Street passenger terminus. This was buried in 1980, when the tunnel was blocked at the Crown Street end and the former station site re-landscaped as a park.[xvii]

The claim for the first modern railway tunnel, built from the outset for the passage of steam-hauled passenger trains on a main line railway, belongs to the 700 yard long Richmond Hill (or Marsh Lane) tunnel on the eastern outskirts of Leeds, built 1830-34 by James Walker for the opening of the Leeds and Selby Railway. The tunnel was built for two tracks, 22 ft wide and 17 ft high, with a horseshoe profile. As was normal, construction shafts were used in its construction, but Walker appears to have been the first engineer to appreciate that if these were left open once construction was complete, they would help greatly in the ventilation of smoke and steam. Despite some of the shafts being almost as wide as the tunnel itself (again a novelty), the bore of the tunnel was still a little small compared to later tunnels and ventilation proved to be a problem until the tunnel was opened out into a cutting in 1894. In order to reassure passengers, the tunnel lining was limewashed throughout and copper reflectors were placed at the base of the shafts to reflect light into the tunnel. The entrances of the tunnel were clearly designed to impress and reassure the public, being faced with stone, with giant rustication and a substantial pediment. [xviii]

With its ventilation shafts double-track bore, Richmond Hill tunnel demonstrated that steam haulage through long tunnels was a practical proposition, allowing railway promoters and engineers to plan with confidence, notwithstanding that geology was still to present many challengers that taxed the available engineering technology to the limit. The first major main line railway tunnel built after Richmond Hill was the 295-yard, twin track Farnworth (or Clammerclough) tunnel, built by Jesse Hartley between 1835 and 1838 for the Manchester - Bolton railway of the Manchester, Bolton and Bury Canal Navigation & Railway Company. This was driven from both ends and from a large vertical shaft in the centre. Built, like Richmond Hill, for two lines of rails, it again proved rather small internally and the line was subsequently singled through it and a second bore provided.

As with so many other things, it was Robert Stephenson's work on the London & Birmingham Railway that ushered in railway tunnels built on a heroic scale, principally the three tunnels at Primrose Hill (1163 yds), Watford (1800 yds) and Kilsby (1mile, 666 yds). Work on the latter started from either end and from 16 intermediate shafts in 1835. It was built both high and wide (25 feet wide and up to 30 feet high), some 160 feet below ground, with two 'Great Shafts', 60 feet in diameter, for enhanced ventilation. Because of unexpected problems with clay and a thick stratum of waterlogged quicksand, it took 1,250 men three years to complete, used 36 million bricks and costing £320,000, over three times the estimated cost. The works required the application of the latest mining and pumping technology, requiring both horse and steam winding engines and thirteen steam-powered pumping engines, the latter working non-stop for over two years, removing 1800 gallons of water per minute for the first eight months.

Kilsby was easily the longest tunnel in the world when opened in 1838, but within three years the mantle had fallen on Brunel's equally heroic (and equally difficult) tunnel at Box on the Great Western Railway (1838-41, 1 mile, 1466 yds). Construction was carried out from both ends and from seven intermediate shafts 25 feet in diameter and between 70 and 300 feet deep, each equipped with steam winches and pumps. It is 30 feet wide and 30 feet high. 247,000 cubic yards of material were removed during construction and the tunnel was lined with 30 million bricks. 1,200 navies were employed, rising to 4,000, of whom over 100 died during the works.

In purely structural terms, the principal innovation of this early, heroic period of railway tunnel building was the introduction of an arched invert beneath the rails, to resist lateral and upward pressure, probably first used by Robert Stephenson on the Primrose Hill tunnel on the London & Birmingham Railway in 1836.[xix] After this the key landmarks were the building of the first hard rock railway tunnel through a major watershed (G. Stephenson and T.L. Gooch's 1mile 1,125 yard Summit Tunnel at Littleborough on the Manchester & Leeds Railway, 1838-41), the completion of the first trans-Pennine tunnels over three miles in length (Woodhead I, 1838-1845 and Standedge I, 1846-9), the building of the first urban cut-and-cover railway (the Metropolitan Railway, opened 1863), the first major under-sea railway tunnel (the 4 miles 624 yd Severn Tunnel, 1873-86), the first iron-lined, deep-level tube railway (and first to use electric traction), the City & South London Railway, opened 1890 and the first major concrete-lined tunnel, the third Woodhead tunnel (1949-53). Otherwise railway tunnels tend to be of particular engineering note because they were longer, deeper or caused more deaths than any other. Despite key advances in America and continental Europe, notably in hard rock drilling and forced ventilation, the United Kingdom remained the country with the world's longest tunnel up to the opening of the Fréjus tunnel between France and Italy in 1871.

The working conditions of tunnel navvies were notoriously bad and enough of a national scandal to merit a Government inquiry prompted by the particularly atrocious conditions experienced during the construction of the Woodhead tunnel (C.B. Vignoles and J. Locke for the Sheffield, Aston-under-Lyne and Manchester Railway, 1838-45). Despite the resultant insistence on the use of safety fuses and, subsequently, the introduction of rock drills and dynamite, mortality remained unreasonably high another three decades. Thus, even as late as the early 1870, over 100 navvies lost their lives on the contract for building the Ribblehead viaduct and nearby Blea Moor tunnel (2,629 yards) on the Midland Railway's Settle - Carlisle route.

Despite the enormous cost and heroic human effort that went into the construction of railway tunnels, the surface expression of such structures in the landscape is normally surprisingly muted. Except in the wildest and remotest areas, such as Woodhead and Blea Moor, the tortured landscapes of shafts, spoil heaps, pumping and winding engines, navvy settlements and temporary construction tramways were normally restored and returned to agricultural use, leaving little trace, save for a line of squat brick or stone chimneys at the top of the retained ventilation shafts. Despite their practical value and importance as the surface expression of often heroic subterranean works, these are seldom richly embellished, decoration normally being restricted to a neat roll-moulding or some modest crenellations around the cap. Rare exceptions, notably the two crenellated red brick drums over the 'Great Shafts' at Kilsby, or the three surviving monumental Italianate towers built over the Wapping tunnel in Liverpool, said to have been built when steam traction took over from rope haulage in 1896. That such examples are so rare appears to indicate that the normal, modest expression of railway tunnel ventilation shafts was a deliberate design intent. A possibly unique survival at Milford, Nr. Belper is a tall square stone tower, said to have been built by George Stephenson for the setting out of the Milford tunnel, completed in 1840. Such towers were certainly used, although no other examples are known to have survived the completion of the tunnel they were built for. Very occasionally tunnels require permanent surface facilities for drainage and forced ventilation. The pumping stations and Guibal fan house serving the Severn tunnel at Sudbrook (Wales) and Pilning (Glos.) house are thought to be the sole British examples.

Of the 1,000 or so main line railway tunnels built in Great Britain built between c.1800 and the First World War, a small number are particularly celebrated for having ornate portals at one or both ends. These fall almost universally into a brief ten-year period c.1838-1848. By far the most popular style was crenellated gothic, usually Norman or Tudor, with particularly notable examples being Grosmont (G. Stephenson, 1836), Linslade north portal (R. Stephenson, 1838), Clay Cross north portal (G. Stephenson, 1839), Clayton north portal (J Raistrick, 1841), St Anne's east and west portals, Fox's Wood west portal, Saltford east and west portals, Twerton Wood east and west portals, Twerton east and west portals, (I.K. Brunel, 1840) and No.2 tunnel, Bristol, (I.K. Brunel, 1841), Woodhead west portals (1845 and 1852), Shugborough west portal (J.W. Livock, 1847), Bramhope north portal (T Grainger, 1849) and Killiekrankie (J. Mitchell, 1863). The west portal of St Anne's (or No.2) tunnel was unusual in having been left as a romantic ruin by Brunel, part having been lost to a landslip during construction, but it was later rebuilt to the original design. The east portal of Fox's Wood tunnel was left by Brunel looking like a natural cave and remains so. Because of its lack of a facing, it is alone of all Brunel's portals on the Great Western Main Line to be undesignated.

Other decorated portals include the Egyptian Shugborough east portal (J.WE. Livock, 1847) and Littlebury south portal (Sancton Wood, 1845), the classical Primrose Hill west portal (R. Stephenson & W.H. Budden, 1837), Watford south portal (R. Stephenson, 1837), Middle Hill east and west portals (I.K. Brunel, 1840) and Box west portal (I.K. Brunel, 1841). The Italianate is represented by Primrose Hill east portal (R. Stephenson & W.H. Budden, 1837). Probably the most bizarre decorated portal is the south portal of Audley End tunnel (Sancton Wood, 1845), which with its concentric circles in contrasting materials and projecting arms and bosses is reminiscent of furniture designed fifty years later by Carlo Bugatti. These decorated portals in gothic and other styles form a remarkable series of fanciful structures which were, almost without exception, designed to either impress stagecoach travellers on rival turnpikes, or to appease major landowners and aristocrats. Generally the corresponding portals at the less visible opposite ends were solid but generally relatively plain. Brunel was exceptional in providing 'romantic' or richly decorated at both ends of almost every one of his tunnels between Box and Bristol.

The remaining tunnel portals, forming by far the majority, are generally of a solid engineering abstract geometric form. The portals of Brunel's Staple Hill (1844) and Harbury (1852) tunnels are cases in point. The austere brick facings of W. Cubitt's Shakespeare Cliff tunnel (1844) are a further example. More normally architectural pretentions are limited to radiating rusticated voussoirs or stripped back geometric forms loosely described as Roman or Egyptian. Such portals grace some of the longest and most expensive tunnels of the early, heroic and later periods, including those of engineers such as T. Grainger who were seldom shy when it came to spending money on a high quality of design and finish. As the cost of a fancy portal was only a tiny fraction of the huge overall cost of a railway tunnel, we can be sure that there was a deliberate design intent, at least up to 1850s, to design intentionally robust, workmanlike tunnel portals that conveyed strength and solidity to an initially frightened and doubting public. Whilst fancy portals remained a curiously British phenomenon, the simplified, stripped back form became the norm and spread around the globe.

5 VIADUCTS

From the completion of the Liverpool & Manchester Railway in 1830 to the close of the 19th Century, British railway works led the world in size, materials, engineering design and complexity of construction. Of all the railway engineering achievements, the most visible, spectacular and iconic were the viaducts and large bridges. Whilst such structures have precedents in Roman aqueducts and the canal aqueducts of the late 18th and early 19th Centuries, the 19th-century railway builders constructed multi-span viaduct structures in so many places and to such unprecedented scales that they have become a key component of the British urban and rural landscape.

In rural areas viaducts were used to cross deep valleys where embankments would have been impractical (e.g. George Stephenson's pioneering Sankey Brook Viaduct on the Liverpool & Manchester Railway (1828-30, Grade I)), or where a gradual descent was required to overcome a rapid change in topography (e.g. Joseph Cubitt's 40-arch Welwyn viaduct, Herts (1850, Grade II). In both cases it was normal to use approach embankments to the point where the embankment's cost or consumption of land made it preferable to use a viaduct. The longest such viaduct in the UK is the 82-arch Harringworth or Welland viaduct (1878-79, Grade II).

Viaducts were also used to take railways into town centres. The width of land taken was only as wide as the tracks themselves, thereby greatly reducing the need to demolish large areas of housing. The height of the structure varied enormously. Such viaducts could be very long and relatively squat, most famously the first such structure (and still the longest), the 3.45-mile, 40 foot high London & Greenwich Railway viaduct, with its 851 semi-circular arches and 27 road bridges (1834-8, part Grade II). Others are quite the reverse, notably the 22-arch, 110 foot high Stockport viaduct (1839-40).

The type of viaduct built often depended on the raw materials available. Local stone was the most suitable for multi-arch structures and, where this was not available brick, was the normal substitute. Such masonry viaducts had a great virtue of requiring minimal expenditure on repair and maintenance. Masonry spans are typically regular and relatively short, although sometimes a wider arch would be included, notably over a river, road or canal. For tall viaducts the cost of many tall piers could be prohibitive, but the cost of longer-span masonry arched spans increases rapidly beyond 66-70 feet. After this point it became cheaper to use girders. In the 1830s and 1840s such long spans were normally of laminated timber arch construction. Pioneers of the laminated arch were John and Benjamin Green, architects of Newcastle on Tyne, who between 1837 and 1841 built the Ouseburn, Willington, Nether Poppleton, West Durham and Esk railway viaducts in the North East, the largest of which (Willington) had seven spans of 120 feet. Such structures (and latterly timber lattice beam viaducts) were also popular in Lancashire, on railways by Locke, Valentine, Robertson and Vignoles, notably the original Dinting and Broadbottom viaducts on the Sheffield, Aston-under-Lyne & Manchester Railway (C B Vignoles and A Jee, 1842-4 (both Grade II)). A pair of laminated timber arches were also built by Brunel, on his gothic skew bridge over the Avon at Bath (1839-40). In all, about 34 laminated timber bridges were built between 1835-50. All were replaced with iron bridges after relatively short lives. In a few cases the replacement cast-iron arches exactly replicated the form and detailing of the original timber spans, for example the Oseburn and Willington viaducts (rebuilt 1867-9, Grade II* and II respectively).

Timber remained a popular material for many railway engineers into the early 1860s, particularly for relatively low, short-span trestle bridges and viaducts, particularly where money was short or where rapid construction was required. Brunel (and his successor, R. Brereton) nevertheless continued to use timber trusses for large viaducts until 1863. The most famous series of British timber railway bridges are thus Brunel and Brereton's 52 trussed timber viaducts on the Cornwall, West Cornwall and Falmouth Railways, but he used trussed timber bridges and viaducts (sometimes extensively) on almost all the railways he was associated with, with the notable exception of the Great Western Railway itself. Brunel’s viaducts were built with masonry piers and with slender timber trestle piers. A number of the Cornish viaducts retain the original masonry piers within or alongside the replacement viaducts and, of the 40 still in use, 19 are listed Grade II, whilst the piers of the Moorswater viaduct are listed Grade II*. A few timber trestle viaducts by other builders do survive in service in Wales and Scotland, although the number is diminishing. The disused Wickham Bishops bridge in Essex is believed to be the only standing timber trestle viaduct in England, although some are thought to exist buried in later embankments or viaducts.

Cast iron was also used for wide spans within viaducts, such as the span over the Rochdale Canal in the Gauxholme No.2 Viaduct, Todmorden (G. Stephenson, 1838-40, Grade II) and where such spans remain, they are significant, particularly so if early. Wide cast-iron arch spans remained popular into the 1870s. Following the success of Robert Stephenson and William Fairbairn’s Britannia and (Grade I) Conway tubular bridges (1846-50 for the Chester and Holyhead Railway), wrought iron girders were increasingly used to span large gaps, both for new construction and to replace earlier timber spans, with tracks being carried either on the bottom of the girder (through girder) or on the top (slung girder). In a few examples metal trestles were used instead of masonry piers. Despite the losses of the outstanding and early metal trestle viaducts at Crumlin (Wales), Belah and Deepdale, only two major examples now survive (the Grade II* Bennerley viaduct and Grade II Oakhampton (Meldon) viaduct).

Classic masonry arch construction classic form continued to be throughout to the end of railway construction in the early years of the 20th Century. Mass concrete was first used on the West Highland Extension Railway by 'Concrete Bob' McAlpine, including the Glenfinnan Viaduct, built in 1897-1901. Its use in England seems to have been restricted to Devon and Cornwall, where all of the three examples built (Cannington (1903), Holsworthy (1897) and Derrion (1898) are listed (II, II and II* respectively). Concrete block construction was employed on the slender Calstock viaduct (1908, Grade II*). Post and beam reinforced concrete construction using the Henebique method was relatively widely used by the railways in the early 20th Century, but only for relatively low freight-only structures in docks and goods yards. The outstanding example is the undesignated 1km-long Milton viaduct on the former

Bowater's narrow gauge industrial Sittingbourne and Kemsley Light Railway, dating from 1906. Reinforced and pres-stressed concrete were little used for viaduct works until after the Secons World War. A late reinforced concrete post and beam viaduct is the railway flyover at Bletchley, built in 1962 as part of an abortive Modernisation Plan scheme for an east-west freight route to the north of London, abandoned in 1967.

6 OVERBRIDGES AND UNDERBRIDGES - INTRODUCTION

Bridges, both overline and underline, are by far the most numerous type of railway heritage asset. Railway bridges are more numerous in Britain than in any other country, due to the crowded nature of the landscape, the undulating terrain and a general preference for bridges, as opposed to level-crossings, amongst engineers, promoters and legislators. Some 25,000 bridges were added by the railways between 1830 and 1860 alone[xx]. Before many of the railways were closed in the 1960s, British Rail owned over 60,000 bridges. Normally bridges along a particular railway line were designed by the same engineer and, where circumstances allowed, built to a similar design. By far the majority were modest, short span arched bridges constructed of masonry and brick. For short spans, traditional masonry arch construction remained the norm into the 20th Century. [xxi]

Larger and longer spans were continually being demanded and bridge engineers turned to using laminated timber, cast iron, wrought iron and later mild steel in order to achieve these spans. The value of pre-fabrication that materials other than masonry offered was nevertheless appreciated from an early date. The earliest non-masonry railway bridges were normally arched, whether of laminated timber or cast iron. The headroom required for an arched structure was not always available and, in order to maintain a level trackbed, the early railway builders were increasingly required to provide of level beam bridges, initially using either cast iron girders or timber king or queen post trusses. Cast iron beams were more durable, but were brittle and incapable of bridging longer distances. In 1839 Robert Stephenson and George Parker Bidder developed a cast-iron level beam trussed with wrought iron bars. The use of these was brought to a sudden end in 1847, with the disastrous collapse of the Dee railway bridge and the subsequent Royal Commission inquiry. Short, un-trussed cast iron level beams continued in use, but they were rapidly phased out for underline use following further disastrous collapses in 1882 (Inverythan) and 1891 (Norwood Junction). The trussed beam concept eventually returned with the development of the reinforced concrete beam.

With its properties of being good in compression and poor in tension, cast iron was far better suited to arched bridges and it remained in use for arched railway bridges structures until a surprisingly late date (e.g. the Albert Edward Bridge over the River Severn (1863, Grade II) and rebuilt Ouseburn and Willington viaducts (rebuilt 1867-9, Grade II* and II respectively)). Brunel continued to develop timber construction, most spectacularly with his viaducts in Devon and Cornwall, although only the masonry piers of these now survive.

Wrought iron was the obvious solution for providing the long, level beam bridges needed by the railway builders. The Britannia Bridge over the Menai Straits, built in 1846-50, used the boxed girder form, and was the world's first use of the beam principal for a very long-span bridge. The wrought iron box girder, 'I' girder, lattice girder and a number of different forms of open truss girder were developed almost simultaneously, with railway construction always being the key driver. By the 1860s wrought iron level beam bridges were becoming numerous, in the main utilising prefabricated plate ‘I’ section girders for smaller spans and lattice girders over greater distances. Multiple bow string bridges were also constructed, the most important of which was that crossing three-qaurter-mile long crossing of the River Severn at Sharpness, built in 1879. After some initial wariness, the completion of the Forth Bridge in 1890 ushered in the use of steel for large and small railway bridges. Steel then remained the dominant material for railway bridge building and generally remains so for underline railway bridges to this day, with reinforced concrete normally playing only a secondary role.

Masonry arch bridges are relatively low maintenance and can normally carry far larger loadings than they were designed for. They remain in widespread use. Cast iron arches have similar properties, and a number are still in use on the main line railway network, albeit often strengthened. The attrition of cast iron beam bridges has been substantial. Most of the oldest surviving metal bridges are of wrought iron and are now more than 100 years old. These are usually of massive construction but are now deteriorating rapidly, due in part to a backlog of maintenance. As a result, historic wrought iron bridges are now being progressively replaced across the active network and relatively few now remain.[xxii]

7 TIMBER BRIDGES AND VIADUCTS

Timber is without doubt the earliest material used for bridge building and will certainly have been used for structural purposes on very early railways. Laminated timber arches had a short vogue in the 1830s and 1840s (discussed above), but all such bridges were replaced in other materials long ago. Timber nevertheless remained a popular material for many railway engineers into the early 1860s, particularly for relatively low, short-span trestle bridges and viaducts, particularly where money was short or where rapid construction was required. The most famous series of British timber railway bridges were Brunel's trussed timber viaducts on the South Devon Railway and Cornwall Railway.

Nineteenth century timber railway bridges were almost invariably planned to have a short life and although more widespread in railway practice than is currently appreciated, very few examples survive today. Those that do survive carrying traffic are all in Wales or Scotland. The two disused Wickham Bishops viaducts near Maldon, Essex (160 ft long and 500 ft long) are believed to be the only standing English examples remaining. All of these surviving bridges are of the timber trestle type.[xxiii]

To minimise disruption to traffic, a number of timber trestle bridges were encased within later embankments or masonry viaducts, with the timber left in-situ. Disused lines have on a number of occasions offered the brief opportunity to record such structures where removal of the embankment or viaduct has been necessary.[xxiv]

8 MASONRY BRIDGES (BRICK AND STONE)

Railways, with their level formations cutting across the grain of the established landscape, created an unprecedented demand for bridge building. Bridges were not only needed where railways crossed rivers, canals, roads and footpaths, but also to allow farmers to access their fields where the railway had been driven through them. For a new railway the engineer would devise a series of template designs for smaller bridges, which would be varied by their draughtsmen to suit each individual location, both topographically and with regard to building materials that would ideally be found within easy reach. Larger span bridges, highly visible bridges such as those over competing turnpike roads or canals, and bridges built to appease influential local land-owners and gentry would occasion more bespoke, individual designs. Such bridges would normally merit a significant degree of oversight by the chief engineer. Bridges were arguably the most ubiquitous and visible manifestations of the railway and until the last quarter of the 19th Century the majority of engineers took significant pains to design structures that harmonised with the landscapes through which they passed. Historic brick and stone railway bridges thus vary enormously in scale, detailing and architectural treatment and many thousands still survive, both on and off the active network.

Brick was not used on any scale for bridge building in the UK until the later 18th century, when the canal age created an unprecedented new demand for small utilitarian bridges.[xxv] As canals were often constructed in alluvial river valleys where clay was prevalent and stone was scarce, canal engineers and contractors became increasingly skilled in its use for engineering purposes. It was to be through the railway that the use of brick as an engineering medium reached a convincing maturity however, eventually supplanting stone almost completely.[xxvi]

During the early period of railway construction from 1599 to c.1825 it is thought that brick may have been occasionally used on some early plateways and edge railways. An early and rare survival of its use is the Newburn bridge on the Wylam Waggonway, where the arch ring is built of brick. Newburn bridge has both an intrinsic interest as an early brick arch, but has added significance in that George Stephenson lived alongside the Wylam line and was doubtless influenced by it. Thus, whilst most of the bridges along the Liverpool and Manchester Railway were built of stone, a number of them make use of an enlarged version of the type of construction used at Newburn, with stone facings and brick arches. The outstanding example is the Sankey Viaduct.[xxvii]

Succeeding generations of the Stephenson school of railway builders became progressively less reticent in their use of brick for bridges. Brick was frequently used for bridges on the London and Birmingham Railway (1833-38) and on the Lancashire side of the Manchester and Leeds (1836-40). Apart from the Stephensons, other early users of brick included Jesse Hartley on the Manchester & Bolton Railway (1833-38), Isambard Kingdom Brunel on the London, Berkshire and Vale of the White House sections of the Great Western Railway (outstandingly at the Wharnecliffe Viaduct (1836-7) and the Maidenhead Bridge (1837-8)) and

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Joseph Locke and George Watson Buck (outstandingly on the two viaducts on the Manchester and Birmingham Railway at Stockport and Dane (1838-40 and 1839-41)).[xxviii]

Use of brick remained largely localised to areas where good building stone was scarce into the 1870s, although its use did increase after the abolition of the brick tax in 1850, materially altering the economic balance between brick and stone.[xxix] Bricks were normally sourced locally, often being made by the railway contractors themselves from material found virtually on the spot. These localised supplies meant that the physical properties of the resulting bricks tended to vary in both size and quality. The spread of the railway transformed this system of brick making and supply. Staffordshire blue engineering bricks were used in the 1850s on the Staffordshire Junction Railway. From the 1870s they were used nationally, especially for the London and North Western Railway who owned their own brickyards in Staffordshire. Accrington reds were also popular. These developments, together with improved kilns and brick-making machines increasingly led to brick replacing stone in bridge building as the railways felt less obligation to make architectural concessions in their bridge building. The utilitarian red or blue brick viaduct thus became the dominant pattern.[xxx]

An important variant of the classical masonry arch, and one much employed by railway builders, was the masonry skew arch. Skew arch crossings occur when the centre line of the alignment of the road, canal or railway intercepts an obstacle which it intends to cross at any angle other than a right angle. Such situations had been relatively rare prior to the advent of the railway, as canal engineers usually preferred to build cheap non-skewed bridges wherever possible, even if this involved putting a double bend in either the canal or the road. They occurred much more regularly on railways, particularly where railways crossed turnpike roads or canals, whose course could not be varied due to their enabling Acts and opposition from the canal or road proprietors. Such situations provided good opportunities for self-publicity and often such bridges were given an additional level of finish or architectural treatment in order to impress.

Like the brick arch, the skew arch were not invented for the railway, but the railway was the most effective agent in popularising it. Thus the 16 skew bridges on the Liverpool and Manchester Railway at the time of its opening in 1830 probably exceeded all previous examples in the UK combined. The majority were brick arches with stone quoins. The London to Birmingham Railway also made extensive use of both stone and brick skew bridges. They became a defining feature of railway construction throughout the 'Heroic' period. Generally such bridges had parallel courses to the arch soffit (helicoidal). A new form was introduced into Britain from France in 1839, using the spiral tapering courses. Known as the orthogonal method, it remained rare. Two such bridges of 1843, built by Froude under Brunel, survive at Cullompton (Devon) and Cowley Bridge (Devon).[xxxi]

Increasingly, but not exclusively, the brick and masonry skew arch was supplanted by the iron girder or truss bridge, as it was considerably easier to arrange a skewed crossing by staggering a series of parallel arched or level girders with normal deck beams than it was to shape masonry and brick. Few true skew arches were built in masonry after 1860, although the brick version survived somewhat longer, usually in the context of a wider span within a viaduct. A late introduction from America was the ribbed skew arch, comprising several non skewed arches set back to back. Whilst somewhat clumsy in appearance, they allowed extremely acute skew bridges to be built in brick or stone. The Midland Railway built one of the earliest in Britain, over the Southdown Road in Harpenden on its London extension, opened in 1867. This crosses the road at an extremely acute angle of approximately 25°, beyond what was theoretically possible with a conventional masonry skew bridge. Other examples include the stone and brick Hereford Road bridge in Ledbury, built in 1881 to carry the Ledbury & Gloucestershire Railway. The bridge now carries a footpath. Others were built in 1906 on the Great Central and Great Western Joint Railway.[xxxii]

Whilst brick and stone railway bridges survive in very large numbers, their survival has been patchy. Many of the earlier arterial main line railways were subject to widening from two to three, four or more tracks in the later 19th and early 20th Centuries, resulting in underline bridges being extended on one or both sides of the original formation. Similarly, overline bridges were either extended with additional arches, or replaced completely with longer spans. The overhead electrification of these arterial routes has proved particularly destructive to the remaining stock of historic overline arched bridges on the routes affected, as complete replacement is considerably less complex to effect than options involving track-lowering or the application of derogations. Even where bridges are listed or have adequate headroom, the application of rigid safety standards to prevent trespass and electrocution, has generally resulted in the raising or replacement of parapets and the cutting back of accessible projecting ledges such as string courses. Unfortunately the routes selected for electrification have been concentrated on the earliest and most historically significant railways. Thus, only a small handful of historic overline survive on the important East and West Coast main lines, these tending to be smaller bridges over deeper cuttings, normally in remote locations. More recently, careful assessment and negotiation has resulted in the designation of a small but representative selection of overline bridges in advance of the Great Western Main Line scheme. Similar designations are currently being consulted on in advance of the electrification of the Midland Main Line.

9 AQUEDUCTS OVER RAILWAYS

Aqueducts over railways are emblematic of the problems faced by railway builders in driving a level formation through an already crowded, undulating landscape. Compared to aqueducts built by the canal builders of the previous generation, aqueducts over railways have been scarcely studied. Much the best study, albeit focussed entirely on the work of Brunel, is Tucker and Brindle's 2011 study of Brunel's use of structural cast iron.xxxiii This study at least indicates the potential of the field with regard to other designers and other railways.

Timber was certainly used for trough construction for a substantial period for minor watercourses. A good example is the aqueduct at the west end of Corsham station, built by Brunel in 1841. A rare example built to carry a canal was Brunel's Avoncliffe aqueduct, built beneath the Kennet & Avon Canal (1850-56, for the Wiltshire, Somerset and Weymouth Railway). Brunel built a brick arch aqueduct on the same route at Dundas.

Possibly the most commonly used type to about 1860 was the cast iron trough aqueduct, pioneered by Telford previously at Longdon on Tern and Pontcycyllte. These took various forms: as a lining in a masonry arch, self-supporting or supported. The last type might be supported on masonry or cast iron piers or on cast iron arches. By 1851 Brunel had built at least five cast-iron trough canal aqueducts over his railways. Two of these (Windmill Lane, Southall (1859, Scheduled Monument) and Resolven (S. Wales) (1849, Grade II)) were classic U-shaped self-supporting troughs similar to Longdon on Tern and Pontcysyllte, formed of bolted cast-iron panels. George Stephenson's Leawood Tunnel aqueduct (1849, for the Ambergate & Rowsley Railway, Scheduled Monument) is probably the best example of the type. At least two of Brunel's other aqueducts (Creech St Michael (1842, demolished) and Halberton (1848) (both undesignated) had their cast iron troughs encased in masonry arches with cast-iron crowns, designed to minimise the thickness of the arch crown. His aqueduct at Trowbridge (1848, undesignated) was probably built the same way, although this has not been confirmed. George Stephenson and T.L. Gooch's River Roch aqueduct at Littleborough (1840, for the Manchester & Leeds Railway) was similar, except that plates of the top-braced trough ran across the top of a conventional masonry arch. Two other variants had the trough supported on level cast-iron beams or on cast iron arches. Much the best of the last type was Brunel's Mytton aqueduct (1850-51) (currently undesignated), carrying the Warwick & Napton Canal over the Birmingham & Oxford Railway east of Warwick. This has a masonry-encased iron trough, supported by multiple cast-iron arches.xxxiv

The cast-iron trough form of aqueduct persisted longest as a non-canal water channel. Several examples were built by water companies and by railway companies, using self-supporting cast iron plate troughs to carry leats or streams over railway cuttings. Brunel's Resolven aqueduct is a very good example. Such self supporting examples are now thought to be relatively rare.xxxv

It is uncertain when the cast-iron trough aqueduct was superseded by wrought-iron or steel troughs, but it seems likely that the cast-iron trough will have become obsolete by 1870. At about the same time, pipeline aqueducts over railways also become more common.

10 CAST IRON ARCH BRIDGES

Cast iron arch brides fall into two principle categories: cast iron arch bridges with the deck supported by spandrels and cast iron arch bridges with suspended decks. The majority were bridges with the deck supported by spandrels, although a number were also built with suspended decks. The former were built in relatively large numbers into the 1870s. The latter were much less common and were only built into the 1850s. After these dates similar designs were perpetuated in wrought iron to a diminishing extent through to end of the century.

Like skew masonry bridges, a number of cast iron bridges were constructed in the pre-railway era, most notably The Coalbrookdale Iron Bridge (1775-9), the Sunderland Bridge (1793-6), Buildwas (Shropshire) (1796), Pontcysyllte Aqueduct (1804-5), Vauxhall and Southwark Bridges (1813-16). Railway cast iron arch bridges introduced no substantive innovations but were more heavily built. The cast iron arched bridge was nevertheless used and developed on the early main line railways to an unprecedented degree and by far the majority of cast iron arched bridges were built for railway service.

The first instance of an iron arch railway bridge was probably Leather's tramway bridge over the Aire & Calder Navigation at Astley (built sometime between 1827 and 1832) The first iron arch bridge to be built on an inter city railway was almost certainly James Walker's single span Shippen Farm accommodation bridge sited beyond Garforth over his Leeds and Selby Railway of 1834 (extant, un-designated).[xxxvi] The first cast iron arch bridges to carry a main line railway, and hence to sustain the exceptional dynamic loading of a steam locomotive and its train, were on the London and Birmingham Railway (opened 1838). The line made use of a variety of cast iron spans including level beams, arched girders and tied arches. The best known examples of cast iron arched bridges were those over the Grand Junction Canal at King's Langley and Blisworth (both now encased in concrete).[xxxvii] It seems that the earliest surviving examples not encased in concrete are the bridges over the Rochdale Canal, Chapel Street, Gravel Lane and Victoria Street, all in Salford and Manchester (all 1844, John Hawkshaw). Only the Rochdale Canal and Victoria Street bridges (the latter erroneously named Stephenson Bridge) are listed (Grade II).

The cast-iron arch railway bridge became increasingly popular, particularly for longer spans where clearances were not an issue and the cast iron bridges which remain in service on British railways today are almost entirely of this type. Succeeding examples mainly reiterated the earlier structures with variations being confined to the way in which the components were assembled, there being a continuing division of opinion between spandrel panels cast integrally with the arch ring (the more skilled foundry technique) and separate spandrel members or frames. Lozenge spandrels (infilled with a trellis of diagonal members) versus vertical spandrel columns also remained an unresolved matter, both forms persisting up until the end of cast iron arch bridge-building in the last quarter of the 19th Century.[xxxviii] Such bridges are nevertheless iconic of the steam railway of the middle quarters of the 19th Century and many are of bold and dramatic appearance.

A sub-type of the cast iron arched bridge used sickle-shaped curved cast iron ribs, with the deck supported above on elegant curved jack-arches or cast iron plates supported off the bottom flanges of the ribs. An early, non-railway example, is the deck of a bridge over the Regent's Canal in Regent's Park (1814-16, by James Morgan), but the type appears to have gained currency when repeated and expanded the due to Robert Stephenson and Brunel both using this deck type around 1837-8, Stephenson on the Denbigh Hall Railway bridge and the Hampstead Road road bridge (and probably elsewhere) on the London & Birmingham Railway and Brunel adapting it on the contemporary Bishop's Road bridge. Stephenson's bridges had distinctive decorative external (face) girders, with spandrels infilled with circles of diminishing diameter. Jesse Hartley used the technology in the basement ceilings in the Albert Dock warehouses in Liverpool (1841-46).[xxxix]

The suspended deck arch bridges designed by Charles Fox and built under Robert Stephenson for the London & Birmingham Railway have now all been removed but two of the three examples on the Manchester & Leeds Railway survive, at Gauxholme in Yorkshire and at Scowcroft (Mills Hill Bridge) in Lancashire (T.L. Gooch and G. Stephenson, 1839, both Grade II). At Gauxholme, deep section plate girders have been installed between the main bowstrings to create a new, independent deck but the Scowcroft example is complete and unmodified, with the modern running lines passing over a later, parallel bridge.

The outstanding cast-iron arch bridge is undoubtedly Robert Stephenson's Newcastle High Level Bridge, whose arches support the railway on spandrels, with the roadway below being suspended from the same arches (1845-9, for the York, Newcastle & Berwick Railway (Grade I).[xl] It this combines features of both main types of cast iron arched bridge.

Reassessment of the live load carrying capacity of cast-iron railway bridges has been almost continuous since they were built. Arched cast-iron bridges have fared better than bridges with cast iron level beams, as the forces in an arched bridge are all in compression. Nevertheless, fractures, corrosion, manufacturing flaws and a general nervousness about the use of cast iron in railway bridges has meant that it has been normal practice to replace the load-carrying girders of railway overbridges with wrought iron or steel girders. In many cases the original appearance of the original bridge was preserved through the retention of the outer (face) girders and parapets. Such survivals are normally important. From the later nineteen twenties it became a practice to encase the exposed elements of many cast iron railway bridges in reinforced concrete. This fate befell a number of the surviving cast-iron arch bridges on the West Coast Main Line during electrification in the 1960s, including the iconic Nash Mills and Blisworth bridges.[xli]

11 CAST IRON LEVEL BEAM BRIDGES

The level beam bridge is undoubtedly the earliest form of bridge construction. Prior to the advent of the railway, its use remained limited to short monolithic stone and timber spans. The requirement of the railway for a level formation, coupled with a desire for spans of minimum depth and uniform height, resulted in railways rapidly developing bridges that used cast iron level beams. On very early horse railways such beams were based on the inverted 'Y' and 'T' fish-belly beam forms that had been developed between 1792-1802 by Bage, Strutt and others for floors in fireproof mills. These developments were followed in the mid-1820s by Hodgkinson's experiments into cast iron beams which combined theoretical physics, practical testing and engineering skills to calculate the stresses and loading capabilities of the beams. Hodgkinson came up with the ideal shape for a beam, the asymmetrical 'I' section which was adopted, with a few exceptions, in most of the cast iron bridges built after this time.[xlii]

Hodgkinson's asymmetrical 'I' beams were first used in bridge construction on the Liverpool & Manchester Railway Line for the building of the Water Street Bridge (1830). This had to be built at a constant height of 17 feet, over a 24 feet span of road, a task at that time only capable of being fulfilled by this form of bridge construction. It was a watershed in railway bridge design. Over the next 20 years cast iron beams were used for low-headroom situations whenever railways were built. Normally Hodgkinson's 'I' section beams were used, but there were variations. Thus 'Y' section beams (attributed to Joseph Swanwick) were used at least once on the North Midlands Railway. Robert Stephenson tried a beam with a shallow curve, with an integrally cast horizontal flange to support the deck (sickle pattern level beam or 'arched girder' (below)).[xliii] Brunel used the archaic inverted 'T' in some locations, developing this into a beam with a wide flange at the bottom and a heavy bulb in place of the top flange.[xliv] To minimise imposed loads, these various designs of level beam cast-iron bridge normally had cast-iron parapets and timber decking.

For spans greater than about 50 feet a cast iron girder, trussed with wrought iron bars was developed. Vignoles claimed that he used such a beam on a railway bridge over a canal in 1831, but it was Charles Parker Bidder, working for Robert Stephenson, who developed the type of trussed cast-iron beam that became widespread. Bidder's first bridge of the type was probably a bridge over the River Lea at Tottenham on the Northern and Eastern Railway, built in 1839. The concept appeared to be the ideal solution to the problem of producing long spans with minimal construction depth and such bridges proliferated, particularly on Stephenson-built railways, prior to the disastrous failure of the Dee railway bridge in 1847. This led to a wholesale condemnation of trussed girders and a general wariness of using cast iron as an element in bridge construction.xlv

The impact of the Dee Bridge collapse had little immediate effect on the use of cast iron girders for spans less than 40 feet, but by the 1850s any significant railway level beam bridges carrying live loads were being constructed using wrought iron plate girders. The collapse of the Inverythan Bridge (dating to 1857) in 1882 led the Board of Trade to forbid cast iron beams in new railway bridges after 1883. The collapse of a London Brighton & South Coast Railway bridge at Norwood Junction in 1891 let railway companies to commence the massive capital investment involved in the replacement of all underline cast iron bridge beams.[xlvi] In many cases, the outer face girders and parapets were retained, beam replacement being limited to the insertion of wrought-iron I beams beneath the tracks themselves. A number of short-span underline bridges did remain in use, principally on minor lines with restricted weight limits or non passenger carrying sidings. A few complete underline bridges thus survive on abandoned or disused branch lines, some of them of great historic importance. Due to the lighter loads, survival was better on overline road bridges, even on some relatively heavily trafficked routes, but the Bridge Assessment Programme has greatly accelerated their demise.

In-situ trussed cast-iron girders are considered to now be extinct however. The collapse of the Dee Bridge ensured that this type of structure was quickly removed from service although a number were temporarily strengthened by the addition of further trussing or props. Even the strengthened examples had gone by the end of the century. Very occasionally such beams may turn up in other uses, for example two cast iron sections of a three-part girder survive incorporated into the parapet of a widened viaduct over Berry Street, Halifax, probably circa. 1886. Such rare survivals are undoubtedly significant.[xlvii]

12 WROUGHT IRON TUBULAR AND BOX GIRDER BRIDGES

Whilst cast iron is excellent in compression, it is brittle and very poor in tension. Conversely, wrought iron was strong in tension, but poor in compression. This had long been appreciated, but the very high cost of manufacture and the small sizes of the plates available meant that the use of wrought iron as a structural material remained very limited until the mid 19th Century. The first important use of wrought iron as a structural material was for the building of iron-hulled ships. William Fairbairn was a key figure in this development. He built his first iron-hulled steamship in 1831, subsequently building a purpose-built yard on the Isle of Dogs in 1835. By 1840 he was employing a workforce of over 200.[xlviii]

It was at this yard that the tubular girders for the famous Britannia and Conway tubular bridges (1846-50 for the Chester & Holyhead Railway) were developed by Fairbairn and Robert Stephenson. These girders were continuous wrought-iron tubes through which the trains passed. The bridges were amongst the most heroic achievements of the railway age and a watershed in the history of civil engineering. The Britannia Bridge was not only the longest bridge in the world when built, but it used a material not previously considered as a structural medium. To quote Fitzgerald, *it was also the first great invocation of mathematically and experimentally rationalised technology which formed essentially a new departure in the science of structural analysis and which was to dominate the century that followed*.[xlix] As a model for future constructional forms, the hollow tube containing the running lines, as used in these two bridges, exerted only a limited influence. Only a single further example was erected in Britain, this being Robert Stephenson's Brotherton Bridge, built to connect the Wakefield Pontefract & Goole and York & North Midland Railways. It was replaced with a steel lattice bridge in 1903. The Conway tubular bridge (Grade I) is now the only complete surviving example in the UK. Brunel's bridges at Chepstow (replaced) and Saltash (Grade I) adopted the principal of the tubular girder, but with the deck suspended beneath. Brunel's bridges remained unique.

Of far greater long-term significance was the contemporary development of the principle hollow wrought iron box girders, beneath, or to either side of the tracks. Thompson had essayed the concept in 1840 on the Pollock & Govan Railway c.1840, using multiple shallow wrought iron box girders in place of cast iron for some short overline road bridges, but it was Fairbairn who developed and patented the concept, using paired, double web fabricated wrought iron girders with a rectangular cellular top flange (the 'tubular beam' or box girder) for long spans. Rather than trains running through these, as was the case with the tubular bridge, the tracks were carried over or between them. These bridges were usually of the parapet girder type, often with an additional girder between the running lines. They were of the half-through type (i.e. with the deck halfway between the top and bottom of the girder) and probably originated this variety of bridge. Fairbairn rightly saw such bridges as the long awaited alternative to cast iron arch and beam bridges.

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After completing the Torksey Bridge in 1849, designed by John Fowler (later Sir John Fowler of Forth Bridge fame), carrying the Manchester Sheffield & Lincolnshire Railway's line from Retford to Lincoln across the Trent at Ferrybridge, Fairbairn was inundated with orders for his box girders. By 1851 he had supplied the girders for over 100 bridges of 40 ft to 180 ft spans. In the following years this figure increased tenfold. In 1863 Fairbairn was awarded the contract for providing iron bridges on the Lancashire & Yorkshire Railway's independent route between Salford and Victoria stations (Victoria extension), which included a 102ft-span bridge over the River Irwell.

In Fairbairn's girders the depth of the beam was obviously related to the span. For long spans and deep sections the concept of the whaleback profile (with a curved top edge) was developed and used with particular success by Sir John Hawkshaw on the railways from London Bridge to Cannon Street and Charing Cross (authorised in 1859) where a number of wide roads had to be crossed on the skew. The swansong of the Fairbairn tubular beam was the construction of the Findhorn and Spey Bridges on the Inverness and Aberdeen Junction Railway in 1858, with a clear span of 245 feet. By this date simple wrought-iron plate I girders had already become the norm for shorter spans, whilst lattice and truss girder designs had become dominant for longer spans.[l]

Partly because it was the first, the outstanding surviving example of the Fairbairn type box girder is the disused (and now 'At Risk') 1849 Torksey viaduct (Grade II*), with its two 120-ft box girder spans and its all-metal approach viaducts. Vauxhall Bridge, Great Yarmouth (1847-52, Grade II) also has very early Fairbairn box girders, albeit supplemented in 1886 with an iron lattice arch and further steel strengthening c.1900. Dinting Vale and Etherow (Broadbottom) viaducts (both Grade II) both have Fairbairn box girders, installed 1859 and 1860 in place of Vignoles and Jee's previous laminated timber arches.

Possibly the most significant and certainly the most original exponent of the principals that emerged from the Conway and Britannia bridges, was Brunel. In 1849 he started using wrought iron girders, favouring both a triangular celled tube (employed by him on his Chepsow bridge (1849, replaced) and his bowstring girder bridge over the Thames at Windsor (1849, Grade II*) his 'balloon flange girder' (an 'I' girder with a circular tube in place of the topmost flange). Such girders were used for three bridges on the Gloucester and Forest of Dean, two of which were swing bridges. Several were also used on the Birmingham & Oxford Junction Railway (completed 1852). Brunel's girder designs were copied by others (including Alfred Jee at Store Street in Manchester in 1849-51 and John Gardener on the Staines, Wokingham and Woking Railway at Staines in 1856. No examples of the balloon-flanged girder bridges carrying railways are known to survive, although the two road swing bridges at Cumberland Basin, Bristol have this type of girder (1848 and 1876, both Grade II*).[li]

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13 WROUGHT IRON PLATE GIRDER BRIDGES

After the development of the tubes for the Conway and Britannia bridges, Fairbairn had continued experimenting with other forms at his Millwall yard. Building on earlier built-up girders he had developed for mill work, in 1846 Fairbairn developed a new wrought iron girder which was solid, not hollow, and had an I section, with riveted plate top and bottom flanges. Fairbairn had thus invented the modern plate girder, predicting that it could be used in spans of over 120 feet. This work laid the foundations for what has arguably become the most widespread bridge type ever, the common plate girder bridge.lii

Unfortunately the chronology of the introduction of the wrought iron I beam remains ill-defined. Robert Stephenson rapidly adopted the new form, using Fairbairn's I girders for a road bridge at Chalk Farm in 1847 and to a railway bridge at Gateshead in 1848. Brunel used I section plate girders for the decking and approach spans of the Chepstow bridge in 1852 and the Royal Albert bridge, completed in 1859. Many relatively early examples were built on northern lines, particularly on the Lancashire & Yorkshire railway. In 1863 Fairbairn was awarded the contract for providing iron bridges on the L & Y's independent route between Salford and Victoria stations (Victoria extension), including a 102 ft span bridge over the River Irwell. Sir John Hawkshaw also used Fairbairn type plate girders as well as Fairbairn box girders on the railways from London Bridge to Cannon Street and Charing Cross (authorised in 1859). Inevitably Fairbairn became a major supplier of plate girder bridges just as he did with box girders. By 1870 Fairbairn claimed to have built nearly 1000 bridges (of both box and plate types), with spans ranging from 40 to 300 feet. However, unlike the earlier box girders he exercised no patent rights over the design and other firms, especially from the Black Country were quick to enter the market, with bridges girders of parallel and hog-backed form. The demand was enormous and the plate girder became the standard format for small and medium spans throughout the world.[liii] Derivatives of the built-up Fairbairn pattern appears to have given way to lighter riveted steel variants during the 1890s.

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14 WROUGHT IRON OPEN TRUSS GIRDER BRIDGES

Alongside the development of plate and box girders, the demands of the British railway builders also led to UK engineers taking an early lead in the development of metal open-trussed girders for railway bridge building, drawing usually on American carpentry practice.

Town or Lattice Truss

One of the originators of the form was Ithiel Town, who developed the Town truss in 1820. The basic concept was that of a trellis consisting of a number of closely spaced bars disposed at an angle of 45 degrees, paired with a reflected series sloping the opposite way and tied into truss form by horizontal top and bottom chords. Transverse ties connected the chords of the two trusses to make up the bridge structure and the deck could be carried on either the top or the bottom chord. Moncure Robinson, an American engineer, bought the idea of the Town truss to Britain in 1836-7, and Captain William Moorsom built timber Town truss bridges on the Birmingham & Gloucester Railway, at Bredon and elsewhere.[liv]

Timber was found to be unsuitable for such construction on British railways and Moorsom's timber Town truss bridges remained unique until Sir John MacNeill and his pupils, WJM Rankine, J. Thomson and George Willoughby Hemans, adapted the lattice girder to wrought-iron construction, transforming an unreliable piece of carpentry to a viable engineered option for long-span bridge building. MacNeil's team built the world's first all iron lattice truss bridges, the Raheny bridge and the bridge over the Dublin canal, for the Dublin & Drogheda Railway in 1843. Thomson also used the design on the Liverpool & Bury Railway (1845-8) and J Hawkshaw used it (with Alfred Jee) at the Paddock viaduct on the Huddersfield & Sheffield Junction Railway (Grade II) (1848), which used four 77 foot spans to make up 375 feet of continuous girder. The largest span achieved by a lattice trussed girder bridge at this time was James Barton's Boyne Viaduct in Ireland (1852). This had three spans, the largest being 264 feet long. These bridges used readily available commercial wrought iron sections which were considerably cheaper than the boiler plate used for tubular bridges. They could be substantially pre-fabricated and were generally more economical to build.lv

The lattice truss was then rapidly taken up for longer spans and remained popular throughout the rest of the 19th century, in the United Kingdom and its colonies and (particularly) in mainland Europe. Lattice girders have a visual attractiveness lacked by plate and box girders and, because the tended to be used for larger-span bridges, there are a number of listed examples, not least the outstanding British lattice girder bridge, the Runcorn Bridge, designed by William Baker for the London & North Western Railway (1863-9, Grade II*).

Howe or Osborne Truss

Whilst the Town-derived lattice truss was more economical in its use of materials than the box girder, it was still profligate in its use of metal, much of which was structurally redundant.[lvi] Alongside the development of the lattice girder, a number of other types of open truss girders were thus developed, again usually building on American timber precedents. The first the Long truss, patented in 1830, which had continuous parallel top and bottom chords and a web built up from vertical posts to give square open panels which were strutted by intersecting diagonals within the rectangle. This formed the basis for the Howe truss, patented in 1840, which substituted wrought iron rods for the timber verticals in the Long truss, whilst retaining timber for the diagonals. The design reached the UK railway network via Richard Boyse Osborne, who developed the design by substituting cast iron for the timber diagonals, producing the first wholly iron truss. Osborne became Resident Engineer to Vignoles on the Waterford & Limerick Railway in 1845. The first example of his Howe type truss was finished in 1847 and it is thought at least eighteen more were built on this line, one of which survives at Pallasgreen. Nathaniel Rider further modified the truss, by adding multiple intersecting diagonals made of wrought iron, but his Rider truss was never used on any British railways. Osborne's combination of cast iron and wrought iron quickly disappeared and no surviving examples are known in mainland Britain. A generic form of crossed diagonal panels with modifications to secure resistance to buckling did find favour, the outstanding example being Sir John Hawkshaw's Hungerford (Charing Cross) Bridge (1859-64, for the South Eastern Railway, undesignated).[lvii]

The Warren Truss

The lattice girder and Osborne's development of the Howe truss were joined in 1850 by what was to become the most economical and long-lasting version of the parallel chord, trussed girder, the Warren girder. The distinctive feature of the Warren girder (and its antecedent, the Neville truss) was the simplicity of the distribution of the web diagonals, which were reduced to a continuous series of forward and backward raked diagonals which formed the pattern of linked W members contained between the top and bottom chords. The Neville truss was applied in its original form, with cast iron triangles, by Barlow at London Bridge, to form the approach viaduct over Joiner Street in 1850-51. Initially such bridges were small in number and generally unsuccessful, but the type was successfully improved by Charles H. Wild, who greatly reduced the amount of cast iron, limiting it largely to the top chord. His developmental work prompted J. Cubitt to use the Warren truss for the original Newark Dyke bridge (1852, for the Great Northern Railway, replaced 1889). The bridge was a success, although the cast iron elements were rapidly phased out in subsequent examples. Between 1853 and 1856 over 1,000 such bridges were dispatched to India alone.[lviii]

The Warren truss was further developed by T.W. Kennard, superimposing two series of diagonals superimposed. Kennard's Crumlin Ironworks were the first to utilise this combined truss, most spectacularly at Crumlin in 1853-8 (with cast- and wrought-iron trestle piers). Kennard's firm continued the development by using 'X' formations for the trusses rather than 'W' formations and further elaboration produced the triple intersection Warren form, the form merging with the lattice type bridge. The Crumlin Ironworks were the first to utilise this combined truss in 1861 in Wales and Italy and over the Wye at Whitney and at Hay, completed by 1864. The Crumlin Ironworks was also responsible for the construction of the Blackfriars Bridge, designed by J. Cubitt (LC&DR, 1864, demolished) and the similar Kew railway bridge (LSWR), designed W.R. Galbraith (1868-9, Grade II). When C.A. Harrison came to build the last great railway bridge to carry a railway over a river in Britain, the King Edward VII bridge over the Tyne at Newcastle (C.A. Harrison for the North Eastern Railway, 1902-6), he chose to use a double intersection Warren lattice of four spans. Crumlin, the most adventurous early use of the Warren girder was taken down in 1967. It is thought that there is now no first generation example of the Warren girder surviving in mainland Britain.[lix]

By the end of the 1850s there were therefore effectively three identifiable generic strands which made up the parallel chord trussed girder, the Osborne development of the Howe truss, the lattice truss girder with 45 degree diagonals and the emerging Warren girder with its alternating struts and ties set at 60 degrees.[lx]

The Pratt Truss

One further truss form however requires to be defined more closely as it occurred with increasing frequency in the latter half of the 19th century and remains a major form to this day, the Pratt truss, patented in 1844 by two Boston railway engineers, Caleb Pratt and his son Thomas Willis Pratt. The modern Pratt truss superficially resembles the Warren girder, with which it is frequently confused. The outline of the chords and the end diagonals are identical to the Warren truss but the web diagonals differ in that verticals divide the frame into square panels. The Pratt truss was the basis of many variants, including its use on the bowstring Newark Dyke bridge of 1890 (replaced 2000), where the engineer referred to it as a Whipple Murphy truss. The Pratt truss became the most extensively used form of triangulated truss. Despite this, its introduction to Britain has not been fully documented and the first UK examples are at present unknown.[lxi]

Bowstring Bridges

Curved top chords, designed to give Warren (and later Pratt) trusses a greater section depth at mid span were introduced in the mid 1850s. Again this development is ill-documented at present, but the idea became very common and warrants further attention. Pratt and Warren trusses with curved top chords merge into the bowstring type of structure. Charles Fox who had been responsible for the early suspended deck cast iron arch bridges on the London & Birmingham Railway was also instrumental in introducing the wrought iron bowstring virtually concurrently with Brunel's Windsor bridge (1849, Grade II*). Brunel had followed Osborne in the use of crossed diagonals in tension between panel verticals in compression at Windsor, a system that Fox made use of at his first major wrought iron bowstring, on the Blackwall Extension Railway over the Commercial Road in Limehouse. Later Fox discarded the verticals and used single Warren panels, or for larger bridges, double intersection Warren panels. Probably the earliest English example was the bridge built for the Maryport & Carlisle Railway over the Derwent at Brigham. Apart from the Windsor bridge, the only other early example that has come to light is the main span of the all-metal Timberley viaduct on the Pulborough to Arundel line of the London, Brighton & South Coast Railway (F.D. Banister, 1861-63, undesignated). The type subsequently became widespread and many later examples are still in service.[lxii]

15 STEEL BRIDGES

Henry Bessemer's development of bulk steel-making in the mid 1850s initially had little effect on bridge building, largely due to resistance from the Board of Trade. Thus the first steel bridge, built in 1863 by London & North Western Railway over the Sankey Brook Navigation (St Helens Canal), was on a freight-only line. In 1877 the BOT regulations concerning the construction of steel bridges was lifted, in response to the improvements in quality due to the introduction of the Siemens-Martin open-hearth process. The LNWR again led the way, replacing the Llandulas Viaduct on the former Chester & Holyhead Railway in steel in 1879. It is unclear how soon after this any successors followed, but Crawford Barlow suggested in 1888 that the next steel railway bridges may not have been built until 1887, when seven bridges and a viaduct of three spans were constructed for the Caledonian Railway. According to Barlow there then appeared to follow a remarkable surge of steel bridge construction and by October 1888 the BOT had inspected 22 new bridges of this material. The opening of the Forth Bridge in 1890 transformed the situation and the transition from wrought iron was virtually complete by 1900.[lxiii]

The substitution of steel for wrought iron initially had no impact on bridge design and the steel fabricated plate girder, truss and arch were generally indistinguishable from their earlier wrought iron counterparts. Even today few engineers can readily identify a wrought iron structure as differentiated from a steel one.[lxiv]

The only constructional technique that did alter in time was the replacement of riveting by welding. The first hesitant experiments with welding for bridges appear to have taken place when London & North Eastern Railway used welds to repair existing riveted structures in the interwar period. In 1938 the first all welded, plate girder, underline bridge was brought into service by London Transport at Ladbroke Grove.[lxv]

It became more common for wholly shop-built bridges to be built using welded steel and for such bridges to be transported to site complete. Other developments included the introduction of the high tensile bolt, developed by The Great Western Railway. These were used in the replacement of Brunel's Chepstow Bridge in 1962. At the beginning of the 1960s welding had moved to a position where riveting was reduced to inescapable repairs to existing structures. Automatic machine welding was being introduced which was capable of consistent results and higher standards. The 1962 Chepstow bridge encompassed all the recent developments in the field and, at the time of its erection, was the largest and most complicated welded bridge structure built up to that point. Another notable welded bridge was the new Grosvenor rail bridge over the River Thames (1967, Freeman Fox & Partners and A. H. Cantrell for British Railways, Southern Region), where the arched spans were of unique design in order to allow the replacement of nine parallel cast iron arch spans with ten, whilst re-using the Victorian piers and keeping one of the world's busiest railway bridges in traffic at all times. The longest welded steel plate girder span erected in the 1960s was the railway bridge built at Tinsley near Sheffield, incorporating a clear span of 52 metres.[lxvi] More recently, the award-winning third Newark Dyke bridge (Mott MacDonald / Cass Hayward, 2000) represents the progenitor of new generation of long steel structure designed for 225kmph dynamic loadings.

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16 CONCRETE BRIDGES

The use of concrete for bridge building was pioneered on the continent and in the United States and is currently thought to have come to Britain c.1870. The earliest known free-standing mass concrete bridge in Britain was a footbridge built in 1870 at Homersfield, Suffolk. Mass concrete was widely used on W. McAlpine's West Highland Extension Railway (most notably the 21-arch Glenfinnan viaduct (1897-1901).[lxvii] Its use for railways in England seems to have been restricted to Devon and Cornwall, notably the viaducts at Cannington (1903), Holsworthy (1897) and Derrion (1898) (listed Grade II, II and II* respectively). Concrete block construction was possibly uniquely employed on the slender Calstock viaduct (1908, Grade II*).

The principal of reinforcing concrete with iron cables or bars to take tensile forces had been independently pioneered in the 1860s by H.Y.B. Scott in the USA and in France, Austria and Switzerland by F. Coignet and J. Monier, resulting in a number of spectacular, slender arched bridges built between 1875 and 1900. The first bridge in Britain to be built (partially) of reinforced concrete was built in Hampshire at Chewton Glenn in 1901-2 and by 1908 the Mouchel-Hénebique partnership had built 89 bridges in Britain,[lxviii] although most, if not all of the reinforced concrete railway bridges built in the early 20th Century were relatively low structures on freight-only lines in docks and goods yards. The outstanding surviving example is the undesignated 1km-long Milton viaduct on the former Bowater's narrow gauge industrial Sittingbourne and Kemsley Light Railway, dating from 1906. British railway engineers of the 1920s and 1930s showed a marked conservatism over the use of reinforced concrete, the earliest British example on a main line being in Northern Ireland (dating from 1933). The Southern Railway and London Transport used the material widely in the 1930s for Modernist buildings and station furniture. The Southern Railway's concrete vernacular was use widely on its Chessington branch, the only significant extension to overground network built in the 1930s and two reinforced concrete bridges on the route were noted by EH in 2001.[lxix] A late reinforced concrete viaduct is the railway flyover at Bletchley, one of the more notable monuments to the 1955 Modernisation Plan, opened in 1962 and largely abandoned in 1967 following the abandonment of plans for an outer London orbital fright route.[lxx]

It is uncertain when precast concrete was introduced, but early applications revolved around railway footbridges, with the London & South Western Railway (and its successor, the Southern Railway) leading the way at Oxshott, Surrey (1908) and Exeter (1923).[lxxi]

After 1945 steel was in short supply and concrete was increasingly used for bridge construction. Whilst many of the smaller post-war bridges continued to be constructed using simple steel reinforcment, a stock of emergency prestressed concrete beams was held during the War and used afterwards in permanent bridgeworks, notably the pioneering Nunn's (road) Bridge, Fishtoft near Boston (1948) and Adam Viaduct near Wigan (1946).lxxii Pre-stressed concrete became the norm for all large reinforced concrete bridges, including most built as part of the motorway programme from the 1950s. By the 1960s pre-stressed concrete had superseded reinforced concrete for all but the smallest bridges. During this period the box girder became the dominant structural form for large bridges in both concrete and steel because of its structural efficiency and economy.lxxiii The box girder was little used for railway projects however. Probably the most interesting concrete railway bridge built since the 1960s is the Lyne railway bridge over the M25. Because the bridge crosses the motorway on a skew of some 28°, the overall span length is 110m. This led to the adoption of a two-span prestressed concrete cable-stayed bridge supported from two towers rising 30m above the level of the motorway. It was the first concrete cable-stayed railway bridge in Great Britain (1982, British Rail (Southern Region) and Stressed Concrete Design Limited, undesignated).

17 MOVABLE ELEMENT BRIDGES

Moving element bridges have a long history, both for defence and for use where a road (or latterly railway) needed to pass over a navigable waterway or dock entrance. Whilst railways made use of, and adapted, pre-existing moving bridge technology, their inherent requirements for a level formation, perfect alignment or rails and their high dynamic loadings placed new demands on moving-element bridge design, resulting in an evolution of technical design that often saw railway bridges at the forefront of technical progress in the field.

Moving element bridges are generally divided into five main groups:, namely, the bascule bridge—descended from the drawbridge of ancient days, the swing bridge, the rolling or retractable bridge and the vertical-lift bridge.

Finally there is the transporter bridge in which the bridge does not move at all, it merely supporting a suspended carriage which runs backwards and forwards. The transporter bridge has never seen main-line railway use and is not relevant to this study.

Lift Bridge or Drawbridge

This is perhaps the oldest form of moveable-element bridge, typically associated with defensive fortifications. In all cases one end of the deck is fixed to a horizontal pivot point. In the drawbridge, ropes, cables or chains are attached to the outer end and running up to a mechanism at the ‘fixed’ end. A winding mechanism allows the operator to wind the lines on to a drum, drawing the lifting end of the bridge up into the air thus cutting off access from one side of the waterway, moat or deep ditch to the other side. A double-leaf drawbridge has two leaves that meet mid-channel. A lift bridge is a counterbalanced form of drawbridge, which typically moves through less than 90 degrees and which may be operated from either end.

Vertical Lift

In the vertical lift bridge both ends of the bridge deck are raised in unison, so that the bridge deck itself remains in the horizontal position and traffic can pass underneath. Unlike swing and bascule bridges this type of bridge does not give access to vessels of unlimited size. Vessels are restricted to the maximum height to which the bridge deck can be raised.

Sliding, Retractable, Rolling and Telescopic

These terms used to describe a moving bridge design in which the bridge deck remains in the same horizontal and vertical plane, but is withdrawn from the waterway in a lateral, sliding movement. In a railway situation truly telescoping bridges have the disadvantage that the moving section normally had to be raised or lowered clear of the approach rails before being slid back over or under them. In the Bridgwater telescopic bridge this was obviated by sliding a section of track to one side, then withdrawing the moving section into the space vacated. On the London & Birmingham Railway, Robert Stephenson built a bridge at Weedon that slid out at 45 degrees to both the track and canal, which required no ligting.

Bascule

A bascule bridge (derived from the French word for ‘see-saw’) is a form of drawbridge where the weight of the deck of the bridge is balanced by an equal weight on the opposite end. By moving the weighted short end of the bridge downwards the longer arm of the bridge deck is moved upwards around a horizontal axis, just as the weights of two people sitting on opposite ends of a see-saw are moved by applying force alternately. Tower Bridge is a double-leaf bascule bridge. A variant is the Schertzer rolling bridge, in which the leaf or leaves are not pivoted, but instead roll on toothed quadrant.

Swing Bridge

A swing bridge moves in the horizontal plane about a pivot point, usually swinging through a 90^{o} arc. The pivot point may be close to one end so that when swung into the open position to allow waterborne traffic to pass the bridge deck lays close to or over the bank. Alternatively the pivot point may be mid-channel, so that when open the swing bridge lies along the waterway and may offer clear passage for vessels along two channels. In these types of swing bridge there is often of necessity a control point on the bridge deck itself, since in most cases the bridge deck is isolated from the shore when in the open position. In some cases the pivot point may be offset from the central point, creating asymmetric spans. A double-leaf swing bridge has two leaves that meet mid-channel.

Small moving element bridges may be manually powered, either simply by pulling or pushing on the structure, or by operating a pulley or windlass system. Larger bridges may be powered by steam or electric motors or may be hydraulically powered. In large swing bridges hydraulic power is needed to physically lift the moving section off the abutments, so that it may be rotated.

Early moving element railway bridges were all hand operated and made use of most known forms, including draw bridge, vertical lift, telescopic bridge and swing bridge. Probably the earliest built for a main line railway was the 1838 Deptford Creek double-leaf drawbridge (London & Greenwich Railway), replaced with vertical lift bridge in 1963. This was followed by the Selby double-leaf bascule bridge (James Walker, for Hull & Selby Railway, 1839, replaced with a swing bridge in 1891), the Ford telescopic bridge (London Brighton & South Coast Railway, 1844, rebuilt 1862 and replaced with girder bridge in 1938), the Humber Dock double-leaf swing bridge (1846, for the Hull & Selby Railway, Grade II), the Reedham and Somerleyton swing bridges (Stephenson & Bidder, for the Yarmouth and Norwich Railway, 1842-4, replaced 1902-3), the Trowse swing bridge (Stephenson & Bidder, for the Norwich & Brandon Railway, 1845-6, replaced in 1905), Oxford swing bridge (Stephenson & Bidder, for the Buckinghamshire Railway, 1850-1, rebuilt c.1890, Scheduled Monument) and Wilmington swing bridge, Hull (Thomas Cabry, Victoria, or East Dock, Railway, 1853, replaced 1907-8).[lxxiv]

According to Armstrong, writing in 1869, the first hydraulic swing bridge was one of two built by Brunel at Gloucester for the Gloucester and Dean Forest Railway in 1852 (probably the

Llanthony swing bridge, replaced 1899). Brunel also used hydraulic power again to operate the Carmarthen telescopic bridge over the Towey at the other end of the line. Larger powered railway moveable element bridges followed, including the Ouse Swing Bridge at Goole (T Harrison and W Armstrong & Co for the NER, 1868-9, Grade II*), the Hull swing bridge (Hull & Barnsley Railway, 1885, Grade II), the Selby swing bridge (T Harrison and W Armstrong & Co for the NER 1891, undesignated), the Sutton or Cross Keys swing bridge (W.G. Armstrong & Co for the Midland & Great Northern Railway, 1897, Grade II*), the Reedham and Somerleyton swing bridges (Great Eastern Railway, 1902-5, undesignated), the King's Ferry bascule bridge over the Swale (South Eastern & Chatham Railway, 1904-5, replaced 1922, replaced 1960, undesignated), Trowse swing bridge (Great Eastern Railway, 1905, replaced 1986), the Oulton Broad swing bridge (Great Eastern Railway, 1907, undesignated), Wilmington swing bridge, Hull (North Eastern Railway, 1908, Grade II) and Keadby (George V) bascule bridge (Great Central Railway, 1912-16, Grade II).lxxv

More recently many moving element railway bridges have been removed, replaced with fixed spans or welded shut. A small number have been replaced with new moving bridges, notably the Deptford Creek vertical lift bridge (1954, Cantrell, A.H., for British Railways (Southern Region), undesignated), the King's Ferry vertical lift bridge King's Ferry bridge, over the Swale (Mott, Hay & Anderson for British Railways (Southern Region), 1956-60, undesignated) and the Norwich (Trowse) swing bridge (1987, British Rail (Eastern Region), undesignated. The last is of note as the only swing bridge in the U.K to carry an overhead electrified railway track.

18 NAVVY SETTLEMENTS AND QUARRIES

Navvies were the labour force used in the building of the canals, railways and great infrastructure projects between the 18th and 20th Centuries. They moved from contract to contract, living in temporary communities near to the projects that they worked upon. The railway age saw the flowering of the navvy culture with about 40,000 - 100,000 men employed in this way. Where existing accommodation was lacking, large shanty towns grew up. Hut accommodation was the norm, either 'shants' or 'sod huts'. A shant was a speculative development built by the contractor or foreman, each housing about a dozen tenants. The sod hut was a more makeshift arrangement, often a lean-to structure, built by individual navvies. A classic site of this period is the Woodland Tunnel, constructed as part of the Sheffield, Ashton-under-Lyne & Manchester Railway to Manchester Railway, between 1839-1845, where the remains of six building types, both shants and sod huts, have been identified and archaeologically investigated. The sometimes ephemeral nature of these workers camps makes them highly vulnerable to destruction, but their investigation provides valuable insights into diet, refuse disposal, layout, and the social structures which existed within the camps.[lxxvi] Similarly, archaeological evidence of quarries and borrow pits has also been noted.[lxxvii]

19 FOOTBRIDGES

Railway footbridges are doubtless almost as old as surface railways themselves. While trains remained relatively slow, level crossings tended to be preferred on account of their lower cost. In hillier areas, where the local topography made foot level-crossings difficult to engineer, relatively substantial masonry bridges were often provided through embankments or across cuttings, sometime carrying relatively minor rights of way. In upland areas, where roads were still relatively sparse and the packhorse was still the default means of transport, such footbridges may more accurately be described as packhorse bridges, although the distinction between footbridge and packhorse bridge is often blurred. The earliest example of such a bridge over (rather than under) a railway that has been noted during this survey is the foot (or packhorse bridge) near Pingle Lane, Belper (1840, George Stephenson, for the North Midland Railway, Grade II). It is unclear when footbridges with steps up on both sides first emerged, but the South Devon Railway (first section opened 1846) appears to have been amongst the first, Brunel providing some particularly spindly timber structures across the tracks. These were doubtless provided because the atmospheric traction pipe between the rails made level-crossings impossible. The silent and extremely rapid progress of atmospheric propulsion (up to 60mph) also made such bridges particularly desirable, as today with electric traction.

As railways evolved, an enormous variety of such pedestrian bridges came into being. These included masonry arches, timber trusses and iron spans of all varieties. Sometimes ornamental footbridges were provided by, or to appease, influential landowners. As railways became busier, footbridges were increasingly built at busy road level-crossings, so that the passage of trains did not unduly interrupt pedestrian traffic. As railways became busier and faster, pedestrian footbridges were also increasingly provided to replace more or less isolated footpath level crossings. Few early examples remain, but it seems that early examples tended to be to relatively bespoke designs, but from around the 1880s level-crossing footbridges, both road and footpath only, tended to make use of pre-fabricated components, mirroring the development of station footbridges (see below). The replacement of foot level crossings with increasingly standardised footbridges is a process that remains ongoing. Indeed, the process is indeed accelerating today because of increasing train speeds and concerns over public safety.

The classic 'railway footbridge' is of an altogether different nature, being a bridge provided at a station to provide safe communication between the platforms of a station. Early station planning tended to regard such bridges as anathema, the extraordinary single-sided station design being the short-lived result for busy locations. At lightly used stations communication between platforms by level-crossing prevailed. Busy junction stations with more than two platforms presented a particular challenge. The passenger subway, as used at Didcot in 1841, was one solution. The station footbridge appears to have first emerged at two such stations where hotel accommodation and refreshment facilities were also provided, the bridges apparently being provided to provide more salubrious communication than a subway could provide. The two stations were at Normanton (opened 1840) and Swindon (opened

1842), both of which has covered footbridges connecting the upper storeys of the platform buildings. Francis Thompson was the architect of the first and was paid for consultancy work by Brunel on the second. The form was revived in the motorway service stations of the 1960s.

As large junction stations became busier and as the number of platforms proliferated, the station footbridge (or subway), together with improved methods of identifying what train was due to depart from where, became essential components in the art of efficient station design, establishing methods of crowd organisation that continue to this day in many, varied applications and settings. The 1852 Great Central Station in Birmingham (today's New Street) was possibly the first multi-platform station where the footbridge was an essential component of the station's layout and organisation. The large station footbridge, usually enclosed and latterly with lifts subsequently became a key design feature of a large station, with detailing to match. Denmark Hill station (1865, for the London Brighton & South Coast Railway) took the concept a stage further, with the main station buildings being built on a bridge abutting the footbridge, for efficient circulation. The form came into increasing vogue towards the close of the 19th Century and into the 20th (e.g. Nottingham and Leicester Midland stations), with the footbridge itself being subsumed almost completely into the station concourse.

Footbridges at two platform stations appear to have started to make an appearance in the 1850s, initially drawing on Normanton and Swindon for inspiration. The large enclosed footbridge added to the second (1840) Coventry station sometime pre-1860 may have been one of the first. The use of footbridges at lesser stations accelerated rapidly from the 1870s, initially with a variety of very functional timber structures that are now virtually extinct. Circa 1880 almost all of the many railway companies then in existence evolved their own individual designs of more-or-less prefabricated footbridges, both covered and open, for both new stations and for retro-fitting at existing stations and other pedestrian crossing-places. Most used various forms of arched or straight lattice girders, although the North Eastern Railway developed its own strain of distinctive wrought iron, then cast iron, arched designs. Some companies, notably the Great Northern Railway, favoured cast iron supports, others adopted all wrought iron designs. Sometimes wrought iron spans were combined with masonry piers and steps. In all cases patterns were evolved that would both suit new stations and earlier works. All were fine examples of Victorian metalwork and their design was such that a well-designed footbridge came to be seen as a quintessential component of a complete railway station.

From around 1900 designs became more functional, with increasing use of plate steel. The grouping of the railways into four companies in 1923 further reduced the variety of prefabricated footbridge design. In 1908 the London & South Western Railway completed its first prefabricated reinforced concrete footbridge, erected on a footpath near Wokingham station. The type was subsequently adopted as standard by the Southern Railway and, to a lesser extent, the London Midland & Scottish Railway. With Nationalisation variety was reduced further still, both as a result of centralised design, but also because of 25kV electrification, coupled with widespread closures and rationalisation, resulting in extensive losses of historic footbridges. These factors continue to affect historic footbridges across the network, although the design response has been more diverse due to Privatisation and the opening of the market to external designers and bridge providers. The lowering of the catenary or raising of historic metal footbridges to clear it has been achieved in some instances where bridges are listed (e.g. Letchworth and Welwyn North), but Network Rail is increasingly adhering to guidance that mitigates against such solutions, even where bridges are designated.

A development with a potentially even greater impact is disability discrimination legislation. In 2006 the Government committed £370million to make 148 key stations 'step free' by 2016 under the 'Access for All' programme.[lxxviii] It is to be anticipated that the programme may be extended until such time as the entire network is step-free. The provision of disabled-friendly footbridges need not result in the complete loss of historic footbridges, as they can be adapted with wheelchair lifts (as has happened at Stamford Town) or retained as secondary facilities for the able-bodied. The retention of duplicate centenarian metal or reinforced concrete structures will always be regarded as a luxury however, resulting in even listed (or curtilage-listed) structures coming under increasing pressure. To date usual response has been the generous commitment to storage for eventual donation to a heritage railway (e.g. the Handysides' footbridge at King's Cross or the 1895 footbridge at Gravesend). As with signal boxes, the identification of a representative cross-section of railway footbridges suitable for preservation in-situ or ex-situ would be timely, as would a review of existing designations, both for listed and curtilage-listed footbridges.

20 ENGINE SHEDS AND ASSOCIATED FEATURES

Introduction

The engine shed is a unique form of industrial structure, evolved and found only on the railways. The earliest engine sheds were the stables used to house the horse power used on the earliest railways. The new steam locomotives introduced in the 1820s and 30s were expensive and needed buildings in which they could be stored and maintained, as well as coaled and watered. This led to the evolution of a variety of specialised building types.

As the name implies, engine sheds could sometimes be small, simple structures, perhaps only providing simple coaling, watering and overnight accommodation for the single engine required to work a small branch line, they could conversely be huge establishments capable of coaling, watering, stabling and maintaining allocations of hundreds of locomotives, sometimes with relatively sophisticated ancillary structures such as large coaling stages, water towers, repair shops and staff welfare facilities, with nearby company-provided housing for sometimes hundreds of workers. Depending on the scale of the repair facilities, it can often be difficult to say conclusively whether a particular building is a surviving example of an engine shed or whether it is a repair works. In many cases a particular building may have been both at different times.

As railways initially went from A to B and were devoid of branches and junctions, locomotives were generally kept at a limited number of locations, normally at either end of a railway such as the Stockton & Darlington or Liverpool & Manchester. In addition to stabling facilities, repair facilities were provided at one end of the route or the other. In many cases, as railways assumed increasing responsibility for repair and manufacture, engineering establishments evolved alongside the sheds at locations such as Edge Hill and Shildon. This remained the case with early medium distance railways emanating from centres such as Derby and York, where each company would stable, maintain and repair its own locomotives in dedicated buildings at either end of its route, leading to duplication of facilities where such railways met. Thus, at Carlisle for example, there were once seven locomotive sheds or depots owned by six different railway companies. Derby not only had the locomotive sheds of three companies on adjacent sites, but also the locomotive and carriage repair works of two of them, also adjacent.

For longer distance routes, e.g. London - Birmingham and London - Bristol, railway planners decided that, following the example of stage coaches, in addition to the terminal depots, an additional stabling point would be necessary at the mid point, so that tired engines could be taken off and replaced with a fresh ones to complete the journey. Such locations were developed as centralised locomotive and carriage repair facilities and thus railway towns such as Wolverton and Swindon came into being. A less well-known example was Horley, on the London & Brighton Railway.

From the 1840s, as the individual routes started to both coalesce into a network, with junctions and branches, additional stabling facilities were needed at both junctions and branch termini. Subsequent growth of urban termini on constricted sites and complaints about pollution led to stabling often being ousted to the suburbs from central urban locations. Changing traffic flows resulting from new routes being opened, coupled with amalgamations and changes in operational requirements meant that some locations became redundant, whilst others grew and new ones were created. Stabling functions tended to assume separate existences from major repair and manufacture, albeit often still on adjacent sites. In the latter part of the 19th Century some stabling locations grew to enormous sizes, with allocations of hundreds of locomotives and maintenance facilities that were capable of very heavy repairs. As these locations tended to be peripheral to established population centres, substantial areas of workers' housing and other facilities were often developed. The 'grouping' of over a hundred railway companies into the 'Big Four' in January 1923 saw some further rationalisation, but generally the emphasis of the new owners was on improving both efficiency and working conditions. A number of sheds were rebuilt, sometimes with Government assistance in the 1930s. Others were updated with improved mechanical handling of coal and ash and better welfare facilities, enginemen on overnight lodging away turns benefitting from purpose-built accommodation for the first time.

In the Second War engine sheds were prime targets for air attack and many suffered extensive war damage. Despite extensive employment of women workers, all suffered from a level of neglect and a lack of maintenance from which many sheds never fully recovered. Shortly after Nationalisation, further rationalisation of duplicate facilities occurred, with many of the survivors being repaired, re-roofed or rebuilt altogether in an attempt to further improve working conditions. Following the announcement of the Modernisation Plan in 1955, those that had not been rebuilt or repaired after the war (and even some of those that had) declined into an appalling condition through lack of maintenance as it became clear that many would soon be obsolete. Ultimately, almost all fell to rapid obsolescence as steam was replaced with other forms of traction in the late 1950s and 1960s. Unlike most of the rest of the world, where engine sheds (and steam engine repair works) were retained for other railway uses, most of the surviving steam sheds and many of the repair works in mainland Britain rapidly succumbed to either abandonment or immediate demolition. Some were reincarnated as diesel depots, with mainly new buildings and some others survived in railway or other uses. The selection of a representative selection for designation was generally slow and, prior to 1990 when the 1940s shed complex at Carnforth was designated, only the very oldest tended to receive any measure of statutory protection, save for rare cases such as Faversham, where a shed of the 1890s was thought to date from the early 1850s.

Generally the remainder, often more or less altered, were considered by those outside of the railway heritage community to be to be relatively recent, relatively standardised industrial structures of little or no architectural or historic merit. As late as 1982 a pair of outstanding London Brighton & South Coast Railway semi-annular roundhouses in Battersea, dating to the 1860s, were lost, despite having lain in prominent public view on the approach to Charring Cross station. In 1999 an outstandingly complete 6-road, 1890s Lancashire & Yorkshire shed at Southport was sold its owning heritage group for demolition and redevelopment. More recently G.J. Churchward's 1906 state-of-the-art locomotive maintenance 'Factory' at the Old Oak Common depot in West London was cleared to make way for Crossrail.

Engine sheds have thus always been vulnerable to change, from fire or relocation, extension or reconstruction and eventual obsolescence. Thus, whilst British Railway inherited over 600 locomotive sheds at the time of its formation in 1947, the number of known shed locations on the national network is over 1400. If the locomotive sheds on private and industrial railways are added, it has been estimated that the total number of sites may exceeded 4,000.lxxix

Due to the substantial eradication of engine sheds from the national network, engine sheds and associated repair facilities have suffered an extreme level of attrition. Attendant structures, such as coaling stages, welfare facilities and railwayman's overnight lodgings are almost completely extinct on the national network and generally only survive at all due to serendipity or through the efforts of the railway heritage sector.

Side Stall type

Whilst the straight shed form (see below) would prove to be the most enduring engine shed type, the best and most economical form for an engine shad was far from clear as main line railways emerged in the 1830s and early 1840s. Layout and architectural treatment of engine sheds and workshops thus varied greatly as railway planners and engineers attempted to find the ideal form for the new building type. Locomotive sheds on the early main line were often reflected the high value of the contents and the prestige of the new railways. Many were thus very fine structures indeed, initially inspired by the stable blocks of grand houses.

The best known high status quadrangle engine house was the Locomotive Engine House provided at Camden by Robert Stephenson for the opening of the London & Birmingham Railway in 1838. This comprised a square complex containing three long parallel ranges, separated by two un-roofed through roads provided with multiple small turntables. These allowed the small, four-wheel locomotives of the day to be turned through 90 degrees to be shunted by hand into multiple individual stalls. The drawback of the form became apparent as soon as the small four-wheeled locomotives the turntables and stalls were built for were replaced by larger six-wheeled machines, which soon grew longer than the short turntables.

At the half-way point on the railway at Wolverton, a similar, but more complex facility was also provided in 1838. This was the Great Engine Shed, where reserve engines could be kept in steam, while those requiring servicing could be maintained, repaired or rebuilt. Built by George Aitchison, this was 314 ft square and of quadrangle form, constructed of brick with Doric stone cornice and Doric detailing. The courtyard had a central entrance with water tank over, with erecting shops to either side. Ranged around the other three sides were of the courtyard were engine stalls for 36 service locomotives, joiners' shop, iron foundry, boiler yard, hooping furnaces, iron warehouse, smithy, turning shops, offices, stores and a steam engine for power. With numerous small turntables, this suffered many of the same problems as the Camden engine house and was supplemented in 1845 with a new works accessed by a traversing table and a new locomotive shed with multiple parallel tracks accessed by points. The Great Engine Shed was incorporated in the expanding works complex and remained in use until 1990. Despite being the world's oldest engine shed and locomotive works, the undesignated building was then demolished to build a Tesco supermarket.[lxxx]

Like Wolverton, Swindon was the chosen half-way changeover point for locomotives on the route it served. It was also a junction. After initial consideration of a 200-foot diameter roundhouse with projecting repair shops proposed by Gooch in 1840[lxxxi], Brunel decided to build a quadrangular repair factory and a large rectangular engine house. This was based on the same philosophy as the Camden and Wolverton engine houses, but with a large, powered traversing plate fitted with rails to slide the engines to their stalls laterally, rather than turning each locomotive into its stall on a small turntable. This form had the same advantage as the 'Camden' pattern shed, in that any locomotive could be withdrawn without disturbing any other. It also suffered the suffered the same drawback, in that it was expensive to build and, once built, could not be easily adapted to accept larger locomotives. It was also vulnerable to a breakdown of the traverser, which would make it impossible to withdraw any engines. It was rarely repeated as a form of locomotive stabling in the UK, although the traverser-accessed engine shed enjoyed a long currency in parts of continental Europe and the United States. The Swindon engine house was soon incorporated into the railway works as an erecting shop. It was eventually demolished in the 1930s, although one wall survives, incorporated into an adjoining (now Grade II listed) building. Whilst the Swindon engine house was short-lived as an engine shed, the side-stall form nevertheless persisted for many decades for locomotive erection and repair work, albeit with the stalls generally served by overhead gantry cranes, rather than by a traverser, in order to maximise working floor space.

The outstanding surviving example of a side stall engine house is the South Range of the former Romford Railway Factory, built as an engine shed by John Braithwaite for the Eastern Counties Railway in 1847 (Grade II). The engine house range comprised a covered, double-height nave, with the two-storey aisles with individual stalls on the lower floor and fitter's shops and stores above. It would appear that the stalls were accessed by individual small turntables, in the manner of the original sheds on the London & Birmingham. Both the engine house and the works generally proved incapable of expansion and were rendered redundant in 1848, when the Stratford Works was opened. The factory became a tarpaulin works c.1854, remaining intact and un-noticed in sundry uses until 1998, when it was converted to flats.[lxxxii] It had been listed ten years previously, although it could be argued that its Grade II listing failed to recognise the significance of the complex as the earliest wholly intact railway works in the world and the last known side-stall engine shed in Britain.

Side-stall engine sheds thus had a very brief vogue in England, apparently lasting only from the building of the London & Birmingham sheds in the late 1830s through to the construction of the engine house at the Romford Railway Factory in 1847. The design had a longer-lasting direct influence on railway factory design, the side-stall form rapidly becoming the default form for locomotive erecting shops worldwide through to the turn of the 20th Century. Any intact early (pre-1850) example would thus be of more than national importance.

Roundhouse type

The railway roundhouse follows the same philosophy as the side-stall type, in that it comprises a number of individual stalls from which any locomotive can be withdrawn without disturbing any other. In a roundhouse the stalls are arranged radially around a central turntable. The inspiration is generally thought to have been the Fenton, Murray & Wood's Round Foundry in Leeds, built at the close of the 18th Century, although the similarity of form is superficial and unrelated to function. The earliest known railway roundhouses were those at Birmingham Curzon Street station (R. Stephenson) and at Paddington station (D. Gooch), both built c.1837-8. The Paddington roundhouse was a temporary octagonal timber building, with a turntable at the centre serving an access road and seven radial tracks with inspection pits. This roundhouse element was used for major repairs, an abutting a long straight shed being used for preparing locomotives for daily services.[lxxxiii] The shed was demolished when the present Paddington station was built 1851-4. It had little subsequent influence on Great Western Railway practice until the very end of the 19th Century. The Curzon Street roundhouse was more mature altogether, being 124ft diameter with 16 radial tracks. Solidly built of brick, it was entered through a large arch beneath a projecting water tower. It was described by Richard Foster thus: 'the building erected at the Birmingham Station is of multilateral form, the diameter being 124 feet… Towards the passenger station is a building projecting from the engine house 60 feet in depth and 63 feet in front; in the middle of this front is an entrance for the locomotives… and on either side are the offices for this department, including a waiting room for the enginemen, store room, office, turnery, wood-room, and a coke heating oven.'[lxxxiv]

The roundhouse plan was adopted soon after by Frances Thompson for the North Midland Railway's engine shed and workshops at Derby, built 1839. For the running shed, Thompson arranged 16 stalls around a central turntable, the whole enclosed within a 140-foot diameter, conical-roofed building. This had a far wider influence, both abroad, but also on the North Midland Railway and its successor, the Midland Railway, which remained loyal to the roundhouse almost to the end of the 19th Century. Certainly the best-known example of the conical-roofed roundhouse in Britain is the Chalk Farm roundhouse at Camden, built for the London & Birmingham Railway in 1846-7 by Robert Stephenson and Robert Dockray (Grade II*). This comprised 23 stalls for freight engines plus an entrance road, ranged around a 41-foot diameter turntable. It was one of two engine houses built to supersede the Stephenson's original Camden engine house. Whilst boldly conceived for its time, the inherent limitations of its overall dimensions resulted in it being converted to a gin warehouse in the 1860s. In contrast the corresponding rectangular through shed built at the same time for passenger engines remained in its original use until it was demolished in 1966. The fully enclosed, conical-roofed roundhouse nevertheless spread rapidly from England through mainland Europe and (particularly) the United States. Whilst a number of British examples survived into the 1960s, particularly in the North-East, with the exception of the Derby and Chalk Farm examples, the type is thought to now be extinct in Great Britain.

The roundhouse plan-form was nevertheless capable of significant variation and expansion, particularly once it was realised that the turntable did not need to be covered, resulting in a doughnut (annular) or crescent-shaped (semi-annular) shed set back from a central turntable. This not only meant that overall size was no longer limited by the economical span of a roof but also it allowed for expansion as locomotives grew, it being possible to both enlarge the turntable and to extended the annular shed forwards or backwards to accommodate larger engines. This evolution is apparent at the former Wellington Road depot of the Leeds & Thirsk Railway. The original layout (completed by 1847) as conceived Thomas Grainger (line engineer) and John Bourne (resident engineer) comprised a detached rectangular repair shop (Grade II) and a 19-stall roundhouse (Grade II*), the latter built as a complete doughnut, albeit that the turntable was also covered over with an independent roof. Interposed between the two lies a crescent or semi-annular half-roundhouse (Grade II), built for locomotive repair sometime before 1853. The site survived to the present, having fallen out of railway use in 1898, following the opening of a new, depot on the other side of Leeds at Neville Hill.[lxxxv]

Annular and semi-annular roundhouses were widely built by a number of railway companies throughout the United Kingdom between c.1850 and c.1880. The last was built by British Railways at the Thornaby depot, near Middlesborough, opening in June 1958. Octagonal in shape, it had 22 roads around a 70ft electric turntable and lasted in use for diesel locomotives until it until it was demolished in 1988. Both annular and semi-annular types became very widespread indeed in continental Europe and the United States from the 1850s, where the type was further developed in the 1920s and 1930s to include large fireproof, ferro-concrete buildings capable of housing some of the largest steam locomotives ever built. Whilst many examples remain extant abroad, the only other surviving example in Britain is the quarter segment semi-annular roundhouse at St Blazey Road, Restormel, built by Sir Morton Peto for the Cornwall Minerals Railway in 1874 (Grade II*). Like the Derby roundhouse and the roundhouses at Leeds, these also formed part of a repair and stabling depot, the associated locomotive erecting and repair shops also surviving (also Grade II*). The workshops and roundhouse fell out of use in 1987 and have now been converted to industrial units. The turntable and (undesignated) c.1877 three-road straight shed to the north remain in railway use.

Whilst the annular and semi-annular types were capable of almost limitless expansion, as demonstrated by the perpetuation of the type abroad, the British railway companies that stayed loyal to the roundhouse concept generally abandoned the circular and semi-circular forms completely in the 1870s and 1880s, developing the uniquely British phenomenon of the square roundhouse. These have a central turntable and radiating stalls, but these are laid out within a large, square covered space. The type appears to have been developed by the Midland Railway in the late 1860s, closely followed by the North Eastern Railway. The type was very widely used by both companies, who both appreciated that two, three or four such units could be joined together to produce very large sheds, with interconnecting roads that would enable most locomotives to enter or exit the shed even if one turntable was disabled. The advantages were such that the Great Western Railway, which had hardly used the roundhouse type since the late 1830s, belatedly adopted the type at the close of the 19th

Century, G.J. Churchward using it for its ultra-modern city depots at Cardiff (Canton) (1 turntable, opened 1897), Plymouth (Laira) (1 turntable, opened 1901), London (Old Oak Common) (4 turntables, opened 1905), Birmingham (Tyseley) (2 turntables, opened 1908,) and Bristol (St Philip's Marsh) (2 turntables, opened 1910). Most of the large square roundhouses built remained in use until the end of steam in the 1960s, with a number of the earlier examples having been updated and re-roofed in the 1950s. Despite widespread losses, several survive in non-railway uses. The sole designated example is the Barrow Hill roundhouse, Staveley, Chesterfield (c.1870s by the Midland Railway for the Staveley Coal and Iron Company). Despite having been re-roofed for use as a diesel depot, the building was listed in 1991 as the last operational roundhouse in Britain and the last to remain a turntable and almost complete complement of associated ancillary buildings.

The roundhouse type was thus much longer lasting that the side stall type, with conical-roofed roundhouses and annular and semi-annular examples being built in Britain from the late 1830s and mid 1840s through to the 1870s, after which time the square roundhouse type became popular with some British railway companies into the early part of the 20th Century. A number of these were given an additional lease of life through modernisation and re-roofing in the 1950s and 1960s. Whilst the square roundhouse seems to have been a uniquely British phenomenon, the conical-roofed and annular / semi-annular types spread around the world to have a substantial global influence. British examples, particularly early ones, are thus of more than national importance.

Whilst probably more than a hundred roundhouses (probably many more) survive around the world, only five conical-roofed, annular or semi-annular examples are known to survive in Britain. Examples from the 1850s, 1860s and 1870s by the railway companies that historically built the greatest number (e.g. the London Brighton & South Coast Railway, South Eastern Railway, Midland Railway and North Eastern Railway) are notable for the totality of loss. Given the highly distinctive plan-form of these buildings, easily recognisable from maps and aerial photographs, it seems implausible that any further substantially complete examples will be found in England, but even fragmentary survivals may still be important.

Square roundhouses have tended to be more easily overlooked, partly because they are of later date, partly because they are less easily recognised because of their square or rectangular plan-forms, partly because they were generally built to standardised, company designs and partly because a number were updated and re-roofed in the 1950s and 1960s. They also tended to be built in clusters at the largest and most important depots and it may be that the large size of such groups has been a deterrent to designation, notwithstanding that these large buildings are easily adapted to other uses. The future of one of the best and most modern depots, the large York North shed (largely rebuilt in 1952 with an impressive arched concrete northlight roof following wartime Baedecker damage) seemed assured after it became the National Railway Museum in 1975. Unfortunately structural problems with the post-war reinforced concrete roof subsequently led to the almost complete demolition of both of the two surviving roundhouses. Only the 1954-bult straight shed (which itself replaced two further roundhouses) now survives, used by the museum for storage and restoration purposes. As a building type, the square roundhouse was evolved relatively late and thus had less international influence than the conical-roofed, annular and semi-annular types. It was nevertheless popular with three major UK railway companies and only one (re-roofed) example by only one of these companies is designated. Protection of further examples is both possible and desirable.

Straight shed type

The term locomotive 'shed' implies a relatively simple structure. Indeed, the longest-lasting form was indeed a simple rectangular building with one or more parallel tracks entering through the one end. Referred to as the straight shed, it remains unclear when the form evolved, although it seems likely that it emerged with the earliest steam locomotives, probably in Leeds or in the North East, some time prior to 1825. No very early examples are known to exist and graphic representations of very early engine sheds are similarly scarce. What had been thought to be the earliest surviving example, the Soho Engine Shed of c.1833 at the former Hackworth locomotive works at Shildon, is now though to have been built as a warehouse, only adapted to straight shed form after 1855, when Hackworth's works was acquired by the Stockton & Darlington Railway to supplement their own locomotive works at North Road, Darlington. During this period the building was used mainly as a paint shop. The building is nevertheless of historical interest as the most important surviving fragment of Timothy Hackworth's Soho Engine Works, opened in 1825.

Map evidence nevertheless shows the straight shed form to have become the default option for small and medium-sized locomotive sheds by the early 1840s. Like the side-stall type and the roundhouse type, the straight shed form was also used for railway workshop, notable examples including the original London & Brighton Railway works at Horley (1838-40 probably by J.U. Rastrick and / or D. Mocatta, Grade II) and the Shrewsbury & Chester railway works at Shrewsbury (1847-8, H. Robertson and T.M. Penson of Chester, undesignated). From the mature form of recorded or extant examples built in the later 1840s, it seems that the type had probably become well established by the end of the previous decade.

Between 1850 and 1900 the gradually coalescing railway companies slowly evolved various standardised designs of straight shed, classically with panelled exterior brickwork and longitudinal or transverse ridge-and-furrow roofs. Whilst the Midland Railway and North Eastern Railway maintained a preference for the roundhouse arrangement for larger depots well into the 20th Century, other large concerns (notably the London & North Western Railway and Lancashire & Yorkshire Railway) built only straight sheds after the 1850s. During this period many concerns evolved their own ranges of individual standardised designs, some preferring longitudinal roofs and others opting for transverse ridge-and-furrow roofs. Very few sheds of this period are designated. The heritage movement had appeared to have ensured the preservation of an exceptionally complete late-19th-century, 6-road, timber-roofed Lancashire & Yorkshire Railway straight shed at Southport and a c.1900 single-road Great Central Railway straight shed at Dinting. Both were outstanding representatives of standard company designs of the period. Neither were designated and the vulnerability of such buildings is apparent from the decision by the Southport enthusiasts to sell their site to a supermarket chain for redevelopment. The Dinting shed remains extant, but is derelict and very much at risk.

Apart from the Great Western Railway, who had a brief conversion to the square roundhouse in the Edwardian period under G.J. Churchward, the straight-shed design type became dominant for large depots from the turn of the 20th Century, remaining so through to the end of steam traction in Britain the 1960s and continuing into the design of subsequent diesel depots. During this latter period, steel- and concrete framing and asbestos cladding came increasingly to the fore. Two outstanding complexes that were preserved by the heritage sector almost as soon as they were no longer needed by the nationalised railway currently represent straight-shed depots of this era. These are the 1930s, steel-framed, Great Western Railway four-road shed, lifting shed and coaling stage / water tower at Didcot and the 1940s, concrete-framed, London Midland & Scottish Railway 6-road six-road shed, repair shop, water tower, coaling stage and ash plant at Carnforth. Both were subsequently listed, Carnforth in 1990 and Didcot in 2000. With these two notable exceptions, no very large engine sheds, or subsequent diesel depots, are designated.

Associated Structures

The structures most commonly associated with engine sheds are those associated with coaling and watering steam engines. Provision also needed to be made for manual oiling and inspection under the locomotive and for replenishing an engine's sandboxes with dry sand for adhesion in slippery conditions. Some provision was made for light or heavy maintenance. Depending on how important a shed was, this might be a no more than an inspection pit and possibly some shear legs, but at larger sheds it might be a separate fitters shop or even a substantial repair shop capably of all but the heaviest of repairs. A manager's office and clocking-on facilities for staff would be provided at all but the smallest sheds. Ash-handling facilities were not mechanised until the 1930s, generally only on the LNER and LMS systems. From this time onwards, welfare facilities, including toilet, canteen, staff lockers and overnight sleeping facilities might also be provided. Such facilities, where they survive, would be important and rare survivals, either in isolation or (particularly) where they survive in association with extant engine sheds. The survival of such associated facilities was a substantial contributor to the designation in 1991 of the re-roofed Barrow Hill shed at Staveley.

Structures associated with locomotive coaling, watering and sanding have survived very poorly. As such, they are important and rare survivals, either in isolation or (particularly) where they survive in association with extant engine sheds. The survival of such associated facilities was a substantial contributor to the designation of the sites at Carnforth (1990), Didcot (2000) and Barrow Hill (1991). The LNER mechanical coaling plant at Immingham docks has been suggested for designation previously and would appear to be a strong candidate. Structures associated with administration and staff welfare survived slightly more widely than steam plant when dieselisation occurred, although no such facilities have been designated to date.

21 WATER TOWERS AND WATER CRANES

Introduction

A reliable means of filling or re-filling the boiler of a steam locomotive is an essential pre-requisite of an efficient steam railway. Whilst latterly water troughs were developed for replenishing locomotive water tanks with the train in motion, static water cranes and water towers were an essential component of railway infrastructure from the earliest days through to the end on main-line steam in 1968. Even today, the spectacle of watching a locomotive taking on water is very much part of the theatre of the modern heritage steam railway.

Whilst Trevithick appears to have mounted a pump on his 1804 Penydarren locomotive and supplied it with cold water from an on-board tank, recent research has indicated that most, if not all other early railway locomotives were supplied with near-boiling water from line-side ‘kettles’. This applied both to early locomotives that had feedwater pumps and those that did not and which were required to de-pressurise the boiler in order to refill it. The line-side steam kettle is little understood currently, but its use was regarded as normal practiced in both Wood and Tredgold’s treatises (both published 1825), whilst Wishaw (1842) discusses its use on the Liverpool & Manchester Railway (1830) and the London & Birmingham Railway (1838). The line-side kettle then passes from view, although the filling of tenders with boiling water by the ‘narrow-gauge’ competitors during the ‘Gauge Trials’ of 1844 as a means of improving performance caused significant controversy during and after the trials.lxxxvi The practice was revived much later with superheated high-pressure water on some industrial sites where ‘fireless’ steam locomotives were required because of fire risks.

Whether or not hot water was used, the form of water crane and larger water tower was established at an early date, at least by 1830. Recognisable water towers with rectangular tanks and cast iron water cranes are part of the early iconography of the Liverpool & Manchester Railway. The additional complication of feedwater heating may explains previously unexplained features of some of these iconic early railway images. Thus Ackerman’s 1833 version of Bury’s 1831 illustration ‘Taking Water at Parkside’ differs from the Bury original in showing a massive chimney stack annexed to the line-side water towers and water cranes. Slightly later the only known illustration of Robert Stephenson’s 1838 Curzon Street engine shed shows two huge chimneys emerging through the water tank over the shed entrance. Contemporary views of Watford and Berkhamstead stations show water towers and water cranes, together with what would appear to be unnecessarily massive pumping stations for their provision. It is tempting to think that pump houses were also used for the pre-heating of the locomotive feedwater. Thereafter railway water towers and water cranes appear to become so unremarkable and so ubiquitous that they largely disappear from railway iconography prior to the development of photography.

RPS

Ordinary Freestanding Station Water Towers

Freestanding station water towers are as old as railways and usually comprise a stone or brick base with a rectangular iron tank on top. They are often mounted on the passenger platform. The may be fed by piped gravity supply or may have a pump in the base, raising water from a well. Some low-cost railways made use of conveniently-placed streams feeding the water tower via a launder, but such unreliable sources of water were normally shunned on all but the most minor or railways. In order to blend with the station architecture early examples had relatively elaborate bases, sometimes with well-worked Classical detailing. Some later examples had gothic detailing, but generally simple panelled stonework or brickwork sufficed. With cast iron tanks the individual panels could have additional decorative detail applied. The appearance of such water towers varied through time and between individual architects, engineers and railway companies. It was realised by at least 1850 (Oxford Rewley Road station) that the tank could be mounted on an openwork base of cast iron, although examples remained rare until the early 20th Century when steel stanchions were introduced. Tanks were initially of bolted cast iron panels. Latterly panels tended to be of riveted rolled wrought iron or steel sheet, internally braced with rolled angles, although some companies, notably the Midland Railway and North Eastern Railway remained loyal to cast iron. Station water towers were often removed rapidly following the end of steam. Those that remain are of intrinsic interest on account of their variety of detailing and materials. Those that survive with other historic station buildings are of invariably of high group value. Surviving evidence of the method of water supply in usually important, particularly if by internal pump or external launder.

Integral Station Water Towers

It was realised early on that station water towers could be disguised or concealed in the main fabric of the station building. At Cheltenham Spa station (1840, S.W. Danks for the Birmingham & Gloucester Railway) the water tank was concealed within a massive Doric colonnade over the station entrance, whilst at Cannon Street in London (1866) Sir John Hawshaw concealed the station water towers within the tall Baroque towers at the river end of the (now removed) overall roof. More such integral water towers may exist than is currently realised, but they were inflexible and offered little scope for enlargement. They appear to have been something of a passing fashion which currently appears to have come to an end in the 1860s. Such water towers are not well understood and any examples are likely to be significant.

Large Station Water Towers

Large and complex railway stations clearly had greater requirements for water supply than smaller ones. This was not just for replenishing locomotives, but also for the purposes of the station itself and any attendant goods facilities, particularly if they involved a hydraulic power supply for capstans, hoists and cranes. As a result, very large water towers increasing came to be an important element of large station complexes from the 1860s onwards. Even where a piped mains water supply was available, railway companies seem to have preferred an independent supply and all known examples have evidence of an integral pump house in the tower base, drawing water from a well beneath. The remaining examples are monumental structures, generally of high group value. Surviving evidence of water supply (pumps, chimneys, etc) is usually important.

Water Towers at Engine Sheds

A reliable water supply is clearly important anywhere that railway locomotives are stabled or serviced. Water towers at engine sheds might be integral with the engine shed itself, might be a free-standing structure or might be combined with the coaling stage. Larger sheds normally had larger water towers. It is known that the early engine sheds at Coventry and Birmingham Curzon Street had integral water towers and this seems to have been the early pattern. In most early large sheds the water tank was placed over the shed entrance, so as to form something of a triumphal arch. Inverness, demolished in the 1960s, was latterly the best known example. Elsewhere the tank might be a large roof-top tank, such as that surviving still at Peterborough (1846-8). Generally from around the 1850s it was found expedient to separate the water tower from the shed. Smaller sheds might have a water tower similar to those found at smaller stations, whilst very large sheds could have very large water towers indeed, normally mounted on or adjacent to the coaling stage. Water towers that survive in association with a surviving engine sheds or other associated buildings would clearly have high group value. These that survive in isolation will need to be judged on their merits.

Water Towers at Railway Workshops

A plentiful and reliable source of water was essential not just for the running of a railway works, but for any associated settlement also. These were initially integral or roof-mounted tanks in the manner of contemporary mills and factories (e,g Braithwaite's Romford Factory (1843-7, for the Eastern Counties Railway)), but as demand grew, very large free-standing masonry water towers were constructed, one of the earliest being at Ashford (c.1850, Samuel Beazley, for the South Eastern Railway, undesignated). Such water towers tend towards the monumental and where they survive they are usually major urban landmarks. They clearly have group value where either the railway works buildings or associated workers' housing survives.

Water Cranes

Whilst it was certainly not unknown for locomotives to replenish their water supplies direct from a water tower, it was far more conveniently done via a fixed or rotating free-standing water crane with a flexible hose or 'bag'. Water cranes could be supplied by a railway water tower, a reservoir or by other means. Water cranes could be located singly, but might equally be provided in multiple, such as at a larger engine shed or at the end of each platform at a station. They might be platform mounted or ground-mounted. Fixed or portable Braziers ('fire devils') were provided beneath to prevent freezing in winter. Early water cranes were little more than a collection of flanged pipes bolted together, but most railways soon either purchased catalogue designs from external suppliers or developed their own distinctive designs. Some companies adopted designs with attached lanterns. Towards the turn of the 20th Century some companies adopted 'balloon' designs which placed a large drum-like water tank on top of a free-standing water crane. These had the advantage that they could be supplied from a low-volume water supply, such as a town 'mains' supply. Water cranes were removed from the national network with almost indecent haste as soon as main-line steam was ended. Many of those that remained, either through serendipity or other purposes such as for filling the toilet water tanks in railway carriages or the steam-heating boilers aboard diesel locomotives, have been subsequently removed to heritage railways. Any that do survive are of clear heritage value, whether for reuse in another heritage context (isolated examples) or for the significant group value they have in combination with other heritage assets.

22 OTHER RAILWAY STRUCTURES (EXCEPTING GOODS SHEDS AND SIGNAL BOXES)

Carriage sheds

Carriage sheds are used both for the storage of railway carriages and to provide sheltered accommodation for their routine maintenance, cleaning.

Other than the very smallest railways, no company has ever provided undercover accommodation for all its carriage stock. Nevertheless, some sheltered accommodation for carriages will always have been necessary, particularly with timber-, and latterly, or steel-bodied rolling stock.

The earliest carriage sheds would appear to have been lightweight, open-sided or half-sided timber sheds and some carriage sheds of this type persisted into the 1960s in some quieter backwaters. A good surviving example (albeit latterly substantially walled in) is the former carriage shed at the outstanding Liverpool Road complex, Manchester (1830, George Stephenson for the Liverpool & Manchester Railway, Grade I). The need for multiple undercover carriage sidings at terminal stations was nevertheless a key driver in the development of the train shed roof for terminal stations (e.g. Crown Street, Liverpool and Selby Old Station) and subsequently for the development of wide-span metal train shed roofs. All of the best known overall roofs (e.g. Derby, Newcastle Central, Paddington, St Pancras) originally spanned many carriage sidings and few platforms.

As traffic grew, space within train sheds was increasingly at a premium and from about the 1860s most railways constructed long gabled carriage sheds spanning multiple parallel carriage sidings near termini and in outer suburban locations. Initially still often of timber, such buildings were increasingly built with blind walls of panelled brick and glazed lightweight metal roofs. By about 1900 some very large carriage sheds were being built with transverse ridge and furrow glazed roofs. By the 1930s such buildings were generally being constructed with full steel frames and lightweight walls of corrugated asbestos.

The key changes to the organisation and layout of carriage sheds was brought about as dedicated sheds were built to accommodate the first electric suburban trains in the early years of the 20^{th} Century. The carriage sheds (sometimes called ‘car sheds’ due to American influence) built around this time tended to be particularly well built, partly because of the additional cost and mechanical complication of the new electric trains, but also because mechanical and electrical maintenance facilities were now required. From the 1920s two distinct strands of electric carriage shed emerged, with the main line railways opting for purely functional steel-framed carriage sheds, whilst the London Underground companies, notably London Transport from 1933, tended to opt for more substantial structures with more modernist external expression. In the 1950s and 1960s main line electrification and dieselisation saw a sharp decline a conventional carriage numbers and a number of conventional carriage sheds were modified as storage and maintenance facilities for diesel and electric multiple units. Recently the traditional carriage shed has been in steep decline. Modern aluminium carriages do not require undercover accommodation, whilst modern contracts for the procurement of complete diesel or trains often include the provision of bespoke buildings for their maintenance. The high value of land, particularly urban land, is also placing pressure on the remaining carriage (or car) sheds. The Wood Lane depot built 1900 for the Central London Railway has recently been demolished for a new shopping centre, whilst the contemporary car sheds at the Lillie Bridge depot are under threat from the redevelopment of Earls Court and a proposal to re-site Chelsea's football stadium on the site.

Large goods yard screen walls, goods offices and gates

From the birth of the main line railway, urban railway goods depots have represented sizeable investments, requiring large tracts of land and substantial, specialised buildings and structures such as goods sheds, warehouses, coal drops and transit sheds. Because of the volume of cargo handled, railway goods depots were as much at the forefront of mechanised goods handling as the docks, particularly with regard to the use of hydraulic power. They were active 24 hours a day and were often amongst the first places in many towns to utilise electric arc lighting. They employed hundreds of porters and clerks to load and unload wagons and to ensure that consignments large and small were logged, paid for, dispatched and paid for.

Such sites, often located in close proximity to the corresponding passenger stations, had a substantial landscape presence. The investment in buildings and land was normally at least equal to the corresponding passenger station, as the traffic volumes and receipts were normally of a similar order of magnitude. The buildings and structures within the goods yard were normally of a scale and architectural vernacular similar to that of contemporary buildings in large docks. As with docks, railway goods yards in urban locations usually required substantial enclosing walls, both to prevent pilferage and to convey to customers that their goods were in safe hands. In a competitive market, and with goods yards (unlike docks) often being in relatively central locations and in public view, the enclosing gates and walls, and the public goods offices, there was an opportunity for the railway companies to make architectural gestures, particularly at the interface between the goods yard and the outside world that would have been largely futile in docks. Sometimes such gestures were aided by pre-existing buildings, for example where an obsolete passenger terminus was converted to a goods station (e.g. Bricklayer's Arms and Bishopsgate goods yards in London and Carrington Street in Nottingham), but pains were generally also taken to ensure that purpose-built urban goods depots had a positive external expression.

Large urban goods yards tended to benefit from continued investment well into the inter-war period. Such investment tended to decline after the Second World War as traffic was slowly lost. Nationalisation also allowed the rationalisation of duplicate freight facilities in many towns and cities. The recommendation of the 1963 Beeching Report that British Railways should move away from wagon-load freight to containerisation and block trains had a dramatic effect on freight infrastructure, although a number of sites were passed to the publically-owned National Freight Carriers (National Carriers Limited or NCL), formed in 1968 to allow British

Rail to transfer the loss-making less-than-wagon-load traffic to a company that could use road or rail transport. The NFC worked in collaboration with British Rail until the railways withdrew from parcels traffic in 1981.

From 1963 the pattern was of sharp decline, disposal and demolition. Unlike the corresponding passenger stations, goods depots tended to be overlooked for designation. Only two historic, substantially complete, large urban goods depots survive in England with multiple designated buildings. These are at Liverpool Road, Manchester (now the Museum of Science and Industry) and Kings Cross (now Kings Cross Central regeneration zone). Bothe sites of more than national historic importance. Generally survivals of major urban historic railway goods depots are nevertheless far rarer than that of the corresponding passenger facilities. What does survive tends to be fragmentary, although some single buildings of great significance do survive (e.g. the former Carrington Street goods station, Nottingham (1875, for the Midland Railway) or the massive, multi-storey Deansgate Goods Station, Manchester (1899, for the Great Northern Railway)). Such remains are highly significant because of how they bear witness to a time when everything, from block coal trains to single parcels were carried by train. They are the more important where the remains may be seen and appreciated in conjunction with corresponding passenger stations (e.g. goods depot buildings at Newcastle Central) or even where the remains are now relatively fragmentary (e.g. the Pancras Arches (1898, for the Midland Railway) and former goods offices at Manchester Piccadilly station (c.1855, for the London & North Western Railway), both now only façades).

Coal and Lime Drops

A coal drop or lime drop is an elevated railway track track designed to allow coal or lime to fall freely between the rails onto the ground beneath, or into waiting carts. It was historically also referred to as a staithe, although today staithe is more commonly used to denote a coal drop used for discharging into a vessel or ship. Coal drops and lime drops are almost certainly as old as railways themselves, the traditional chaldron wagons of early wooden railways in the area having no doors for side discharge.

Because of the disconnected nature of the developing main-line railway network in the 1830s and 40s, most railway-builders chose to adopt side-discharge wagons for bulky goods. In the North East, tradition and the huge number of existing chaldron wagons in service forced the main-line railway builders to provide drops anywhere that bulky cargoes needed discharging. Hopper wagons and open drops for coal and covered drops for lime thus became a regional speciality and remained so through to the end of wagon-load traffic in recent times.

Drops had the disadvantage that soft coal tended to break into smaller and less valuable pieces. They had the corresponding advantage that they were an extremely efficient way of unloading large amounts of coal very quickly and with minimum manual handling. From the 1850s onwards, coal drops were thus provided at very large industrial and population centres, even by railways conveying coal from areas with no tradition of chaldron use. Vast semi-mechanised coal drops were thus provided at locations such as King’s Cross and St Pancras to rapidly empty block coal trains from the Derbyshire and South Nottinghamshire coalfields.

Since the 1960s bottom discharge has once again become the norm and modern railway wagons for coal, iron ore and limestone once again only have bottom openings.

Drops are thus important, both as a regionally distinctive element of a traditional station or goods yard, but also as artefacts that tell a story about the evolution of wagon design and freight handling.

Railway Stables, Provender Stores, Horse Hospitals etc

Horses were inseparable from railways from the earliest horse railways through to 1967, when the last shunting horses at Newmarket goods yard were finally pensioned off. Like canals, most early railways and tramroads operated on a toll system, where the horses used for haulage tended to be owned by private operators. There are numerous known examples of stables being located adjacent to these early railways, indicating that at least some of these operators kept horses especially for their railway haulage duties.

The advent of steam railways did not spell the end of the railway horse. The Whitby & Pickering Railway (opened 1836) was built for house traction and remained so until 1845. Several early branch railways were initially operated by horse, and in some cases the horse was substituted for steam where traffic proved inadequate. Such branches served Tewkesbury, Ilkeston, Weston Super Mare and St Ives. Port Carlisle was served by the last horse-worked railway passenger service in England, ending in 1914.

Railway-owned horses were extensively used for shunting wagons in goods yards as they were easily moved from one siding to another and could be attended by only one man and were available at all times for immediately use. At the Grouping of 1923 1,123 shunting horses came into the ownership of the 'Big Four' railway companies. 238 were still in use at Nationalisation in 1948 and the last stopped work as late as 1967.[lxxxvii] The railways also used horses for local omnibus services (generally phased out or replaced with busses in the early 1920s) and for 'internal' uses such as working in railway-owned ballast quarries.

Steam railways appear to have initially relied on external hauliers for deliveries of goods and parcels, but soon found it profitable and economical to take such work in-house anywhere where there was enough trade to cover expenses. The railways' share of national traffic was such that they came to be the largest owners of horses in the country and, despite inroads by early delivery lorries (of which the railways were also the largest operators), in 1914 the 11 largest railway companies were still using nearly 26,000 of their own horses.[lxxxviii] Many of these were requisitioned during the First World War, but despite an influx of cheap war-surplus lorries post-war, in 1923 the 'Big Four' companies inherited a total of 32,327 horses, by far the majority of which were used for local deliveries. In turn, in 1948 British Railways inherited 8,793 railway horses and 24,095 carts and drays.[lxxxix]

The railway stable was thus an almost ubiquitous feature of the railways well into the 1950s. Almost any goods yard of consequence had one, whilst in metropolitan areas railway stables housing up to 300-400 horses were relatively common. To feed and maintain these huge numbers of horses, all but the smallest railway companies maintained large provender stores and many maintained dedicated horse hospitals.

Other Railway Goods Yard Features

Hydraulic power

Because of the volume of cargo handled, railway goods depots were as much at the forefront of mechanised goods handling as the docks, particularly with regard to the use of hydraulic power; the only practical centralised power source for heavy work prior to the advent of practical electric power. One of the very earliest applications of hydraulic power was at Brunel's Bristol Temple Meads goods shed, completed in 1842. The goods shed, accessed via small turntables, was 12 feet below rail level. As described by Bourne in 1846, to overcome this difference in height, Brunel provided a balanced hydraulic lift, with two platforms working together like a pair of scales, with wagons 'alternately raised and lowered by the exertion of water power obtained by the regular working of a small hydraulic machine'.[xc]

The acknowledged pioneer of hydraulic power was William Armstrong, who realised its potential as a multiplier of power. Armstrong successfully demonstrated the first successful hydraulic crane at Newcastle in 1845. Following his establishment of a company to build and market his cranes, one of the very first orders received by the firm was from the Edinburgh & Northern Railway. Armstrong's invention of the hydraulic accumulator in 1850-1 made relatively compact hydraulic power installations a reality for the first time. The first hydraulic swing bridge, built by Brunel at Gloucester for the Gloucester and Dean Forest Railway in 1852 utilised an early installation and similar power plans became an essential adjunct to moving element railway bridges thereafter (see Moving Element Bridges, above). A relatively early installation was at the Central railway station and goods station, Leeds (c.1854), where the sole surviving vestige of the goods station is a lift tower that was used to move wagons between the approach viaduct and a goods yard at ground level.

Hydraulic engine houses and accumulators were subsequently installed widely in railway workshops (for presses, etc.) and in major goods depots, in the latter powering wagon hoists (lifts), cranes, elevators, hoists, traversers and capstans for the mechanical shunting of wagons using cables. The hydraulic power could then be transmitted to other nearby facilities, notably larger railway stations, to power hydraulic goods lifts associated with footbridges and subways. When the Midland Grand Hotel at St Pancras was opened in 1873 it was the first privately owned building in Britain to have a hydraulic passenger elevator. It was powered by the same power source as a wagon hoist that lowered wagons of beer to sidings in the station's undercroft. Other railway hotels followed suit, for example the adjacent Great Northern Hotel, in 1880. Once mains electricity became available, the tendency was to retain hydraulic accumulators and equipment, with electricity being used instead of steam to power the necessary pumps.

Any substantial hydraulic accumulator tower and / or hydraulic engine house associated with a major railway station, moving element railway bridge or large goods yard is likely to be significant, as are any passenger lifts, bridges, goods lifts, wagon lifts, cranes or shunting capstans that they powered. Substantial hydraulic accumulator towers are often visually impressive and a number have been designated, notably those in large goods yards (e.g. at Derby (St Mary's) (c.1860), Middlesbrough (c.1870), Stockport (1877), Derby (Friargate) (1878), Stepney (1886) and Huddersfield (1885). Some are included in the designations of swing bridges also. There has nevertheless been a tendency to overlook hydraulic engine houses and hydraulic equipment. Some very large designated goods warehouses retain internal or external wagon hoists and other equipment, notably the five-storey New Warehouse at Huddersfield (1885, for the London & North Western and Lancashire & Yorkshire railways, Grade II) and the huge, multi-storey Deansgate Goods Station, Manchester (1899, for the Great Northern Railway, Grade II)). The hydraulic equipment that survives in the later is briefly mentioned in the statutory description, but at Huddersfield it is not mentioned at all, the external wagon being described as a loading bay. Any surviving hydraulic goods lifts at stations are highly vulnerable to station and accessability upgrades. An Edwardian hydraulic passenger lift at Bath Spa station has recently been restored as part of a station upgrade.

Goods offices and coal offices at country stations

Goods offices at smaller stations were used for station staff to log and administer incoming or outgoing consignments of general merchandise. They could be attached to a goods shed or could be free-standing. They were often unexceptional buildings architecturally, although the best reflect the design of the goods shed they are attached to or the main station building. A coal office had a similar purpose, but were dedicated to the land-sale of coal. They might be built by a local coal merchant who leased siding space within a goods yard, or might be railway built and leased to the coal merchant instead. Again, they were often unexceptional buildings. Both small goods offices and coal offices are seldom significant in isolation, but they should not be overlooked for designation where they have group value with related assets, including stations.

Weighbridges and weigh houses

Railway weighbridges and weigh houses pre-date main-line railways, early examples generally being used to calculate the tolls payable by hauliers on horse-worked railways. With the advent of main-line railways the weighbridge became an essential component of the railway goods yard, allowing the goods clerk to calculate the weight of a consignment so that the consignor could be invoiced accordingly. They were also very useful for the land-sale of coal by any coal merchant(s) operating from the goods yard, although fees were payable. Non railway customers could use the weighbridge on payment of a higher fee. The weighbridge and weigh house was thus a ubiquitous feature of the railway goods yard from the earliest time through to the final demise of wagon-load freight traffic. Some endured even longer, in instances where coal merchants continued to trade from a railway goods yard, albeit receiving his coal deliveries by road. Weigh houses associated with horse-worked railways are of high inherent interest. Weigh houses on main-line railways are often unexceptional buildings architecturally, although the best again reflect the design of the associated railway station. Unless very early or of unusual architectural interest, they are seldom significant in isolation, but they should not be overlooked where they have group value with other related assets, including stations.

Loading gauges

A loading gauge was a simple, gallows-like structure with a suspended metal arc hung on chains. A loading gauge would be found at the entrance of any siding or goods yard where wagons were loaded. It was to make sure that any goods loaded into open top wagons did foul lineside structures such as bridges and tunnels. They disappeared from the railway system at the same time as wagon-load freight. They could be purchased from external suppliers or made in house, most larger railway companies having their own design. Earlier examples tended to have timber supports, resulting in routine replacement. Any surviving today are likely to be of later steel or reinforced concrete types. Whilst not normally of intrinsic interest, loading gauges are of interest where they survive as part of a wider group of associated designated (or designatable) structures.

Wagon turntables

Small turntables or turn plates were widely used for shunting wagons on early horse-worked railways. They may have been introduced in mines, where there was an obvious requirement for wagons to make sharper turns than could be accommodated by curves or points. They were widely used on early main line railways, both for wagons and for passenger carriages. Such turntables were an essential element of early main-line termini, where carriages had to be moved rapidly from the arrivals platform to the departure platform, or to carriage sidings in between. Whilst such small turntables became obsolete in passenger stations as carriages became longer, the wheelbase of ordinary freight wagons remained almost constant until the 1960s. Part of the reason for this was because of the very extensive use of such small turntables in goods yards, industrial premises and even in the ultra-modern multi-storey goods warehouses. These turntables were rapidly phased out with the winding down of wagon-load freight in the 1960s. It is unlikely that any visible examples now survive on the national railway network, although some may still survive buried beneath modern surfaces. Those that have come to light in recent years (some now removed to heritage venues) have survived on abandoned dockside sidings. Any survivors are likely to be at least 100 years old, most would be older. As they were once such a feature of both goods yards and, in the days of 4-wheeled carriages, railway stations also, they are of great historic significance.

Cattle docks and loading banks

One of the most revolutionary features of early main-line railways was the ability to rapidly move livestock to the growing industrial towns, there having been no alternative previously to the time-consuming and wasteful practice of moving animals ‘on the hoof’. The special trucks built for cattle and sheep thus feature prominently in the earliest images of the Liverpool & Manchester Railway and, to a lesser extent in early images of the London & Birmingham Railway. This development was most clearly manifested in the development of meat-trading centres the United States such as Chicago, but the importance here was such that all major livestock markets and major slaughterhouses became rail connected, Smithfield Market itself having a vast underground railway goods yard.

In railway parlance, a cattle dock is a dedicated goods platform used for loading or unloading livestock of any sort. The term is often applied to goods platforms used for other purposes, including the side loading / unloading of machinery and other bulky items (a loading bank) or for the end loading of specialised wagons and railway vans (an end-loading dock). A true cattle dock was normally equipped with fixed or moveable pens. Passenger stations also had specialised non-passenger platforms, for example parcels docks and milk docks. To handle private carriages and later motor cars, passenger stations sometimes had an end loading dock built behind one of the platforms, referred to as a 'carriage shoot'. Carriage shoots consisted of a short length of track running into a bay in the platform or along one side to a dead end.

Whilst seldom of inherent significance in isolation, such platforms are important where they have group value with related assets.

Gas houses and gas plant

Whilst lighting using coal gas had first been demonstrated in 1792 and horizontal retorts were invented in 1816 (both by William Murdoch), gas lighting was economically unviable away from the coalfields was navigable water until the advent of main line railways. Where gas for station and goods yard lighting was unavailable, most railways made use of oil lighting until such time as a mains supply became available. In a small number of rare instances, the more highly capitalised early main-line railways built their own small gas plants for station lighting. The best-known instances of such plant at smaller stations are on railways of the mid 1840s built under the control of George Hudson, who had a reputation for an unusual degree of liberality when it came to his shareholders' money. The discover of a comparable surviving plant at the former Arthington railway station (1876, for the North Eastern Railway, undesignated) implies that such small gas works may have been more common than is generally understood. Otherwise most railway station appear to have been first lit with gas as and when mains gas supplies became available. A number of more isolated railway stations retained gas or oil lighting into the 1960s. Most railways developed their own designs of more or less decorative cast iron lamp standards, which were used for both oil lamps and gas lamps. Some, latterly equipped for electric lighting, still survive on the national railway network.

The growing degree of self-sufficiency of the railway companies often led railways to build their own gas works, notably in the 'railway towns', to supply the railway works and associated streets of worker's housing. Such plants were generally similar to municipal gas works.

Oil lighting was first used in railway carriages in 1842. Tentative steps in the use of coal gas for carriage lighting were made in the 1860s, supplied either by larger bags in the guard's vans or from on-board gas generators. Pintsch's compressed oil gas lighting system was introduced from Germany for carriage lighting in the late 1870s, requiring the railways to build their own specialised gasification and compression plan at convenient centralised locations, the compressed gas then being moved around the system in purpose-built wagons.[xci] Despite the advent of improved electric carriage lighting towards the end of the 19th Century, oil-gas carriage lighting was still common in the 1930s and a few gas-lit coaches still survived on remote outposts of British Railways until the early 1960s. The associated plan was thereafter redundant and tended to be removed quickly. No examples are known to survive.

Transfer shed

A particularly rare goods building type is the transfer shed, used at 'breaks of gauge' for the trans-shipment of goods between broad gauge and standard gauge wagons. The use is normally apparent from the absence of doorways in the sides and the different sizes of the end archways for the different-sized trains. Trans-shipment would have ceased in 1892 when the broad gauge was converted, but the transfer sheds were easily converted to goods sheds or transit sheds.

Such buildings are of considerable historic interest, coming at the break of gauge between the two systems, providing evidence of an important episode in British transport history. As a result all three known examples are already listed, one of them a relatively basic timber-built shed of little architectural merit. Any further examples would almost certainly merit designation, even if altered, subject to the original function remaining discernible.

Transit sheds

The open-sided or semi-enclosed transit shed is a dockside building type reflecting the introduction of main-line railways into canal and coastal docks. Allowing the direct transfer of cargoes between train and ships or barges, they marked a revolution in cargo handling as fundamental as containerisation more than a century later. The building type has unfortunately been decimated since the 1960s and only two examples directly associated with railways have been noted. Due to rarity and historic importance, almost any surviving example of any date and any material is likely to be worthy of consideration for designation.

Railway cuttings and embankments

Early horse railways tended to be built with steep gradients and sharp curves in order to keep expenditure to a minimum. In common with contemporary canal engineering, 'hybrid railways' from the late 18th Century through to the 1840s were often more ambitious in their engineering, steep-sided, stone reveted embankments in particular being one of the hallmarks of this type of transitional railway type.

The requirements of main-line railways for straight and level formations resulted in cuttings and embankments of a quite different scale. Generally the new cuttings and embankments, however magnificent, were functional, earthwork structures whose exact appearance and steepness depended wholly on the specifics of the local geology.

In some locations, where the local terrain was particularly steep, where land prices were high, or where good taste demanded something of more distinction, fine stone retaining walls were provided. Such structures continued to be built into the early years of the 20th Century where good quality stone was available and many structures of high landscape or townscape value remain, both on and off the current operational railway network.

Atmospheric Railway Engine Houses

The atmospheric railway was a phenomenon of the 1830s and 1840. It used the difference between atmospheric air pressure and a partial vacuum to provide power for railway propulsion. The principle, as patented by Jacob and Joseph Samuda in 1838 and 1844, used a large cast iron pipe between the rails with ran a piston suspended on a bracket beneath a power car (or *'piston carriage'*). The large pipe between the rails made crossings and rail intersections problematic, but the downfall of the system was the necessity for a continuous longitudinal slot along the top of the traction pipe, sealed with a continuous leather flap, to allow the piston to be physically connected to the piston carriage and thence to the rest of the train.

At the time, the supremacy of the steam railway was still far from assured, due in part to primitive steam locomotive's perceived inability to climb gradients over 1 in 100 without slipping, or even at all. It was thus far from certain whether main line steam railways could ever be economically constructed in hillier areas and thus become a national network. With the atmospheric system the stationary power source could be of enormous power. Adhesion between wheel and rail was also not a problem and because the train was anchored to the rails by the piston, trains could not fall over going round curves. The lack of a locomotive meant the engineering structures could be of lightweight construction. The atmospheric system thus promised railways that were fast, silent, smoke free and unrestricted by steep hills or sharp curves. The first full-scale demonstration of the Samuda system was in 1840, on a short length of the West London Railway. The last railway to utilise the system was the Paris – St Germain railway (1.5km, between Pecq, - St Germain, opened 1847), who finally abandoned it in 1859.

The system was used commercially three times in the United Kingdom. The first two were on relatively short railways, first between Kingstown and Dalkey, near Dublin (about 2 miles) (J & J Samuda, for the Dublin & Kingstown Railway, operational 1843-1854) and between Dartmouth Arms and Croydon (about five miles) (William Cubitt, for the London & Croydon Railway, operational 1846-7). The most ambitious application was Brunel's, who approved the system for the entire South Devon Railway, between Exeter and Plymouth, and its branch to Torquay. Whereas the Dalkey and St Germain railways had employed two pumping stations and the London & Croydon had three, the South Devon main line would require over 20. In the event atmospheric trains only ever ran between Exeter and Newton Abbot and then only from 1847 to 1848.

Whilst the engineering structures were lightweight, the engine houses on the London & Croydon and South Devon Railways were of heroic proportions. For the London & Croydon Railway, large gothic engine houses with tall spires for chimney stacks were provided at Dartmouth Arms, Jolly Sailor and Croydon (later West Croydon) by W.H. Brakespear. For the South Devon railway, Brunel completed eleven engine houses before the experiment was abandoned. These were Italianate, with tall chimneys resembling campaniles.

Whilst generally considered a heroic failure, the atmospheric railway prefigured the electric railways of the 20th Century in using a centralised stationary power source for locomotion. The system was certainly capable of producing rapid acceleration and high speeds on the level (regularly over 60 mph on test) and high power for freight haulage and hill climbing. Its technical problems, most particularly the vulnerability of the continuous leather flap to rats and the weather, were never satisfactorily overcome. By the later 1840s advances in locomotive construction and power output had made the system obsolete. Substantive remains are considered to be of great historic and technological significance.

Rope Haulage: Railway Incline, Railway Inclined Plane, Winding House (incline) and Steam Engine House)

Rope haulage is the practice used for moving wheeled loads using a rope or iron or steel cable. It almost certainly made its first appearance underground, on the early wooden 'guided ways' in the mines of Germany and Transylvania, perhaps as early as the later 16th Century. The railed, self-acting inclined plane, where loaded, descending wagons on one line haul empty wagon up a parallel or interlaced track, may have made its first appearance above ground at Brosley, Shropshire, as early as 1609 (described as 'tilting rails'), although the first unambiguous instance is currently a short branch railway built at Combe Down, Bath, built by Sir Ralph Allen in 1755. The self-acting incline is thought to have transferred to the coal-hauling railways Tyneside in 1797. Such inclines could only be used where descending loads were heavier than those ascending. Mechanical power was required where ascending trains were heavier than those descending or where loads were unpredictable, for example on public railways. Whilst there were earlier examples of mechanically-powered railed inclines on the Shropshire tub-boat canal network, the earliest steam-powered railway incline appears to have been one built as part of the short-lived Urpeth Waggonway, opened between Chester-le-Street and Fatfield in 1805.[xcii] All of the coal railways of the North East that pioneered early locomotive traction made use of both self-acting inclines and steam-powered inclines, alongside locomotive haulage. Whilst many hundreds of self-acting inclines and numerous powered inclines were built on industrial railways and tramways, they are particularly iconic in the North East of England because of this relationship.

Rope haulage is essentially a characteristic feature of early wooden railways, horse tramroads and industrial railways. It is relevant to this study because one or more rope-worked sections were a feature of a number of the early transitional public railways ('hybrid railways'). These include the Stockton & Darlington Railway (1825), the Canterbury & Whitstable Railway (1830), the Cromford & High Peak Railway (1831), the Leicester & Swannington Railway (1832), the Stanhope & Tyne Rail Road (1834) and the Whitby & Pickering Railway (1835). When the Whitby & Pickering Railway was converted into a conventional steam railway in 1846-7, steam trains continued to be rope hauled over the Goathland incline until 1865, when a deviation line was constructed. Rope haulage continued in use on the Cromford & High Peak Railway (absorbed into the main line network in 1862), its Sheep Pasture incline having the distinction of being the last rope-worked incline on the national railway network when the line closed in 1967.

A number of early main line railways also made use of rope haulage. Indeed, rope haulage was very nearly the primary motive power employed for the entire Liverpool & Manchester Railway and the foundations for at least some of the series of engine houses that would have been needed were laid before the practicability of the high-speed steam locomotive was proven during the famous Rainhill Trials in October 1829. Generally rope-haulage on early main line railways was restricted to steep gradients into and out of city terminal stations.

Notable instances were the four steeply-graded Edge Hill tunnels in Liverpool (to Crown Street station, Wapping dock (goods), Lime Street station and Waterloo (goods) (rope-worked 1830-??, 1830-1896 and 1836-1870, 1849-1895 respectively), Camden Bank (into London Euston, cable-hauled 1838-1844) and on Cowlairs incline (into Glasgow Queen's Street, cable hauled from 1842-1909). Miles Platting bank, running down to Manchester Victoria (1844), was also laid out for rope haulage, but by this date locomotives were adequately powerful for the haulage engines to be left unfinished. Main-line rope haulage finally ended in the UK in 1909, when rope-haulage in the Cowlairs incline was finally abandoned.

These main-line applications universally made use of the most sophisticated form of rope haulage, using an intermittently-moving or continuously-moving endless rope, to which trains or vehicles could be attached or detached as required. Like the atmospheric system, in the 1830s and 1840s this system was seen as a promising alternative to locomotive haulage and was applied by Robert Stephenson to the entire London & Blackwall Railway and used from its opening in 1840 until the line was converted to conventional steam haulage in 1849. Prior to the adoption of electric power, haulage by endless rope was seen as providing a silent and smoke-free form of urban traction. It was applied to London's first 'tube' railway, the Tower Subway (1870), assorted street tramways in Highgate, Brixton, Edinburgh, Birmingham, Matlock and Douglas (1890s), the Glasgow Subway (from 1896 to 1935) and (without grippers) on the Great Orme Tramway (1902). Most famously, the system provided the motive power for the San Francisco cable tram system, which at its peak operated twenty-three routes, built between 1873 and 1890.

Railway Locomotives, Carriages and Wagons

Generally speaking railway vehicles fall outside of the scope of this survey, as wheeled vehicles are portable artefacts falling outside of the remit of English Heritage. Only one railway locomotive has ever been listed by English Heritage or its predecessors, this being *Invicata*, built by Robert Stephenson in 1829 for the Canterbury & Whitstable Railway and for many years a plinthed monument in a Canterbury park.

The reuse of redundant railway vehicles as buildings has a history probably almost as long as railway covered vehicles. A number were reused as grounded bodies by the railway companies themselves, as stores and mess rooms at stations, engine sheds and goods yards. Railway reuse was relatively simple, as bodies could be easily moved by rail to their new locations.

Redundant van and covered wagon bodies in particular have long been highly attractive to farmers for use as cheap, ready-made sheds, as they tend to be small, ruggedly constructed and relatively easily transported. The reuse of carriage bodies as buildings may have had a shorter history, although various discoveries of ancient broad-gauge carriage bodies (mostly in an advanced state of decay) indicates that carriage bodies have been sold off for reuse since at least the 1880s. Carriages tend to be longer than wagons and the widespread sale and reuse of railway carriage bodies seems to coincide with improvements in road transport (both surfacing and the use of steam traction engines) towards the end of the 19th Century.

The use of railway carriage bodies as cheap homes then continues through to 1930s. The practice seems to have declined post-war for a variety of reasons, not least stricter planning and building control and the greater availability of local authority housing. This brief period nevertheless saw many thousands of carriages, generally dating from the 1860s to 1890s, being sold on to prospective smallholders or for cheap holiday homes. Such carriage bodies were the initial staple of some sizeable planned communities, for example Peacehaven and Mabelthorpe, where speculators were offering plots on easy terms. By far the majority were subsequently replaced by more substantial and permanent homes, a process that continues to this day. A number have been acquired by heritage railways for preservation or canibalisation, either for re-mounting on a suitable underframe or as sheds and stores, but neglect and redevelopment results in the loss of historic vehicles every year, often without knowledge or record.

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