

THE CITY & SOUTH LONDON RAILWAY ELECTRIC TRAIN

1 – A NEW APPROACH

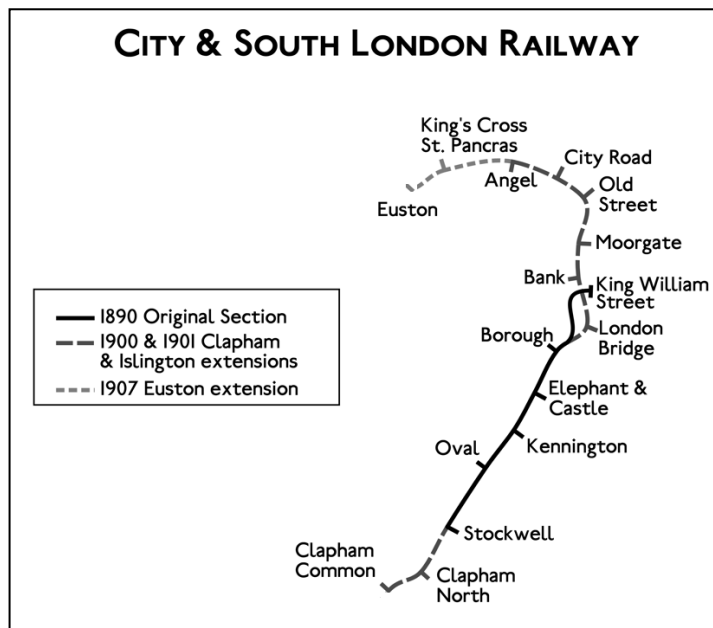
by Piers Connor
with Printz Holman

A NEW STORY

This article is the first of a new series on the electric rolling stock of the City and South London Railway (C&SLR). As many readers will know, I've written a number of series for *Underground News* over the last 14 years, each being about electric rolling stock on the Underground, usually basing a series on a particular company, like the District or the Central London. Up to now, I've hesitated about writing on the City & South London, largely because I didn't think there was much more that I could find out about it that hadn't already been discovered by others like T.S. Lascelles¹ and, more recently, Printz Holman. I thought that Printz, in particular, had already done a lot of research into the subject over a long period and much of this went into his book 'The Amazing Electric Tube', published by the LT Museum in 1990. So, I thought, there would be little I could add to that excellent work.

However, I agreed with our editor that I would write a series on the C&SLR rolling stock but, in doing this, I wanted to be sure that none of the research that has already been done was wasted, so I got in touch with Printz and he immediately agreed to help with the articles. So, this series is a joint effort, with me doing most of the writing and Printz adding his expertise and comments from his extensive notes, drawings and papers from his 50 years of research.

There's quite a bit of technical stuff in this series but we think it's worth telling the story in some detail for three reasons. First, we can learn a lot from history. We don't always but we should. Knowing what went badly last time and what went well, should give us pointers to what we should do this time. It's called lessons learned or experience and it's a valuable resource. Secondly, electric traction is a complex subject and a good way to understand it is to see how it was developed. It helps with getting to understand the more complex applications we see today. It's helped me anyway. And thirdly, it is worth recording all the details we can, as these can become a good record of the heritage of the Underground.



THE ROUTE

The original name of the City & South London Railway was the 'City of London and Southwark Subway' (CLSS). This choice of name was logical when the line was first proposed, since the route chosen was from King William Street, near the Monument in the City of London, to the Elephant & Castle in Southwark. The Bill authorising its construction was passed by Parliament on 20 July 1884. According to James Greathead², the tunnelling engineer who oversaw the construction of the original railway, work on the tunnels was begun in October 1886. An early realisation that the line, as planned, was probably too short to make any money, led to a proposal to extend the route south to

Stockwell (see map, Left), which was then a well-to-do suburb, and this was authorised in July 1887. To reflect the new destination and to allow for aspirations to go further south, the railway later

¹ Lascelles, T.S. (1955), 'The City & South London Railway', Oakwood Press, Lingfield, Surrey.

² Greathead, J.H. (1896), 'The City and South London Railway; with some Remarks upon Subaqueous Tunnelling by Shield and Compressed Air', Journal of the Proceedings of the Institution of Civil Engineers, Volume 123, Issue 1896, January 1896, pp. 39-73. Part 1.

changed its name to the City & South London Railway in July 1890³, five months before it opened to the public.

THE TRACTION SYSTEM

All through the early design phases and into the start of construction of the line, the project was based on the assumption that the railway would be operated by cable traction using the Hallidie system. This is the system still in use today for the San Francisco cable car operation. The CLSS tunnel size (having a 10ft 2in or 3.1m internal diameter) was based on the idea that small, cable-hauled cars would be dragged along the tunnels by ropes driven from a power station. They wouldn't need space for any other equipment apart from lighting and a water main for the hydraulic lifts. Then, in January 1888, the Patent Cable Tramway Corporation, who were supposed to supply the system for the CLSS, went into liquidation⁴. This left the CLSS with a serious problem and it is probable that Greathead, as their engineer, would have very quickly turned to electric traction as a possible solution. Doubtless, he would have been encouraged by the chairman, Charles Grey Mott, who was already not entirely convinced that a cable system was suitable for the line.

In 1888, electric traction was new technology. With only a few working electric railway systems in the world, it was a bold step to take it on but Greathead obviously thought it could be made to work, given the right expertise, and he knew where the expertise lay. He had, only a few weeks earlier, attended the presentation of a paper to the Institution of Civil Engineers⁵ by Dr. Edward Hopkinson on 6 December 1887, where Hopkinson described the electric traction system he had designed for the three mile long tramway between Bessbrook and Newry (B&N) in Northern Ireland. Greathead even took part in the discussion that followed the presentation of the paper.

Hopkinson was originally employed as assistant to Dr. (later Sir) William Siemens and, when Siemens died in 1883, he took over the electrical design of the Bessbrook and Newry system. The electrical equipment for the line was supplied by Mather & Platt (M&P), an engineering company based at the Salford Iron Works in Manchester and, in 1884, while the B&N was being equipped, Hopkinson joined Mather's. He rose to be made a partner in 1887.

We have no direct evidence for this, but it is likely that, faced with the collapse of the cable company, Greathead contacted Hopkinson and asked him to look at the possibilities of Mather & Platt putting in electric traction for the CLSS. He probably roughed out his ideas of what he thought the CLSS needed: a power generating station, a current transmission system and three-car trains with a capacity of 100 passengers and powered by an electric motor at each end. He knew what had been installed at Bessbrook and may have suggested something similar could be done for the CLSS.

THE PROPOSED TRAINS

The first documented evidence we have of some sort of request being made to Mather's is in May 1888, when M&P offered a 'Proposed Scheme for Working by Electricity'. It was dated 2 May 1888, less than five months after the collapse of the cable company. Although it's not signed, we can be pretty sure that Hopkinson was involved with its preparation, even if he didn't write it himself. It is clearly based on some sort of requirements list, although we haven't found one. The proposal began by estimating the power required to operate the railway and then it described how the traction current would be transmitted to trains by 'bare copper wires'.

The proposal acknowledged a requirement for motor car trains that could carry up to 100 passengers but, about the use of motor cars, it went on to say, "On further consideration, however, certain practical difficulties appear, arising from the special conditions, peculiar to the Subway, which would not occur in the case of an ordinary line".

M&P went on to say that, because of the severe curves on sections of the line, it would be impossible to use cars longer than about 30 feet, "and even with cars this length the clearance on the curves is reduced to very narrow limits. If 6 feet of this length is taken for a dynamo compartment, the room available for passengers is seriously diminished". They couldn't see how they could get 100 passengers in a three-car set so they suggested four-car trains would be required. They described

³ BTHR, CSL 1/2, p.64.

⁴ Holman, P. (1990), 'The Amazing Electric Tube', LT Museum, p.21.

⁵ Hopkinson, E., (1888). Electrical Tramways: The Bessbrook And Newry Tramway', *Minutes of the Proceedings of the Institution of Civil Engineers* (Vol. 91, No.1888, pp.193-217).

how the floor of the car “must necessarily be very low, almost on a level with the axles. This makes the bogie construction very difficult and cramped, and makes it impossible to allow proper room for the driving machine”. When they spoke of the “dynamo compartment” they meant space for the electric motor and by “the driving machine”, they meant the motor itself.

The proposal said that there would be one motor on a bogie at each end of the train. It is here that certain similarities to the Bessbrook & Newry (B&N) system can be seen. The tramcars built for the line (Figure 1) had one motor driving one axle through a chain connection which was then connected to the other axle by a coupling rod. However, they had already learned that the chain drive was not ideal. Hopkinson knew that they needed a better drive system and he proposed putting the armatures directly on the axles, an idea he had got from Siemens when he worked for him.

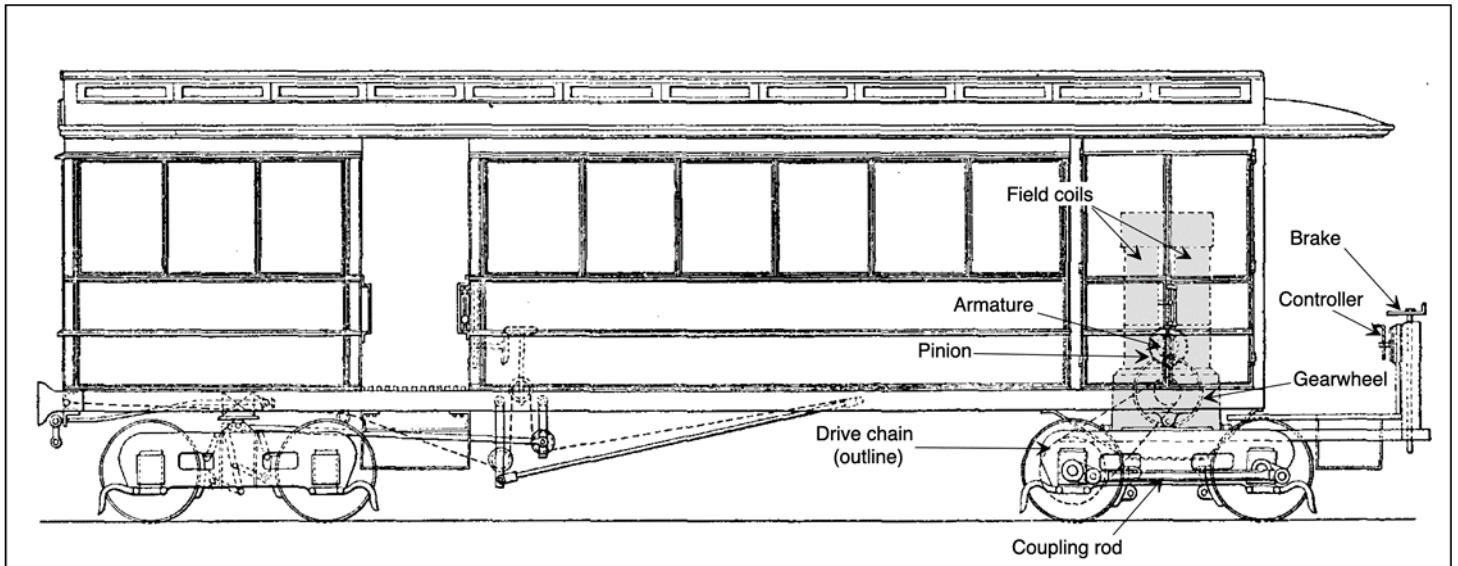


Figure 1: A drawing of the first Bessbrook & Newry tramcar of 1885. This is relevant for our story because the electrical equipment was supplied by Mather & Platt under the direction of Dr. Edward Hopkinson and it seems to have informed some of the thinking for the first Mather & Platt proposal for the CLSS. It shows the outline of the single traction motor (in grey) mounted on top the leading bogie. The field coils are very large compared with the tiny armature. The rotational speed of the motor was very high for a vehicle speed of 8.5 mi/h at over 850 rpm. The motor was connected to the axle by a pair of gears and a chain. The two axles were connected by a coupling rod. The chain drive setup proved to be problematic. Later motors had smaller but wider and more intensely wound fields and larger armatures with better drive systems.

Drawing adapted by P. Connor from Hopkinson, E., 1888. *Electrical Tramways: The Bessbrook and Newry Tramway*, 'Minutes of The Proceedings of The Institution of Civil Engineers' (Vol. 91, No.1888, pp.193-217).

One problem with the B&N motor was its size. It sat on top of the bogie and protruded through the car floor to over 4 feet in height. While this was fine on a rural tramcar, it would not work well on the small cars intended for the CLSS. Fortunately, in the years following the opening of the B&N in 1885, motor technology improved rapidly. Size was reduced and power was increased so that, by 1888, a 50 h.p. motor could be built at about half the size of the 20 h.p. B&N motor. Even so, getting one to fit in the proposed CLSS motor car was going to be a challenge.

The M&P proposal to the CLSS went on to suggest that the rear motor car would be unpowered unless it was needed to get a train up the steep gradient to King William Street. But, they said, “the use of the motor on the rear bogie as a bank engine is open to objections, and moreover the weight of this motor when not in use is dead weight and, when working, it has to work without supervision, as it is proposed to have one driver only to each train, who would be in the front dynamo compartment, and consequently would have to control the working of the rear motor by levers or connections, which would have to pass the whole length of the train.

These objections are no doubt not insuperable, but they are well avoided, if possible”. To avoid “these objections”, M&P proposed that they should build separate locomotives hauling trailer cars. They pointed out the cars could then be the full length of 30 feet, “capable of accommodating 34 persons each”.

They suggested a locomotive weighing 5 tons⁶ would give the necessary adhesion, as the whole weight could be put on the driving wheels, with a separate motor on each driving axle, removing the need for coupling the wheels. They proposed to put the armatures of the motors directly on the axles⁷. They reckoned the only disadvantages would be an increase in the weight of the train by about 3 tons and the necessity for changing locomotives at the termini.

The M&P proposal gives us some feeling for the thinking of the time, including the phrase, “motor-dynamos”, which succinctly described the electric motor in its context of being mechanically similar to a dynamo or generator. It also described the principle that the motors could be used as a brake thus, “the whole power of which [the motors] can be exerted in stopping the train if the current through them is reversed, which can at any time be instantaneously effected by the driver”. This was, of course, all very well in theory but, while the idea of regeneration was well understood at the time, getting it, or the very similar rheostatic braking, to work effectively and reliably on an electric railway was never really achieved until power electronics became widely available in the 1980s. Even on Underground trains with rheostatic braking built in the 1960s and 1970s, it was never really that reliable and experience (including mine amongst many others) showed that controlling it was a pig of a job for the driver.

REJECTION

Despite the sensible arguments presented by M&P in favour of locomotive traction, the CLSS rejected the idea and they apparently told Mather & Platt to offer a bid with the four-car ‘motor car’ train design only. The rejection might also have had something to do with the limited speed of 12 mi/h offered by M&P and by the fact that they proposed to build 24 locomotives for the line. I suspect they may have thought it was all rather expensive for what they were offered.

Four months later, on 15 September 1888, Mather & Platt delivered a new proposal, ‘Description of Proposed Scheme for Working by Electricity and Estimate of Cost’. In it, there were a number of interesting differences from the first proposal. The proposal envisaged the line being electrified by a “separate conductor” (to remove any idea that it might be a battery fed system) at a voltage no higher than 500 volts, supplied from a power station to be built at Stockwell. The original proposal had suggested a maximum voltage of 350 volts.

The current was to be supplied to trains by twin overhead wires (instead of a single wire) with the return current using the running rails. I imagine the twin overhead wires were considered necessary to carry the expected currents.

The mandated four-car train was in the proposal, with a motor bogie to be provided at each end of the train. The motor cars were to have room for 20 passengers and the intermediate two trailer cars, 30 passengers. The reduction in capacity for the motor cars was obviously to provide space for the control equipment and the driver’s cab. It was expected that the trailer cars would be 4 tons in weight, while the motor cars “although shorter” would, with all the electrical equipment, weigh about 11 tons.

Whilst the proposal to have motor cars that were shorter than the trailers might seem counter-intuitive, there was a good engineering reason for this. There was some sharply curved track at the City end of the CLSS and, to negotiate this, each bogie needed to rotate around its centre point to allow the wheels to follow the curve of the track. For the M&P designers, the difficulties arose because the motor bogies had to project into the body of the car through openings in the floor structure and these would rotate relative to the car body – something that would not apply on a fixed wheelbase locomotive. This meant that, the greater the length of the car, the greater the rotational movement of the motors and the bigger the holes in the floor, resulting in less space for equipment or for the driver to work. There was also a finite limit to the amount of rotational movement that could be achieved within the width of the underframe, particularly in such a narrow tunnel. The shorter body proposed by M&P kept the rotational movement within workable limits.

⁶ By comparison, we can note that the first batch of locomotives built for the line actually weighed over 10.35 tons.

⁷ This idea was said by M&P to have been first put forward by Sir William Siemens in a proposal for a new tube line to be built from Charing Cross to Waterloo. The line was proposed in 1882 but abandoned in 1885. Siemens died in 1883.

The trains were now expected to achieve a top speed of 24 mi/h with a load of 100 passengers. Lighting was to be provided by on-board batteries, not fed from the traction supply as we might expect. The traction control system would allow the driver to control both front and rear motors from the front of the train. There was no reference as to how this was to be done, nor any mention that, in order to do this without the benefit of multiple unit control, it would be necessary to run traction power cables along the train. Mather & Platt envisaged the rear motors only being used during acceleration from stations until the train was on the descending 1 in 30 slope leading out of the platforms, or as necessary to get the train up a gradient. This suggests two controllers would be required at each driving position, one for each pair of motors. The whole setup was going to be complex and would require a lot of space.

ELECTRIC MOTORS

Mather & Platt retained their original idea that the armature should be mounted directly on the axle. They considered gears too noisy, “when absolute freedom from noise is essential”. The motor’s field windings were to be fixed on one side of the armature, not surrounding it as later became the norm. They proposed “carrying the magnets at one end by journals on the axle, and supporting the other end from the framework of the car in such a manner as to allow limited freedom of motion round the axle”. It was an early form of what we later knew as the ‘nose suspended motor’.

Unusually, Mather & Platt’s new paper described an elaborate system for getting the motors out of the train. Normally this sort of thing was left to the customer, but this was new technology and Mather’s appear to have been trying to be helpful. Traction motors were, in those days, primitive compared with what we see today and were prone to breakdown rather often and the need to take them off the train regularly seems to have been considered in detail by Mather’s. They proposed that, “The roofs of the cars over the motor compartments are made strong enough to lift the magnets from”. The idea was that the motor field magnet would be attached to the roof by lifting chains and would then be disconnected from the motor and the chains used to raise it clear of the armature. “This”, they said, “will leave the armature perfectly free and accessible for repairs”. Not mentioned was that the chains would need pulleys to lift the mass of the magnets clear of the armatures.

They then described how, if it was necessary to remove the armature, the car would have to be run over a drop table and, after lifting the magnets and hanging them from the roof, the motor bogie would be lowered on the table. Looking at this proposal, we can see that, aside from some odd sentence construction in the text, Mather & Platt’s proposal to build the car roofs so that they were strong enough to withstand the suspension of a couple of traction motor field magnets was novel to say the least. It would also have added a lot of unnecessary weight to trains that were already going to have to work hard just to run at a reasonable speed. However, as Printz Holman pointed out to me, we should remember that Mather & Platt were used to working in a factory environment, where lifting tackle was readily available, usually from cranes working over the equipment on the factory floor. The idea was simply transferred to their railway proposal, but it lost a little in the translation.

M&P retained their intention to use regenerative braking. They describe how the trains would slow down at the stations because of the 1 in 30 uphill gradients on the run in. Brake power, if required, was to be “provided by the motors themselves”. They also stated that screw operated handbrakes acting on the eight wheels of the leading car could be used if necessary. How to get the handbrake rigging around the motors on the front bogie and to the rear trailing bogie in such a cramped environment obviously hadn’t been closely considered. Air (or vacuum) brakes were not mentioned⁸.

A NEW APPROACH

As we’ve seen, the original, non-compliant Mather & Platt proposal for locomotive-hauled trains was delivered in May 1888 and then promptly thrown out. However, during that summer, while Mather & Platt were rewriting their offer to make it compliant, their loco idea seems to have nudged the CLSS into looking further at the option and getting some advice on it. So far, the CLSS’s engineering

⁸ The Bessbrook & Newry tramcars only had hand operated brakes and the idea seems to have been carried over for the CLSS. There were two sets of brakes on the tramcars – one on the leading bogie and one on the rear. The brakes on the leading bogie were operated by the driver while those on the rear were operated by the guard.

advice had been largely based on civil engineering and the tunnel construction aspects of the line. This was Greathead's forté, but his railway knowledge was slight, so the CLSS commissioned a review from Charles Spagnoletti to consider the electrical engineering aspects of the system.

Although electric traction was a new science and very few people had any practical experience of it, Spagnoletti was as well qualified as anyone to offer advice, having been employed by the Great Western Railway since 1855 as Telegraph Superintendent. In the following years, he designed a block signalling system using the electric telegraph as the communications medium. His system was first applied on the Metropolitan Railway and then on the Great Western. He also designed the signalling for the CLSS. His report on the electric traction proposals appears to have provided the reality check for the CLSS. It must have been obvious by then that the motor car idea was not feasible within the small profile of the 10ft. 2in. diameter tunnels and that a locomotive hauled train was really a much better prospect. Spagnoletti delivered his report on 31 July 1888 and offered some basic ideas to allow them to offer a 3-minute train service.

Just a fortnight after accepting Spagnoletti's report, on 14 August 1888, a new draft specification, this time for the supply of locomotives, separate trailer cars and electrical equipment for the locos and traction power system, was approved by the board and was then sent out to potential suppliers. In what seems to us today as lightning speed, tenders were returned within a month and were opened on the 18 September. They were then sent to the engineers for a technical review, the engineers doubtless including Greathead (as chief engineer) and Spagnoletti. We know that at least Mather & Platt, Siemens and the Anglo-American Brush Electric Light Corporation tendered⁹. There may have been others¹⁰.

Ten days later, on 29 September 1888, Siemens wrote to the Board of Trade (BoT), the government body responsible for approving railway schemes, to inform them of their intention to offer a system of electric traction for the CLSS and to ask them if they were going to approve it. They included with their letter, a copy of their proposal to the CLSS, describing four-car electric trains without locomotives. There was some surprise at the BoT when they got the letter since, just as today, it was supposed to be the railway itself that got the approval not the supplier and it is interesting that, despite the new tender for locomotives and trains having been submitted, Siemens were telling the BoT they were offering motor-car trains. Regardless of that, the BoT had to tell Siemens they would not formally respond but that they would be expecting to hear from the CLSS. In December 1888, the CLSS formally sought approval from the BoT but, by then, the motor car train idea had finally been laid to rest and locomotives were the chosen option.

During the last three months of 1888, the CLSS carried on negotiations with Siemens over the supply of the electrical equipment. On 18 December, the CLSS board formally considered a draft of a contract with Siemens for the supply of 14 locos, 10 x 3-car trains, the necessary generating plant, station lighting and signalling. The contract rather ambitiously required Siemens to deliver an experimental train within eight weeks. Talks apparently continued for another month, doubtless with a suitable break for Christmas, when there was an apparent change of direction.

Printz Holman tells how, on 15 January 1889, William Mather and his electrical engineer Dr. Edward Hopkinson, appeared in London before the CLSS board and presented a new offer from Mather & Platt. The deal that emerged was for M&P to provide locomotives and electrical supply equipment only. Strangely, notwithstanding the months of negotiations with Siemens, Mather's offer was accepted and a contract signed within three days. Siemens were thus, apparently, unceremoniously dumped.

This suggests that Greathead and Spagnoletti had been talking to M&P for some time previously but they were not formally telling the board. This might seem to have been odd behaviour but it is possible that Siemens were being used as a stalking horse to keep Mather & Platt honest in their

⁹ The Anglo-American Brush Electric Light Corporation sold equipment in the UK supplied under patents from the American inventor and electrical engineer Charles Brush. The corporation became Brush Electrical Machines Ltd. and later Brush Traction, based in Loughborough. I worked for them for a time.

¹⁰ A company called 'Series Electrical Traction Syndicate' asked for the return of plans in a letter to the board of 5 April 1889. These plans were probably submitted as part of the September 1888 tendering process; there is, however, no indication of when they were received.

pricing. It was a brutal strategy but it worked. Some years later, Alexander Siemens, cousin to the late William, in a presentation to the British Association in 1893, seemed to confirm this when he said that they'd lost the job on price.

Two weeks after the signing with Mather & Platt, tenders were received in response to an enquiry issued by the CLSS for passenger cars. A board minute of 29 January 1889 records that they received a tender from the Ashbury Railway Carriage & Iron Company for 15 carriages, conditional upon two experimental carriages being delivered within nine weeks and the whole order within six months¹¹. By this time, the CLSS had decided they would order their equipment themselves rather than their original idea to get the contractor to supply the carriages as part of a turnkey contract. This was logical; in their position, I would want the electrical contractor to concentrate on the supplying the technical stuff, which as we have seen, was new and largely untried.

Now that Mather & Platt had the job in the bag, they needed to show that they could deliver. Accordingly, they started work on a trial locomotive. The order for carriages was finally confirmed with Ashbury's in April 1890¹². By now, it had been agreed that the order would, as originally planned, be for 10 x 3-car trains.

To be continued ...

¹¹ BTHR, CSL 1/1, p.243.

¹² BTHR, CSL 1/2, p.37.