# A RESEARCH AGENDA FOR THE EARLY BRITISH RAILWAY

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## INTRODUCTION

Although the form and development of Early Railways in Britain is generally understood in outline, much of our current understanding can be revealed, upon closer examination, to be based either on received wisdom or on a small number of frequently quoted sources. Until recently, little organised research has taken place on this crucial aspect of transport history and technology. The standing committee of the International Early Railways Conference has canvassed available informed opinion to enable the production of the Research Agenda which follows. Although no claims are made that the document is comprehensive, it is hoped that the Agenda will help to identify further areas of useful study, and to inform archaeological investigation of the remains of sites of this date and type.

## SCOPE OF AGENDA

For the purposes of this Agenda, early railways are defined as lines which were pre-main-line in concept if not necessarily in date, excluding, for example, the Great Western Railway of 1838, which was clearly a 'main-line'. However, it is intended to include the many lines in industrial regions such as Wales, which for decades continued to be operated or built to pre-main-line patterns.

The basic technology of the railway appears to have been introduced into Great Britain sometime in the late 16th century. For centuries the typical railway was privately owned, carried only the owner's goods (most often coal) and was operated by horse, rope or hand. From about 1800 the public railway gradually emerged which, like a canal or turnpike road, could be used by persons or entities other than the owner, with users employing their own vehicles on payment of a toll; however, this might be regarded as a new form of organization, not of technology. Even after the development of steam traction in the early 19th century, locomotives were few, and passenger carriage was marginal.

In 1830 the Liverpool & Manchester Railway brought together, for the first time on a public railway, goods and passenger carriage in the company's own vehicles, exclusively mechanical traction, and a regular timetable, inaugurating what may be called the 'modern railway' or the 'main-line railway'. Although this marked the end of the initial stage of railway development, private and public railways of the earlier type continued to operate, persisting in some areas well into the 20th century.

## DEFINITIONS

The terms below are defined for the purposes of this Agenda:

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| *railway* | a prepared track which so guides the vehicles on it that they cannot leave the track |
| *waggonway* | a privately-owned railway without public access |
| *public railway* | a railway open to the use of the public on the payment of tolls |
| *iron railway* | railway using either plate or edge-rails of iron |
| *plateway* | iron railway using L-shaped rails and flangeless wheels |

## PHYSICAL EVIDENCE

Specific areas of archaeological potential are outlined in the following agenda. However, it should be assumed that the physical remains of all possible early railways are of potential significance. The evidence for pre-1830 waggonways is of particular interest, since this site-type is only patchily understood, and excavations and recording have often seen a strong regional bias.

Recent finds of a 16th century railway in Cumbria have introduced new factors in our understanding of the very first British railways and further information gained by landscape analysis or excavation may be of the greatest significance. The Cumbria finds certainly suggest that relevant sites dating from before the first recorded 'standard' railway in Britain (1603/4) should be closely examined for evidence of railways, and that such evidence is more likely to come from archaeological rather than archival sources.

(NB: All measured drawings and other measurements taken as part of archaeological recording on early railway sites should be scaled in imperial as well as metric measures)

## DOCUMENTARY EVIDENCE

It is becoming increasingly clear in the first years of the 21st century that even documentary sources which were previously considered to have been well-examined may contain information and images of great significance to an understanding of the development of early railways. Traditional sources and established archives should be re-examined in the light of the current agenda and of recent developments in this field of study.

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## THE CIVIL AND MECHANICAL ENGINEERING OF EARLY RAILWAYS

The physical remains of railways form a major part of British material culture. Features of the permanent way survive both as prominent landscape features and as buried remains. Objects of varying complexity, from minor components to complete engines, have pride of place in both regional and national museums. There is, however, little doubt that the very great majority of these remains relate to the main-line railway. Those from the early railway have seldom received the same level of interest or examination, although plentiful evidence exists in the form of track-beds, civil engineering in situ and items within public museums. These remains form a significant part of the resource base for an improved understanding of both the physical form and technical development of early railways.

### RUTWAYS

Rutways (rock-cut grooves which served as guides for sledges or wheeled carts) are one of the earliest forms of the railway, with examples known internationally from the Classical period. The categorisation of several of these examples as railways, rather than furrows formed by repeated usage or wheel guides on difficult sections of roads, has however been frequently controversial. Rutways discovered in Britain often have the same problems of classification. Evidence for deliberately-formed rutways in the British Isles requires identification and analysis. Information is also required on the waggon type which these lines were intended to serve, and on the performance characteristics of lines of this type.

At least one Roman mine on the Continent was known to use a railway in the form of stone-cut ruts. The possible use of this technology should be borne in mind during any survey or excavation of mines believed to be of Roman date. Localised rutways from the Industrial Period are known in Britain[1] and the presence of possible rutway forms should be carefully recorded. Particular care should be given to establishing whether measurements of depth, wear, construction marks and gauge are constant along the whole of the surviving length of the feature, as significant variation is a key factor in determining whether such ruts were formed deliberately as a railway or are the result of wear.

### WOODEN WAGGONWAYS

On the basis of the available documentary evidence, underground man-powered railways in metal mines are believed to have been introduced by German/Austrian miners to the Mines Royal in Cumbria in 1569. Documentary sources have now been confirmed by recent archaeological discoveries at Silver Gill, at the northern end of the Lake District.[2] The physical evidence suggests a simple railway of *leitnagel* form (the waggons guided by a projecting pin which slotted into a channel between plank-type rails) – a technology which is unquestionably of continental origin. Previously encountered evidence from the Mines Royal should be re-examined with a view to establishing the presence or absence

of railways of this type. Any remains observed in areas known to have been using imported European engineers should be subjected to similar analysis.

After their introduction in upland metal mines, the evolution of waggonways becomes more obscure. It initially appears to have involved the development of overground lines, with the technology not commonly used underground again until the 18th century. However, this premise requires further examination and confirmation, as the evidence base for this period is currently exceedingly small. The available evidence suggests the existence of waggonways, particularly in the West Midlands, in the late 16th century – this too requires examination and verification.

The first firm evidence of the British railway relates to that built for Huntington Beaumont in 1603 or 1604 to serve a pit near Nottingham. This is believed to have taken the form which subsequently became conventional to wooden waggonways in Britain: flanged wheels running on wooden edge-rails running on the surface, carrying coal, and horse-operated. However, the evidence for this is slim, and begs the question of what happened to the knowledge of the Mines Royal system. This apparent discontinuity should be closely examined and evidence sought both for the true form of the early 17th century waggonways and for the evolution or abandonment of the *leitnagel* system.

Further information on the earliest waggonways appears most likely to be obtained by archaeological excavation. It is essential that all known sites of the Mines Royal and other extractive sites up to the early 17th century should be carefully examined. Appraisal of the available evidence needs to recognise that the remains may not be obviously railway related (i.e. guide pegs, oddly-worn timber).

As far as is known, wooden edge-rails were the norm from the early 17th century until their replacement by iron rails (initially in the later 18th century, but typically from the start of the 19th century). However, there is no objective reason to suppose that the form, employment and operational use of the wooden waggonway remained consistent throughout the period 1600-1830. Further data-gathering and analysis is required to test the assumption of conformity with a developed technology. In addition, little is known about the performance characteristics of wooden rails. Areas which would particularly repay study include:

(a) frictional characteristics, especially as affected by the reputed tendency to dent;
(b) normal patterns of wear and tear, especially on joints and curves;
(c) degree of stability of the trackwork, particularly in terms of maintaining gauge;
(d) strength in carrying a moving unsprung load;
(e) the impact of atmospheric conditions (eg humidity, temperature, formation of ice or frost) on the above characteristics.

These aspects need to be considered both for the employment of horse-drawn waggons and for when the rails were used for early steam locomotives.

The impact of specific materials on the performance characteristics of both the individual rails and the more general permanent way also requires examination, for example the comparative performance of different woods and the possible emergence of an industry preference. Consideration of materials should also include the development of the form and function of track-bed, track and sleepers.

Waggonways of all dates, especially those founded before 1830, should be examined archaeologically; gauge, track and track-bed engineering features, support structures (such as loading/unloading points, weigh houses, stables) and components are all of significance. Wooden track may unexpectedly survive in areas where anaerobic conditions have been created (eg in water-logged sites; under later slag heaps). Adjacent landscapes need to be examined for related features, such as soaking ponds for waggon wheels. Evidence of check rails, points (switches) and turntables may be particularly valuable, as will marks of wear or damage. It is important to identify the type of timber and to note any evidence of fixings and iron or iron-staining.

Experimental work is necessary to establish the performance and characteristics of wooden waggonways. Ideally, this should take place in consultation with wood technologists and other appropriate materials scientists.

In some areas (such as north-east England) collieries constructed private roads for the carriage of coal (wainways), as an alternative to waggonways. Almost nothing is known of them. Evidence should be sought and analysed on construction (including costs), size and type of intended loads, and the performance characteristics, compared to waggonways of the period. It would be relevant to investigate whether other industries constructed private roadways for carrying freight at this period.

Any roadways of the 18th century or earlier that may have been purpose-built for private goods traffic alone should be subject to detailed archaeological examination.

## IRON RAILWAYS

Iron rails were developed in the later 18th century, with the metal used either as a running surface applied to wooden rails or as complete rails. Although the initial cost of the iron rail was substantially higher than wood, such rails were typically considered to have lower friction and maintenance costs, longer life and a substantial scrap value when worn out. Two principal forms emerged:

Iron *edge-rails* – projecting above the track-bed to engage with the flanged wheels of the waggon. Often used as direct replacements for wooden rails.

*Plate-rails* (plateway) – an original design of **L** section for unflanged wheels, which became popular soon after its development in the 1780s. From the mid-19th century the form was generally superseded overground by the edge-rail.

The advent of the iron rail saw generally rapid and complete replacement of wood as a rail material. By the early 19th century, virtually all new lines were of iron, and most wooden waggonways were being converted. Even today iron, in its various alloys, remains the most common rail type – a situation which makes the study of the history and development of iron rails particularly relevant.

The overall evolution of the iron edge-rail, from simple spiked cast-iron bar to chaired wrought-iron fish-belly, is thought to be broadly understood. Plate-rail similarly evolved from a simple form, spiked or wedged to wooden sleepers, to a more complex form held in chairs or cast-iron ties. The development of both rail types requires analysis, particularly to observe any relationship of the pattern to region, engineer and maker.

For both edge and plate forms there is a need to research the development of the scientific principles which were adopted in the design of rails and the processes by which knowledge of design was disseminated. Rail performance and design in the late 18th/early 19th centuries should be considered in relation to the contemporary debates surrounding the development of iron beams for use in building construction and civil engineering structures such as bridges.[3]

A waggonway of *c*5 miles required several hundred tons of iron rail, while the formation of the early public railways could produce single foundry orders exceeding 1000 tons.[4] Substantial and sometimes urgent production of rail was needed, both at periods of construction and at those of replacement or repair. Although the effect of railway orders on the iron industry has been discussed for early main-line railways, little work has been done on the subject as it applies to railways constructed prior to 1830. Research in this area would have much to add both to an understanding of railway development and to any study of the development of iron production in the late 18th century.

The use of iron allowed much greater weight to be applied to the rail. The success and near-universal adoption of iron occurred at a time when the technology of the railway was fast changing with the development of mechanisation and particularly that of the locomotive. The demands of the new technology often tested the rails to the limit; in turn, the capacity of the rails limited the motive and waggon technology that could be applied. The relationship between the two factors is important, but has seldom been examined in depth. The observations of extreme stress or failure and the urgent necessity to develop improved designs and more appropriate materials within the context of the railway may have significant application to our wider understanding of contemporary structural engineering and materials science.

Iron track components are among the most archaeologically abundant evidence of early railways, offering an unequalled insight into technical, economic and regional development. However, this evidence is widely scattered and often difficult of access.

A national database should be set up to record in standardised form the dimensions, weight, exact provenance, known or inferred date, and if possible designer and manufacturer of all permanent way components of the period in all British museums and

(as far as possible) in private collections, as well as those known from contemporary and later literature and archives.

Any discussion of iron rail development must be underpinned by an understanding of the fundamental alternatives which were available to those converting to or building with iron rails. The first choice was the decision whether to use plate- or edge-rail.

In the choice of plate versus edge there are often clear regional preferences. Most notable was a strong inclination toward the use of plateways in south Wales, where a very large number were built from the beginning of the 19th century. Conversely, the waggonways of north-east England saw an almost total conversion from wooden to iron edge-rails. There has been little analysis of the factors which may have contributed to this preference, for example comparison of construction and running costs between the two systems. Local practice and convention, the use of existing waggon stock and the background of individual engineers and owners may all be significant.

The use of plate-rail underground was popular even in areas which used edge-rail overground. Research is required, for example, to establish whether deep mines, which required transhipment at the shaft, tended to use surface edge-rail whereas areas of drift mines and open quarries used plateways throughout because transhipment was not necessary. Plate-rail offered the further opportunity to transfer road waggons directly onto a plateway and vice versa, an option that seems seldom to have been adopted (see GENERAL, below). The importance of this and other factors to the divergence of the two systems over- and underground requires consideration.

There is an essential need for analysis of the mechanism by which the knowledge and practice of the plateway was disseminated. Although the plateway was essentially a new system, the reasons behind the decision for its adoption have seen little discussion.

The choice could have significant repercussions. The ‘L’ shape of the plate-rail allowed an accumulation of dirt and debris on the rail surface that led to increased friction. This effect was generally undesirable, but became especially problematic with the introduction of already underpowered locomotives. Plateway was also regarded as lacking the strength to bear the weight of locomotive engines which were considerably heavier than the laden waggons which had previously been run on lines of this type. These perceptions require testing. While there is no doubt that locomotive development would occur principally on edge-rail systems, it has yet to be clearly established if this was a necessity, or an accident of history.

The second fundamental choice faced by those converting to or building with iron rails was that between cast iron and wrought (or malleable) iron. The choice was particularly crucial in relation to the use of edge-rails. The early forms were of cast iron: short, weak in tension and apparently prone to edge chipping. At the beginning of the 19th century, longer malleable- (or wrought-) iron rails promised a solution, with properties of greater strength in tension and an element of ‘spring’ to reduce shocks. However, initially there were production problems and objections that such rails laminated in use. The debate

between those favouring cast or wrought was at times intense and deserves study, especially with regard to an engineering and materials assessment of the argument.

New rolling techniques, credited to the Bedlington ironworks, were key to the successful production of wrought iron rails. These both yielded the required profile and allowed the formation of long rail lengths; essentially similar rails remain the industry standard today. It would be useful to consider what, if any, impact the impetus for new production methods and contemporary observations on the properties of cast and wrought iron had on the iron industry in general.

Wooden, plate and iron edge-rails require in addition a comparative analysis of their overall engineering and financial performance. Key issues for study include whether the choice of rail type or material limited engineering decisions such as the maximum allowable gradient of the line or the minimum possible radii of curves (see WAGGON BRAKING, below). Technical analysis is also required of the different strengths of plate and edge-rails, and of the working performance of each in terms of friction.

All plateways or iron railway and their related features should be examined archaeologically. Evidence of points (switches) and turntables may be particularly valuable, as may evidence of damage or wear. It is important to differentiate between cast and wrought iron, and the weight is significant (pounds per yard). The wider landscape should be examined for stone sleepers, rails, components, support structures and boundary walls on or close to the routes, and these should be recorded in detail where found.

## STATIONARY ENGINE & ROPE-HAULAGE SYSTEMS

In the first third of the 19th century the use of stationary engines (for powered inclines and reciprocating rope systems) and/or balance inclines was a very real alternative to steam locomotives. The engineering of such systems was simple and well-established, and the technology permitted the use of gradients beyond the limits of the locomotive, allowing in turn more direct routes and potentially reducing the costs of line construction. As a result, inclines and rope-haulage were extensively used on waggonways as late as the 1970s. Nevertheless, locomotive-powered railways became the preferred form of haulage on more level lines and on the public railways constructed in the Victorian period.

Studies of railway history have a strong bias towards the development of the locomotive, but these alternate haulage systems were of considerable importance. There is a distinct need for analysis of their effect on railway progress and operation, and for a technical assessment of both balance and rope-haulage systems.[5] In particular, a greater understanding is needed of both the relative performance characteristics of powered and balance inclines (including such essential points as their braking capacity) and of their performance in comparison with the other principal power systems of the horse and the locomotive.

A complementary study should be made of the contemporary issues that determined which system was adopted, especially with regard to initial costs, running costs, capacity and potential. This should include a consideration of the original estimates compared with the actual results.

There has been remarkably little examination of the development stages of mechanical, non-locomotive railway power. Particular consideration should be given to whether these power sources were direct transferral of those in use in other industries or forms of transport (such as canals), or whether they required new skills, practices or technologies.

All powered inclines, reciprocating rope systems and balance inclines and their related features should be examined archaeologically. Key features for recording are the gradients (which may vary along the line), embankments and cuttings, measurements of any 'kip' or hump at the highest point and evidence for the number of rails used along the width of the plane (essentially at the ends and at the central meeting point of the waggons). Structures such as engine and drum houses are important, as is any evidence of signalling.

## LOCOMOTIVES

Overall, the use of non-locomotive mechanical power for the railway is one of the most under-researched of all railway topics. The same could hardly be said of the use of steam locomotives, which has been and continues to be subject to exhaustive study, often in numbing detail. Even here, however, there is a very strong bias towards the analysis of locomotives of the 20th century. Forensic and rigorous studies of 19th century locomotives are distinctly unusual, while those of the pioneering engines of 1804-30 are rare indeed.

This lack of published analysis raises the question of quite how well the development of the early steam locomotive is understood, both in terms of physical detail and of influential factors. The engines built before 1830 saw unrivalled experimentation in terms of both form and principle, as the basic engineering was refined from theory to working examples to fully-realised components that were satisfactory both in engineering and commercial terms. The tensions between engineering requirements and cost are of particular relevance, and their resolution (eg with regard to steam-raising, speed, distance, engine weight, and weight and type of rail) is of central importance to the success of the technology. The contemporary understanding of the core principles behind the engineering of these first locomotives (such as adhesion, friction, valve events and boiler performance) requires comparison with modern engineering knowledge.

The crucial economic stimulus for the adoption of the steam locomotive is generally explained as the result of greatly increased costs for horse-traction during the Napoleonic Wars. However, this statement of cause and effect has seldom been backed by any firm research data; as a central tenet, it requires confirmation.

The other stimulus for the introduction of locomotives was the availability of appropriate technology. The few attempts at using low-pressure steam to power self-moving engines appear to have demonstrated that it was physically possible, but hardly practical. The use of high-pressure steam, with its greatly improved power-to-weight ratio, was the essential step necessary in the development of the mobile engine. The first locomotives, for both road and rail, are credited to Richard Trevithick (see ENGINEERS, below), the pioneer of the high-pressure steam engine. Despite their ground-breaking implications, Trevithick appears to have regarded these first examples as essentially demonstrations of the potential of his engine, indicative of its portability and capacity to self-move, rather than as an end in themselves.

Trevithick's trials ended, as far as is known, in 1808. There followed a hiatus of some years with no apparent work on the steam locomotive. This period requires review and examination to see if it was indeed a lacuna in the development of the locomotive, and the possible reasons for such a lull. Establishing the degree to which Trevithick's trials were known within the contemporary engineering community should be central to such an examination.

The Blenkinsop cogged railway at Middleton (opened 1812 ) is perceived as the first commercially successful locomotive-worked system and the Blenkinsop/Murray engine used on the line as the first example of a practical locomotive. Its general history has been well examined. However, a technical assessment, calculated in modern engineering terms, is needed of the advantages and problems of both the locomotives and the specialised rails employed in this system. A similar (and comparative) analysis is required on other contemporary non-adhesion examples, such as the 'leg locomotive' of William Brunton and the chain-haulage system of William Chapman. This should be coupled with an examination of why, for a short period (effectively 1812-15), adhesion was commonly considered impractical.

Although non-adhesion systems were generally short-lived, the twin-cylinder design of Murray's locomotive was a crucial step in locomotive progress. The flurry of locomotive-powered waggonways that followed was located almost exclusively in the coalfield of north-east England. An assessment of the reasons for this is overdue, as it is for the mechanism whereby George and Robert Stephenson became the dominant voices in locomotive design, construction and promotion in the period 1822-30.

One possible reason for George Stephenson's ascendancy was that he approached the locomotive-powered railway with an understanding that engine and rail design must necessarily progress hand-in-hand. A fundamental problem which plagued early steam railways was the physical properties of the rails, which tended to break, lose gauge or suffer damage under the weight and hammer blows of the engines. The relationship between rail types and their development and the development of locomotives is critical, but has yet to be adequately researched.

The design of locomotives themselves presented particular problems. These included the stresses imposed on steam engines by the motion of the wheeled platform, the need to

reduce damage and maintain adhesion through a mechanism such as springing, the lubrication of parts over a long distance at speed, and the maintenance of an adequate boiler-water supply. Research is needed to establish an understanding of the relative importance of these difficulties and to address the question of how well these and other issues were appreciated by contemporary engineers and how they were addressed.

Similar working conditions and difficulties were experienced for steam road carriages, which were subject to numerous trials and intense development in the same period. However, there are very few sources which directly compare the designs for road and rail, discuss the application of one to the other, or explain the apparent disparity between the engineers of steam carriages and those of railway locomotives. In the wider context of steam engineering, an examination is needed of the extent to which the dramatic improvement in locomotive design between 1804 and 1830 reflected or led that of other engine applications, such as marine and stationary.

Detailed archaeological examination of pioneer locomotives has proved of great value (for example, in the case of *Rocket*).[6] All other surviving early locomotives (such as *The Agenoria* and Stephenson's *Billy*) should be subject to similar informed examination. A selection of surviving contemporary stationary engines should also be examined for comparison.

Several contemporary working models of locomotives for road and rail were built, some of which survive. These were frequently designed to be demonstrated on plain surfaces rather than track, and were often fitted with steerable wheels. The question of whether this constitutes evidence that such engines were considered to be interchangeable between road and rail, or is a feature unique to the models, has yet to be addressed.

The recent re-examination of well-known models and the rediscovery of others from the Georgian period suggest that much remains to be understood of the intended role of such models, whether as test beds, demonstrators or promotional material. They deserve much greater forensic examination of their construction and design, and there is a clear requirement for the formulation of a database of the surviving (and those known but lost) models from the period.

A comprehensive survey and detailed (non-destructive) archaeological examination of surviving models is required.[7]

The role and significance of modern locomotives intended to replicate those of the Georgian period is also open to new analysis.[8] Replicas are undoubtedly effective in recreating some of the atmosphere of this pioneering era, and vividly demonstrate the great gulf between these early engines and most people's perception of how a steam locomotion looks, sounds and operates. The debate is still very open as to whether these engines also have a deeper significance, with particular regard to whether any useful conclusions can be drawn from the design, construction and working of the available replicas about historic technology, construction techniques and methods of operation. Consideration needs to be given to such matters as the possible relevance of performance

tests undertaken by the replicas, and the degree to which the compromises inevitably necessary in their construction and design distort their relevance to the understanding of the first engines.

The replicas are examples of modern precision engineering and safety practices applied to early designs. Discussion of their value may serve to increase understanding of the extent to which the relative engineering crudeness of the originals affected their performance and practice in such areas as: materials; mechanical tolerances and fitting techniques; the balancing of forces; gaskets and glands; bearings; lubrication; instrumentation; safety devices.

Trials of the replicas should be made, with comparison to the recorded performance of the originals if appropriate.

## GAUGE AND 'TRAIN' FORMS

Waggonways developed into two distinct forms – the wider gauge (generally of 4-5 feet) or the narrow gauge line (significantly under 4 feet).

How exact gauges were decided is unknown for most of the lines, and it is likely that this information has not survived. However, many of the traditional theories on the origins of the 4 feet 8 inch 'standard' gauge (particularly the suggestion that it is based on some universal axle standard from roads) can certainly be dismissed. A more promising theory, although potentially harder to prove, is the possibility that the gauges of the wider system were based on the pulling capacity of the horse, which determined the general size and shape of the waggon. The resulting waggon form in turn naturally produced a gauge of between four and five feet, with the exact measurement not being of great significance. Arguably, however, the origin of standard gauge is less important than the distinction between the narrow and wider gauge systems.

The choice between these systems was another of the fundamental alternatives of railway design, and had considerable implications for the construction, working practices and equipment of the line. Little is known of the reasons behind the decisions made in the case of individual lines, and there has so far been little comparative analysis of the performance and costs of each alternative. It has been suggested that the origins of the two systems may relate to the type of mining they served. Evidence is still required to prove or refute the proposal that the typical Shropshire-type narrow gauge derived from its use for drift mines and was thus determined by the tunnel size, whereas the wider gauges were based on transhipment from the shaft mouth in areas using deep mines. Factors such as the personal preferences and experience of an owner or engineer, the custom of the area, or a specific need (such as the need to use existing rolling stock or to make a connection with another line) might all have been relevant. Similar factors have been suggested as influencing the choice between edge- or plate-rail, and there may well be intrinsic connections between rail type and gauge type. With most of these possible factors, the difficulty for the modern researcher may lie in distinguishing between cause and effect.

All physical remains of early railways (surface and underground) should be archaeologically examined to determine their characteristics in terms of gauge.

## ROLLING STOCK

A reasonable amount is known about early railway rolling stock, but the picture is still far from complete. Archaeological survivals range from fragments such as wheels, often discovered in a buried context, to complete items preserved in museums. Some examination of documentary and pictorial sources has also taken place. These include not only technical literature and plans, and the archives of the undertakings that ran or were served by early railways, but also paintings, early photography and local historical sources.

Detailed archaeological analysis of surviving components and complete items is likely to prove of considerable value. Complete items in museums and collections should each be the subject of a Conservation Management Plan.

Both the material and the documentary evidence confirm that there was a considerable variety of rolling stock types, varying from the 'chaldron' for carrying coal in the north-east of England and its lineal descendants, to flat waggons for carrying stock blocks in the Forest of Dean. Given that many early railways were common carriers, it is likely that there was a great variety in what stock ran on any one system. Edge-rail systems carried very different types of rolling stock to plateways. Some early railways operated dedicated passenger vehicles. It seems probable that now-familiar railway technology such as the bogie waggon evolved on pre-1830s railways.

Further research may illuminate the evolution of early railway rolling stock by: targeted searches in archives; careful examination of what is known of design in terms of the mechanics of loading and unloading; analysis of inter-modal sites (rail/road, rail/canal, or between railways of different track-types). It may prove possible to establish a typology of rolling-stock evolution, and to examine the influence of different regions of the United Kingdom on one another. The building of replica items on replica track presents an opportunity to study both the 'fitness for purpose' and the development of the technologies.

Archival research has the potential to illuminate the evolution of this essential component of the early railway. This should encompass not only company archives and contemporary technical papers but all other potentially informative sources, including pictorial material.

Trials of replica rolling stock should be made, in conjunction with horse-working or replica locomotives wherever possible.

## WAGGON BRAKING

Ruling gradient is a further critical factor governing the location and form of any railway. Here again it can be difficult to separate cause from effect. Gradient determines the choice of route, the civil engineering required to achieve it, and the power which must be available to operate along it. Traditionally, the question of power has been considered to be decisive. However, a factor that has seen insufficient research, and which may have been equally crucial, is the braking capacity required at the limits of gradient and load.

It has been recognised that a major concern of the early (and later) railways was not so much a stall on uphill gradients but a runaway downhill. Although the former affected performance, the latter was likely to result in injury to workmen and stock, delay in returning the line to use and the probability of considerable cost. Nevertheless, analysis is generally lacking on the braking capability of the early railway. A number of issues deserve greater research to achieve a more considered view of the significance of this factor. Evidence is required on whether braking capacity was considered, how it was measured and the influence that it had on the route, engineering and working practices of the line. Particular consideration should be given to whether it was a factor in those lines constructed with different routes for loaded and unloaded waggons.[9]

Little is known of the braking performance of individual waggons or waggon groups, especially under differing climatic conditions, and when working on various rail types (such as wooden, plate, iron edge) and wheel materials (which could be of wood, iron or one axle fitted with wooden wheels and the other with iron). The use of sledges and sprags should be examined. The development of braking systems requires study in terms of their use, form and effectiveness in relation to different railway systems (horse, locomotive, rope haulage, narrow and standard gauges, wooden and iron rails, etcetera).

There are certain anomalies that require explanation. Some waggon types were without brakes entirely, while others, such as the chaldron, typically had a brake on just one side, operating on a single wheel. This situation has obvious implications if braking capacity was indeed a significant factor in deciding the ruling gradient. On the horse-operated railway, the braking effect of the horse itself seems likely to have given an additional means of control. However, there appears to have been little discussion, either contemporary or modern, of the extent of that effect or of the harness type it would require to be effective.

Remarkably, the pioneering locomotives up to and including *Rocket* were completely without brakes as far as we know, despite the increased speed and vastly greater load. The loss of the horse as a retarder appears to have been compensated for by the ability to reverse the engine. However, this required some finesse by the driver and the stresses produced threatened the integrity of the valve gear and motion. This circumstance begs the question of whether these locomotives were not considered to require brakes for themselves or their train, or whether it was not mechanically possible for brakes to be fitted to them[10] (see SAFETY, below).

Information should be sought from modern horse-haulage users, with a view to determining the braking capabilities of the horse. The braking capacity of replica early waggons should be tested under varying conditions (although the compromises inherent in modern replicas should be borne in mind).

Surviving waggonway routes should be surveyed to establish actual gradients; where possible, the presence of differing routes for laden and empty waggons should be identified.

## RAILWAY SURVEYING & CONSTRUCTION

Canal engineering changed from a philosophy of adapting to the landscape (the contour canal) to one of adaptation of the landscape. The evolution of early railways should be examined to see if a similar principle developed. Particular consideration should be given to the degrees of civil engineering demonstrated and to the adoption of balance and powered inclined planes. In a similar vein, analysis is required as to whether or to what extent canal and turnpike engineers and surveyors transferred their skills to the early railway (or vice versa). This will be helpful in determining the degree to which railway construction demanded unique civil engineering methods and forms.

Related to these questions are those regarding other factors which may have determined route selection. The engineer may well have been involved in matters of construction and running costs. However, there will have been other more commercial issues involved such as capital costs, convenience of the route to industry or settlement, avoidance of significant opposition, landowners' interests, wayleave conditions, the threat to or from competitors, and so on. Historically, research has tended to focus on the engineer. More information is required on how and by whom these other factors were considered, and on who made the ultimate decisions.

There is certainly evidence that many of the early railways, particularly prior to 1800, were constructed and operated under the supervision of the engineer of the principal concern (usually the mine or works engineer). However, their primary role was in the operation of the main business, and analysis is required in order to determine whether a correlation existed between the engineer's experience and practice in his main field and in that of the railway.

There is an understanding that after 1800, and following the introduction of mechanisation, railway engineering became increasingly dominated by specialist engineers. This perception needs testing, but there is evidence that the railways were becoming generally longer, more complex and more expensive: a situation emphasised by the appearance of the first public railways. Information is required on the type of contracts arranged for consultation and construction, with a particular view to determining whether a common pattern emerged, and how such contracts compared with the works for canals or turnpikes.

As the network of public railways expanded vigorously from the 1840s, parts of their routes inevitably mirrored or were in close proximity to those of private lines. Some waggonways were absorbed, others were not; the factors behind such decisions require further study.

A major problem of the first public railways (and many that followed) was the fact that estimated construction costs, running costs, traffic and receipts often turned out to be markedly and sometimes wildly inaccurate. It is important to review and analyse these discrepancies, particularly with regard to the discovery of any general patterns, and to compare the accuracy of predictions for the public railways with those for private railways, canals and turnpikes.

A vital decision for any new railway was whether to employ a single or double line. The choice had obvious and serious implications for the cost, capacity and operation of the system. A study to establish the basis of this decision is necessary. It would also be useful to explore the question of how often a single line was engineered when built to allow the possible later addition of further lines.

## ENGINEERS

Trevithick is generally credited with the invention of the steam locomotive. Despite intense interest in his career, his early railway work remains unclear and little new information has surfaced in some 70 years.[11] While it seems unlikely that substantial documentary evidence remains to be discovered, any new evidence or analysis may have a particular significance.

Any sites with a connection to Trevithick should be examined archaeologically for evidence of waggonways, engine construction, etc.

The early development of the steam locomotive has been briefly touched upon above (under LOCOMOTIVES). It is important to review how and to what degree Trevithick's locomotive trials at Penydarren, Gateshead and London became known to the other locomotive pioneers, the engineering community and to the wider world.

It appears that few of the first pioneers of steam locomotion (for example: Richard Trevithick; Matthew Murray; John Blenkinsop; William Hedley; William Chapman; John Buddle; William Brunton), played a substantive part in its later development or that of the main-line railway. The same might be said of many of the established names in engineering, such as Boulton & Watt, many prominent canal engineers, and many of the mining engineers who built waggonways. If this observation can be confirmed, it requires explanation.

The advent of the mechanised railway and the main-line railway brought their engineers into some prominence. There has been limited research on the reaction of the engineering establishment to this brash new arrival, or on its possible role in the later division between Civil and Mechanical engineers.

Analysis of the precise role of the early railway engineers is limited. It remains to be established whether the engineer typically oversaw the design, construction and operation of new lines in detail and in person, or whether a broad specification was drawn up and skilled craftsmen left to interpret it.

## GENERAL

The emphasis in railway history has always been overwhelmingly biased towards the above-ground lines. Very little work is available on below-ground railways and the extent to which they mirrored or differed from developments on the surface.

The containerisation of freight was apparently applied to the railway at early as 1788.[12] The inspiration for its use probably came from canals, but little is known of this application or others on the early railway, or of how they compare to other forms of transport. It has been noted above (in IRON RAILWAYS) how little apparent use was made of the potential for road/rail crossover on the plateways; only slight information is currently available on other forms of cross-modal transport (such as waggon ferries).

The intense development work on the engineering of the mechanised railway has been noted. The locomotives, rail types and infrastructure (such as ropes or bridges) often pushed contemporary technology to the limit. Consideration is therefore due to the part played by the early railway in the development of new materials and applications, whether as beneficiary or as innovator.

Advances in railway construction, technology and operations generally increased the capacity of the system in terms of tons per day. Study is required into the consequences which this had on, or which were produced by, factors such as gauge, waggon size, train length, braking and speed. The effect on capacity of such systems as plate-rail, narrow gauge and rope-haulage would be particularly relevant.

Accounts of the track of the early railways suggest that to modern eyes it would appear very rough – and indeed sometimes appeared so to contemporary eyes. Study is required on the possible effects of this irregular quality on the reliability and performance of the track, horses, locomotives and rolling stock. The measures taken to alleviate any such problems in terms of practices and equipment call for research, as does the extent to which such track problems might have influenced the public's perception and experience of the railway.

In various sections above, a need has been noted for modern technical analysis of such features as rail and locomotive design. In more general terms, this can be widened to the need for a study comparing the contemporary understanding of early railway engineering and materials with the modern perception of these, and the implications of any major discrepancies between the two.

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## COMMUNITY, COMMERCIAL AND GOVERNMENT

### PASSENGER TRAFFIC

One of the characteristics of railways to 1830 and of the early railway type that continued is that, with rare exceptions, passenger traffic was not considered or was not allowed. Even on such substantial new public railways as the Stockton & Darlington Railway, the demand for passenger travel appears to have come as a surprise to the managers and engineers.

The emergence of railways planned and built for passenger traffic, such as the Liverpool & Manchester Railway, was a crucial development in rail transport, changing its form, economics and place in the community. Yet there have been few analyses of quite how, when and where the potential benefits of passenger business were first realised, and of what specific effect this had on the early railway (and see SETTLEMENT, ARCHITECTURE & LANDSCAPE below).

### PERSONNEL

The construction, maintenance and overhaul of early railways required engineers, waggonway wrights, waggon builders, drivers, etc. Little is known about how specialised such skills were, about the processes of recruitment and training, or about whether any collateral effects such as the migration of skilled labour can be identified.

### SAFETY

Railways had always seen accidents. However, mechanisation brought the new dangers of heavier loads, higher speeds and the hazards of steam machinery and rope haulage. The advent of public railways added passengers to those at risk, but studies on the development of signalling and safety tend to begin only with the main-line railway and to ignore the earlier period. Work is needed on the extent to which safety was considered and signalling used, and on whether such practices were continued or adapted for the new public railways. The authorities appear to have had little interest in waggonway safety, but studies to consider whether the introduction of the public railway had altered their attitude prior to 1830 would be useful.

Related to the studies of safety and the operation of the early railways, research is lacking into the emergence of the need for operating rules and regulations. Information is particularly needed with reference to single-track lines, the operation of inclines (where distant operations had to be strictly synchronised) and signalling.

In the satirical cartoons of the early 19th century there is a marked emphasis on the explosion of steam road carriages rather than of steam railway locomotives. This apparent bias should be examined, especially in relation to the possible London-centred perceptions of the cartoonists and their market.[13] In a wider context, Boulton & Watt

(among others) conducted a campaign against the dangers of high pressure steam. Research is needed with regard to the effect of this on attitudes to, and the development of, the steam locomotive and on its use on public railways. A comparison might be made with related contemporary issues, such as steam-powered shipping.

## PUBLIC CANALS & RAILWAYS

Canal companies were already long established when dedicated railway companies emerged in the first years of the nineteenth century. A comparison of the two would be enlightening with regard to their formation, constitution and management.

The canal companies had an acknowledged public role, but it is unclear to what extent railways built under the 'x-mile clause' of canal acts were, in actual practice, 'public'.[14]

## SETTLEMENT, ARCHITECTURE & LANDSCAPE

The public railway was to have an undoubted effect on the character and form of national landscape and settlement. The waggonway was more localised, but there has been little research on its impact on its area. Questions arise as to the effect on the location and form of industries and settlements (such as coal merchants, warehouses, offices, supply merchants, the sites of mills, mines and factories) leading to the development of functional groupings of buildings or altered settlement centres. A comparison would reveal whether railway warehouses, for example, were different in form and function from those serving canals, ports or roads. The extent to which waggonways affected other local transport systems also requires study.

Waggonways required varying degrees of civil engineering and support structures which inevitably changed the landscape. Research is needed into the immediate and long-term effect of the waggonway on its surroundings (including after abandonment), into public attitudes to these changes and into how they were reflected in the visual arts (including, for example, map-making).

With regard to passenger traffic, the waggonway seems to have rarely been used to move the workforce of the industry it served, except in the most remote locations. Instead, purpose-built housing (such as pit villages and forge rows) often had to be constructed near the workplace. A study of the reasons for this would be informative.

## GOVERNMENT and THE NATION

There has been research into the attitudes of government towards transport systems such as turnpikes and canals. However, little has been published on their positions towards waggonways and the earliest public railways. This raises questions as to the comparison between government approaches to these systems, with particular reference to the different and changing attitudes of successive governments, of the party groupings, of influential individuals (especially those with a personal or financial interest) and between the two Houses of Parliament.

The politics, principles and processes in relation to the first railways built under Act of Parliament are particularly relevant. Railways required far-reaching powers over private property in return for public gain. Currently there has been limited research into how arguments in favour of this were presented and received, to what extent rights when granted were different from those awarded to canals and turnpikes, to what extent clauses were simply copied, regardless of relevance, from earlier railway (or even canal or turnpike) Acts, and how Standing Orders relative to railway bills changed over time.

Governments took a role in funding what might be called useful public works. The Exchequer Bill Loan Commissioners (1817-42) were often active supporters of transport improvements, including loans to some early railways. Studies have been made of these transactions,[15] but additional research is necessary into the comparative attitude of the Commissioners to the various types of transport and into the conditions and reports required by them.

In the early nineteenth century there were periods of civil unrest centred on the introduction of machines and the effects of industrialisation. Railways were having an increasing effect on competing systems such as turnpikes and canals throughout this period, and were themselves becoming increasingly mechanised. The perception that the railways did not form a target for disturbances of this type remains to be tested.[16]

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## WIDER PERSPECTIVE AND KNOWLEDGE

### THE UNDERSTANDING OF A 'RAILWAY'

An understanding is needed of the point at which such terms as 'railway' (or its variations such as railroad), waggonway, plateway, tramroad and locomotive were not only introduced but generally incorporated into the language, and their meanings commonly appreciated. This in turn suggests that a study is required of the manner in which the principles of the early railways were disseminated, particularly with regard to the process by which awareness became routine in interested groups such politicians, engineers, scientists and business men. Comparative studies might involve how knowledge was spread of other systems such as canals and turnpikes, and related technologies such as steam road carriages and ships. In railway terms, comparisons might also be made with knowledge abroad, particularly on the Continent and in the Americas.

The detailed examination and the publication of British industrial technology and practice by foreign observers was a feature of the later 18th and early 19th centuries. Although sometimes characterised as 'spies', it is clear that many if not most of these visitors were given co-operation by the industrialists and engineers of the time, including the railway pioneers. Assuming this was not altogether altruistic in their hosts, a close analysis might clarify the reasons for this goodwill, and establish the extent and accuracy of the information given.

By way of contrast, the widespread assumption that British railway technology was the world-leader needs testing and justification across all aspects and periods of the early railway. Although reports by visitors to British railways are numerous and well known, there appear to be remarkably few descriptions of foreign railways by British observers.

There are instances where railways were used in highly localised environments, such as within factories or docks. Little study has yet been made of these installations. Similarly, although railways are known to have been used in their own construction, more research is required to test if they were also involved in the construction of canals, turnpikes, major civil engineering projects and so forth. If this is found to be the case, information is required not only into the mechanics of railway use in this context, but into the degree to which they were integrated into or had independent control outside the central scheme.

This approaches a fundamental division of the early railway. Although some work has been done, further clarification is desirable as to the point at which the waggonway, subordinate to the industry that it served, graduated into the railway that was a distinct industry in its own right. The advent of the public steam railway would appear to acknowledge the reality of this distinction, but not necessarily to mark the beginning or the end of this process. Waggonways as a secondary feature of a core industry still exist, while other private railways before the Stockton & Darlington had multiple users and/or were awarded rights by Parliament, and others still were public companies or had a degree of general access.[17] The recognition of a 'railway industry' may ultimately boil down to a question of public perception, whereby a short horse-hauled waggonway was regarded by the non-engineering public in a quite different light to a longer waggonway worked with impressive engines and locomotives, despite the fact that their functions were identical. For this reason railways such as the Stockton & Darlington and the Liverpool & Manchester may not be the definitive watersheds that they appear to modern eyes, and comparative reassessments are required.

The advent of the locomotive-powered railway is regarded as having changed perceptions of time, space and speed. Initially, however, the early locomotives operated at little more than the pace of the horses they replaced. The remarkable speeds attained in the Rainhill Trials of 1829 demonstrated the potential of the locomotive, but further study is required to establish if the engines used before that date had already prompted a review of these perceptions.

## CHOICES OF TRANSPORT

Through the 18th and into the early 19th centuries, the clearest choice for heavy inland transport was between the canal/navigable waterway and the railway. Information is needed on the circumstances in which both options were discussed and on the nature of the deciding factors. This should be considered, together with the corollary: the circumstances in which only one option was considered. Such a study should test the contemporary attitudes to the costs and revenues of both systems and their ability to be directly compared. How these attitudes may have altered in reaction to changing

technologies on each of the competing systems is an aspect that also requires examination.

The principal remaining alternatives for inland transport were the road waggon (for general freight and low-cost passenger travel) and the coach (for high-value light goods and premium passengers). Here, too, research is needed into the effects of the growth of the early railway on the road system, with particular regard to such matters as the viability of investment and the discontinuation or realignment of routes and services. A comparative study would illuminate a possible contrast of the attitude of turnpike trusts and road operators towards the canal and the railway.

## THE STUDY OF EARLY RAILWAYS

It was proposed in *Early Railways* (the volume of papers from the 1998 Early Railways Conference) that this was the only book in print in Britain wholly devoted to the subject, despite the vast amount written on railways in general. This suggests there might be little interest in, or understanding of, the subject, not just by the public, but more surprisingly, by 'railway enthusiasts'. The accuracy of this proposition needs testing and aspects examined, such as the coverage of the subject of early railways in museums, documentaries and railway magazines, celebrations of anniversaries, content in education and the extent of popular knowledge. Related questions might focus on the accuracy of available material and the extent to which modern research is reflected within it.

Experience suggests that much apparently-modern material may have its origins in 19th and early 20th century texts, reworked and recycled time and again. This may account for a pronounced emphasis in the available texts on technical and engineering matters, rather than a more up-to-date concentration on context and analysis. The accuracy of this perception would repay examination, as would comparison with the treatment of related subjects.

There tends to be an assumption that texts on railways published prior to 1830 will provide accurate contemporary information. Such sources are unquestionably valuable, but this supposition requires critical analysis predicated on an awareness of the possible financial interests of the authors and the likely extent of their personal knowledge of the railway. The degree of the influence (real or anticipated) that such works had on the public, government and potential investors would be relevant to any analysis of their accuracy, as would the effect they may have still on our understanding of the subject.

Private railways constructed, owned and operated by industrial concerns are still a feature of the British railway scene. Many of these industrial railways come within the definition of early railways as 'operated or built to pre-main-line patterns'. A distinguished railway historian has suggested that at times these industrial lines matched and probably exceeded the track mileage and freight tonnage (but not necessarily ton-miles) of the public railway companies. The data are not readily available; their preparation and analysis are required. If such a proposal can be supported, the scale and importance of the industrial railway would see a significant reassessment.

## CONCISE BIBLIOGRAPHY & RESOURCE GUIDE

There are a very large number of railway titles, but few examine the early railway reliably or in detail. An inevitably basic, but accessible introduction, to the subject and its terms can be found in *The Oxford Companion to British Railway History*, edited by Jack Simmons and Gordon Biddle (Oxford University Press, 1997). See especially the entries for 'Early Iron Railways' and 'Wooden Railways'.

The master list of railway books is by George Ottley: *A Bibliography of British Railway History* (London, 1966; 2nd edition HMSO, 1983); with a first *Supplement* in 1988 (HMSO). Since then the Railway & Canal Historical Society has continued with the *Second Supplement* (NRM, 1998) and annual additions published in conjunction with the *Journal* of the Society.

An examination of under-researched topics for the railway in general, but with some specific reference to the early railway, can be found in R W Ambler (ed), *The History and Practice of Britain's Railways: a new research agenda* (Aldershot, 1999).

The classic and unrivalled work on the first railways is M J T Lewis, *Early Wooden Railways* (London, 1970).

Two important books study the early iron railway in Wales, with the archaeology described in detail: Stephen Hughes, *The Brecon Forest Tramroads* (Aberystwyth, 1990) and John van Laun, *Early Limestone Railways* (London, 2001).

For Scotland, an outstanding introduction is C J A Robertson, *The Origins of the Scottish Railway System, 1722-1844* (Edinburgh, 1983), which unusually concentrates on economic rather than engineering characteristics. A W Brotchie and Harry Jack provide a ground-breaking local study in *Early Railways of West Fife* (Catrine, [2007]).

The North East of England had arguably the greatest length and complexity of early railways. G Bennett, E Clavering and A Rounding, *A Fighting Trade: Rail Transport in Tyne Coal 1600-1800*,(two volumes, Gateshead, 1990) examines the history and remaining traces for an area south of the Tyne, giving a vivid description of the many and changing routes and demonstrating some of the historical sources that may be available.

Modern researches are collected in an important series of publications of the International Early Railways Conference : *Early Railways*, ed Andy Guy and Jim Rees (London, 2001); *Early Railways 2*, ed M J T Lewis (London Society, 2003); *Early Railways 3*, ed Michael R Bailey (Sudbury, 2006), and *Early Railways 4*, ed Grahame Boyes (Sudbury, 2010).

Occasional excavations or analysis of early railways may be found in the *Industrial Archaeology Review*.[18] Of particular significance, the discovery of a very well preserved wooden railway in Durham: 'The archaeological excavation of wooden railway remains at Lambton 'D' pit, Sunderland', by Ian Ayris et al, volume XX, 1998.

The *Journal of the Railway & Canal Historical Society* is an important source,[19] especially the occasional papers of the 'Tramroad Group' (now renamed the 'Early Railway Group'), as is the *Transactions of the Newcomen Society* (now *The International Journal for the History of Engineering & Technology*).[20]

The most useful contemporary text is that by Nicholas Wood, *A Practical Treatise on Rail-roads and interior communication in general...* (London, 1825). Further editions appeared in Britain in 1831 and 1838, and it was published in France and the USA.

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Currently, the only sizeable museum display of the early railway is at Beamish, the North of England Open Air Museum at Stanley, County Durham. Its Pockerley Waggonway site includes a recreation of an early wooden waggonway and working replicas of *Puffing Billy,* the *Steam Elephant* and *Locomotion*.

The Institute of Railway Studies & Transport History in York[21] contains dissertations and theses that are relevant to the early railway and has an awareness of ongoing projects and researches. It is closely allied to the National Railway Museum, whose library is outstanding.

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1 Chris Down, 'The Maltese cart ruts as railways: an experimental reconsideration' and Geoff Smith-Grogan, 'Rutways in Cornwall', both in *Early Railways* [*ER*] *4*

2 Warren Allison et al, 'An early railway in the German mines of Caldbeck', *ER4*

3 M J T Lewis, 'Bar to fish-belly: the evolution of the cast-iron edge rail', *ER2*. For the development of beam technology, see Ron Fitzgerald, 'The development of the cast iron frame in textile mills to 1850' in *Industrial Archaeology Reveiew* 10 (1987-8), 127-45.

4 For example, the Wylam waggonway (6.5 miles) contained over 400 tons of plate rail in 1827, increased to over 500 tons of edge rail following conversion (from the Wylam (Blacket) papers in the Northumberland County Record Office). The Stockton & Darlington Railway made single orders to two foundries, one for 1200 tons of malleable rail and another for over 600 tons of cast iron rail and chairs: W W Tomlinson, *The North Eastern Railway; its rise and development* (Newcastle-upon-Tyne, [1914]; repr Newton Abbot, 1967), 80.

5 Discussed, for example, in Colin E Mountford, *The Bowes Railway* (Sheffield, 1966; rev edn, London, 1976) and in the papers by Mountford in *ER1*, *ER2*, *ER3* and *ER4*

6 Michael Bailey and John Glithero, *The Engineering and History of 'Rocket': a survey report* (London, 2000)

7 Jim Rees, 'The *Sans Pareil* model: a pivotal moment', *ER4*

8 Currently such working replicas in Britain include: those of Trevithick design ('Coalbrookdale' 1803, 'Penydarren' nee Gateshead, 1805 and *Catch Me Who Can,* 1808); *Puffing Billy* from the Wylam waggonway (*c*1814/28); Buddle & Chapman's *Steam Elephant* (1815); George Stephenson's *Locomotion* (1825); Robert Stephenson's *Rocket* (1829); and Hackworth's *Sans Pareil* (1829)

9 Discussed in Lewis, *Early Wooden Railways*
10 A stated objection to brakes on the driving wheels was that they would cause unacceptable stresses on the axles, as in E L Ahrons, *The British Steam Railway Locomotive 1825-1925* (London, 1927; repr London, [1961] and 1987), 105. It is notable that the engine requirements for the Rainhill Trials of 1829 made no mention of brakes.
11 A basic source for Trevithick remains to be R W Dickinson and A Titley, *Richard Trevithick: the engineer and the man* (Cambridge, 1934)
12 As in John Farey, *General View of the Agriculture and Minerals of Derbyshire*, 3 (London, 1817) 295-7, discussing the Ankerbold & Lings Railway near Chesterfield.
13 In terms of the situation whereby steam road carriages saw much experimentation in London, whereas most early locomotives were tried well outside the capital.
14 Stephen Hughes, 'The emergence of the public railway in Wales', *ER4*
15 Grahame Boyes, 'The Exchequer Bill Loan Commissioners as a source of canal and railway finance, 1817-42', *Jnl Railway & Canal Hist Soc* 24 (1978), 85-92.
16 Aspects are discussed by Dr David Gwyn in 'Artists, Chartists, railways and riots', *ER2*
17 Discussed by Hughes, *ER4*.
18 The Review's website is at: www.industrial-archaeology.org.uk/aiareview.htm. All volumes and individual papers are available for (paid) download: www.ingentaconnect.com/content/maney/iar
19 The website for the Society is at: www.rchs.org.uk
20 Electronic access is available via www.newcomen.com
21 www.york.ac.uk/inst/irs/