# Congested Infrastructure Capacity Analysis

**The Railways (Access, Management and Licensing of Railway Undertakings) Regulations 2016:** – Regulation 27

## North West and Central Region

## North West Route

## Weaver-Crewe

*Congested Infrastructure – Power Capacity*

**Weaver to Crewe Congested Infrastructure Report 1**

25/05/2026

V2.0

# Overview

| Overview | |
|---|---|
| **Infrastructure Manager & Route** | Network Rail, *North West and Central* |
| **Congested Infrastructure (location/ID):** | *NW&C Region, West Coat North Route, Weaver to Crewe* |
| **Regulation declaration is made under:** | Reg 26(2) |
| **Date of declaration (Reg.26(2) ):** | *26/11/2025* |
| **Six-month deadline (Reg. 27(5)):** | *26/05/2026*<br>*(This is the date by which this Analysis was to be produced at the latest and is 6 months from the date of the declaration having been made.)* |
| **One year deadline (Reg. 28 (1)):** | *10/11/2026*<br>*(This is 6 months from the publication of this Analysis and applies to the production of the capacity enhancement plan.)* |
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| **Authorised by:** | *Julien Dehornoy Deputy Region Managing Director*<br>*18 May 2026* |

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| **1.2** | 01/05/2026 | Jade Perry | Chris Winfield | Region Executive Review |
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| References | | | | |
|---|---|---|---|---|
| **Ref.** | Document Name | Document Ref. No. | Date | Rev |
| **1.** | Analytical Assurance Operational Policy (contained in IMS) | **Assurance Policy** | 03/08/2022 | Issue 2 |
| **2.** | Annual Statement 2025 | | 07/2025 | V6 |
| **3.** | May 2026 Timetable Power Assessment | NWC-EP-POW-2025-REP-38 | 09/10/2025 | |
| **4.** | Preliminary December<br>2026 Timetable Power Assessment | NWC-EP-POW-2026-REP-43 | 26/01/2026 | |
| **5.** | Management of Congested Infrastructure Network Rail's Code of Practice | | 2024 | |
| **6.** | Energy Networks Association (ENA) Engineering Recommendation P24 | ENA EREC P24 | 2020 | Issue 2 |
| **7.** | Annual Statement 2026 | | 31/03/2026 | |

| Key term | Explanation |
|---|---|
| **Asset - Cable** | A conductor that is insulated to prevent electric shock, and used to transfer power over long distances such as at traction power supply points. The size of the cable limits the amount of the power that can be moved. If a cable is overloaded it can get hot and resulting in a circuit breaker trip or even catch fire in extreme cases. |
| **Asset - Switchgear – including K11 switchgear** | Switchgear is equipment that manages sections of high-voltage power by switching it on or off and disconnecting faulty parts of the system, helping protect trains and the railway when a problem occurs. If old oil filled switchgear gets hot from too much load it can lead to localised hot spots, rapid insulation degradation and eventual catastrophic failure. Heating can also cause degradation of the oil and gas generation, resulting in the circuit breaker being unable to clear a traction fault, and causing catastrophic failure. |
| **Asset - Transformer** | A transformer is a piece of electrical equipment that changes the power coming from the grid into the right voltage needed for trains to run safely. |
| **Bi-mode train** | A train which operates under two or more traction types, most commonly DEMU – diesel electric multiple units or BEMU – battery electric multiple units. It should be noted that a battery unit would be assumed to being charging when operating on an electrified section of the railway and therefore would still contribute to electrical load issues. |
| **Energy Supplier Limit / FSC** | This is a cap on the amount of power the railway should draw. This is a contractual limit but is often set in relation to the capability of the energy suppliers' own assets. |
| **Low Voltages** | This is in relation to High Voltage and references when the 25kV is operating at lower Voltage levels than expected. Not to be confused with Low Voltage such as is |

| | |
|---|---|
| | used for signalling supplies, points heating or station facilities etc. Low Voltage is legally anything <1000V (AC network). |
| **N-1** | "N" stands for the total number of critical components needed to operate the railway). N-1 contingency criterion is a reliability standard used in power system planning and operation. It assesses the system to ensure it is able withstand the loss or failure of any single major component—such as a transformer, switchgear, cable or substation—without causing service disruption. |
| **Power trip** | When the power system experiences too much load and switches itself off – like a fuse tripping. This may last several minutes and requires ECR to reset the switch. However, the load may damage the assets meaning the fault cannot be reset without works. |
| **Traction power** | The power used to run trains |

| **Abbreviations** | |
|---|---|
| **Abbreviations / Acronyms / Initialisms** | **Meaning** |
| **AT** | Auto Transformer |
| **ATFS** | Auto Transformer Feeder Station |
| **ATT** | Advanced Timetable Team |
| **AWC** | Avanti West Coast |
| **CoP** | Code of Practice |
| **CP** | Control Period |
| **DIRFT** | Daventry International Rail Freight Terminal |
| **DMU** | Diesel Multiple Unit |
| **DNO** | Distribution Network Operator |
| **ECO** | Electrical Control Operations |
| **ECR** | Electrical Control Room |
| **ECS** | Empty Coaching Stock |
| **EMU** | Electric Multiple Unit |
| **ESDD** | Engineering Services Design Development |
| **FOC** | Freight operating company |
| **FSC** | Fixed service capacity |
| **GSM-R** | Global System for Mobile Communications – Railway |
| **GSP** | Grid Supply Point |
| **HS2** | High Speed 2 |
| **HST** | High Speed Train |
| **IMS** | Integrated Management System |
| **MVA** | Megavolt-Amperes – kVA /kV - Kilovolt-Amperes/ kilo-Volts |
| **N-1** | (Normal minus one) |
| **NGET** | National Grid Energy Transmission |
| **NPS** | Negative Phase sequence |
| **NR** | Network Rail |
| **NTL** | Northern Trains Limited |
| **NW&C Region** | North West and Central Region |
| **OEM** | Original Equipment Manufacturer |
| **OLE / OHLE** | Overhead Line Equipment |
| **PCB** | Polychlorinated Biphenyl |
| **SOAR** | Sale of access rights |

| | |
|---|---|
| **T&RSMD** | Traction and Rolling Stock Maintenance Depot |
| **TAC** | Track Access Contract |
| **Tiploc** | Timing point location |
| **TOC** | Train operating company |
| **TPH** | Trains per hour |
| **TPR** | Timetable Planning Rules |
| **TPT** | TransPennine Trains |
| **TRU** | Transpennine Route Upgrade |
| **TSC** | Track sectioning cabinet |
| **TSI** | Technical Specifications for Interoperability |
| **TT** | Timetable |
| **WCML** | West Coast Main Line |
| **WCPSU** | West Coast Power Supply Upgrade |
| **WMT** | West Midlands Trains |

# Contents

# Part A: Executive Summary

## A.01 General Overview

Electric demand across the North West & Central Region and the West Midlands has grown quickly as more passenger and freight services replace diesel fleet with electric and bi-mode services. However, the power system that supports these routes has not kept pace. Much of the infrastructure is old, heavily used and already working at its limit. For this reason, this declaration of congested infrastructure has been issued specifically because there is not enough electrical capacity, rather than track capacity.

This constraint limits the number of electric and bi-mode services that can safely operate. When the timetable is busy, or when part of the system is unavailable, demand for traction power can exceed what the equipment can deliver, leading to slower running, reduced performance and increased safety risk of failure and/or fire. These issues are most evident when trains accelerate from low speed such as from station stops or when several services run close together.

The system has little resilience remaining with outages happening more frequently and assets deteriorating faster. As fleets modernise and traffic grows, even small timetable variations, including routine perturbation or service disruption, or freight running early or late and minor changes to timetables (such as retiming a service by +/-10 minutes) can create spikes in electrical demand that the system cannot always absorb.

Operational measures such as reducing traction power, shortening trains, switching bi-modes to diesel or restricting certain services provide only temporary relief and generally worsen passenger experience, performance or network connectivity. None of these options support long-term growth, including the outputs of committed fleet changes and major programmes like TRU and HS2 and all conflict with decarbonisation objectives.

The underlying issue is that the power system on NW&C Region is at full capacity. There is very limited remaining electrical headroom to support additional electric trains, longer formations or future fleet changes. Without investment to modernise key assets and increase power capability, the railway may be forced to cap electric and bi-mode electric services at existing levels from December 2026, meaning any additional service would require removing another—effectively a one-in, one-out situation.

Based on the evidence, the risks associated with current and future electrical loading are reasonably foreseeable, and the consequences of operating without additional power capability are both understood and demonstrable.

## A.02 WCML Weaver-Crewe

The section of the West Coast Main Line between Weaver Junction and Crewe is one of the most intensively used mixed-traffic corridors in the country. It carries high-speed intercity services, regional flows, and heavy freight movements. While the track layout and signalling allow this density of traffic to operate, the electrical power system that supports the corridor can no longer meet the level of traction demand placed upon it. Much of the power infrastructure in this area dates back to the late 1950s, is beyond its intended life and increasingly unable to support modern electric rolling stock.

The area is fed partly through modern equipment at Weaver Junction, but the power supply southwards toward Crewe relies on ageing, oil-filled switchgear and older transformer arrangements that were never designed to handle today's operational pressures. These assets experience high levels of deterioration, frequent tripping, (which in turn reduces the asset life further) and sustained periods across the day where current demand approaches or exceeds operating thresholds. In parallel, voltage levels fall below what modern trains require to accelerate reliably, particularly when several services draw power at once or when the system is in an abnormal (N-1) feeding state, which occurs regularly. During these periods, trains accelerate more slowly or may even be forced to stop for several minutes for minor system trips, impacting performance and resilience and risks causing cascading delays due to tight junction margins with limited flexibility.

The corridor is further stressed by the high density of freight and depot activity. Crewe Basford Hall, Liverpool and other terminal locations generate power peaks as trains depart from standstill, each drawing a high level of current and passing through the feeder area. While track capacity can support these movements, the power system cannot. The impact is not merely operational; the ageing switchgear poses an elevated safety and reliability risk, and the system has reached a point where further load growth cannot be accommodated without breaching electrical safety ratings generating a significant risk of fire or significant failure.

Although limited operational work-arounds exist (primarily bi-mode services operating in diesel), these do not provide a meaningful or sustainable solution. Reducing headways, running trains closer together or running longer trains concentrates electrical load into fewer, but more power-intensive, movements, exacerbating current spikes. Retiming services redistributes peaks rather than removing them and often creates new conflicts elsewhere on the route.  Running services slower (notching back) or switching bi-mode units into diesel reduces electric load only at the cost of slower acceleration and reduced network performance. These actions can temporarily manage risk but cannot expand capacity or restore resilience, because the underlying constraint lies in the physical limitations of the power equipment, not in timetable design.

Whilst immediate safety concerns could be resolved by renewal-only options (replacing the aging oil filled switchgear with a modern equivalent) these would not resolve existing or future power capacity constraints. The primary solution remaining that would address the safety risk and the power capacity problem, restore resilience and enable future growth, would be conversion to modern autotransformer-based traction power systems. This would remove the current bottlenecks, create sufficient electrical headroom for long-term service growth and bring asset condition back within acceptable limits. It would also increase weather resilience. However, this option is dependent on funding, both for design and delivery. Without that investment, the Weaver–Crewe section will remain at the limit of its electrical capability, leading to a requirement to cap electric and bi-mode services at current levels limiting the region’s ability to grow or adapt its timetable in future.

# Part B: Purpose and Legal Basis

Where railway infrastructure has been declared to be congested in accordance with Regulation 26 (1) or (2), the infrastructure manager must undertake a capacity analysis of the congested infrastructure, as set out below, unless a capacity enhancement plan, as described in Regulation 28, is in the process of being implemented.

Where required in accordance with the above paragraph, the infrastructure manager must carry out capacity analysis of the congested infrastructure in order to identify the reasons for the congestion and the measures which might be taken in the short and medium term to ease that congestion.

In conducting the capacity analysis, and in order to identify the reasons for the congestion, the infrastructure manager must consider the—

(a) characteristics of the congested infrastructure;

(b) operating procedures used on that railway infrastructure; and

(c) characteristics of the different rail services which have been allocated capacity to operate on that railway infrastructure.

In seeking to determine measures to alleviate congestion the infrastructure manager must consider, in particular—

(a) re-routing of services;

(b) re-timing of services;

(c) alterations to the line-speed; and

(d) railway infrastructure improvements.

This capacity analysis has been carried out following the curtailment of electric traction train growth, triggering Early Warnings of Congested Infrastructure in July 2024. Assessment of the May 26 timetable as bid indicates that a number of passenger and freight services with rights (firm and contingent) cannot be supported. As it is likely that there will be requests for additional electric traction capacity within the areas where the May 2026 timetable cannot be accommodated, Network Rail has declared this infrastructure to be congested.

## B.01.01 Weaver-Crewe

Network Rail published its declaration of Congested Infrastructure for the WCML rail network between Weaver and Crewe on 26th November 2026.

This was preceded by an Early Warning of Congested infrastructure declaration issued to the industry on 09 July 2024 – Appendix H.02.04.

# Part C: Scope and Study Area

## C.01 Introduction to Congested Power Capacity

The Congested Infrastructure process provides a structured approach for assessing network capacity in relation to operational demand. While this framework is well established for reviewing track capacity, the assessment of power system capacity and capability introduces a broader set of interdependent technical variables. Unlike track capacity, power capacity does not have a single, precisely defined point at which failure will occur. Consequently, assessments rely on informed engineering judgement within an agreed risk appetite. Risk levels are shaped through engagement with train operators and consideration of regulatory performance and cancellation metrics, with emphasis on maintaining safe and reliable operation of the railway. Safety is paramount and is determined by the established safety thresholds for power systems set by Network Rail and National Grid, ensuring that energy system operation remains within limits that protect passengers, staff, and infrastructure.

Given these additional dimensions, this report presents a level of technical detail that goes beyond what is typically required for conventional track-based congestion assessments. This is to ensure that the specific technical factors influencing available power capacity and not spatial constraints alone are fully and transparently represented.

## C.02 Geographic extent (lines, junctions, stations)

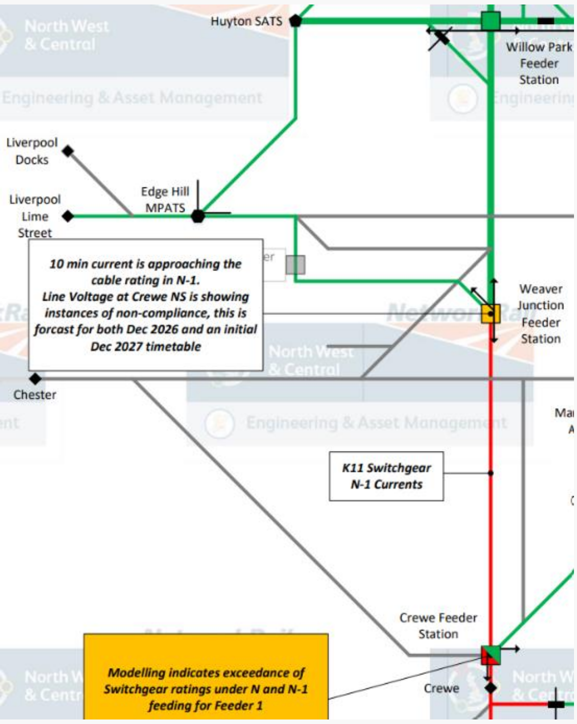
The analysis covers the declared congested infrastructure sections including key junctions, stations, and line segments where capacity constraints have been identified.

### C.02.01 Weaver – Crewe:

| Area | Northern Boundary | | | Southern Boundary | | |
|---|---|---|---|---|---|---|
| | Line of Route | Mileage | Nearest Tiploc | Line of route | Mileage | Nearest Tiploc |
| Weaver Feeding Area – Crewe | CGJ1 | 174 miles<br>53 chains | WEAVERJ | CGJ1 | 158 miles<br>68 chains | CREWECY |

**Table 1 - Weaver – Crewe Congested Infrastructure Boundaries**[1]

[1] Letter of Congested Infrastructure – Weaver Feeding Area – 26/11/25

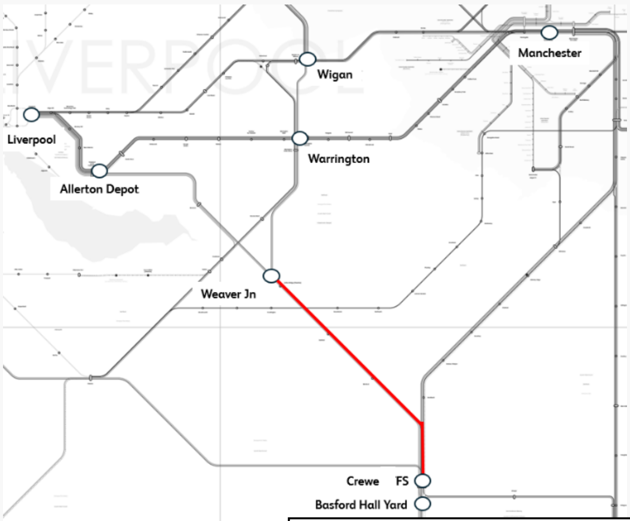


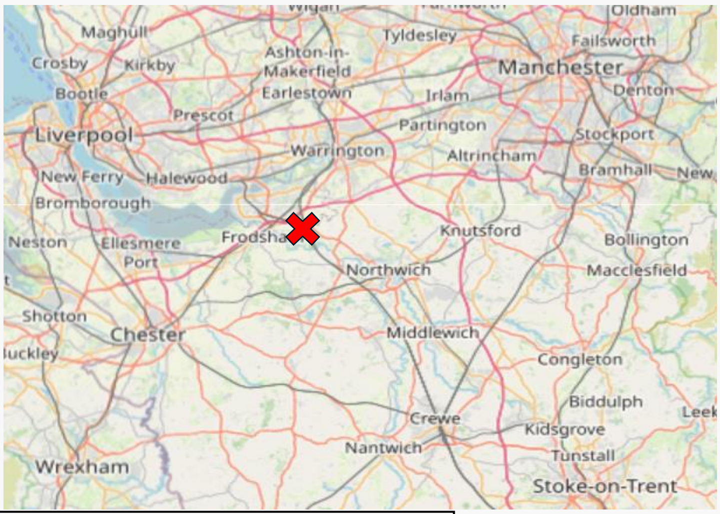

The geographical area extends between Weaver Junction to the north and Crewe Neutral section (circa 1 mile north of Crewe Station).

The tiplocs identified above are the nearest available to ensure the full area is captured within the notice scope.

The geographic scope reflects the operational boundaries relevant to the congestion, including feeder routes where applicable. A map of the declared congested infrastructure is available in the images below.

*Left - West Coast Main Line traction power capacity assessment segment showing Weaver Jn to Crewe neutral section in red.*




*Above – Crewe and Weaver Jn in broader geographical context.*

# C.03 Timeframe and timetable period covered

## C.03.01 Weaver – Crewe:

This analysis applies predominantly to the May and December 2026 timetables. Reference is also made to timetables since May 2022.

# C.04 Background and Context

Over recent years, electric traction has grown rapidly due to service expansion and replacement of diesel fleets with electric or bi-mode rolling stock. These include, but are not limited to, WMT introducing the Class 730 Fleet, AWC replacing diesel Voyagers with the electric and bi-mode class 80X fleet, lengthening of existing electric services and a rise in the amount of electric freight. Further growth and decarbonisation are expected including lengthening of existing services, further fleet changes including in the long term faster and more reliable new HS2 fleet.

This growth and change have outpaced investment in power infrastructure, with planned upgrades in Control Period 5 and 6 deferred due to funding constraints. In 2022 the NW&C Region cited power concerns as a potential barrier to the full rollout of AWC's new electric and bi-mode fleet. In 2024 Network Rail:

- Applied operational length restrictions on new WMT services
- Placed an objection to the Vehicle Change for electric freight Class 93's due to power concerns;
- Issued three Early Warning Notices for Likely Congested Infrastructure, including Weaver-Crewe;

In 2025, Network Rail issued four AWC Contingent Rights and new Open Access applications were not supported by Network Rail due to power limitations.

Against the backdrop of ongoing change and increasing expectations recent incidents demonstrate the sensitivity and fragility of the power system infrastructure, where even rapidly detected and managed failures can generate a disproportionate network impact. For example, two incidents in February 2025 on the WCML South; a fire and a separate power outage on the West Coast Main Line were identified and actioned within five minutes, yet still resulted in significant service disruption, affecting more than 40 trains from a single incident. Similarly, the Dunton oil-filled switchgear explosion on the Anglia route had consequences extending beyond the immediate asset, with impacts felt across an approximate 100-metre radius. These events underline that, in highly utilised corridors, limited headroom reduces the network's ability to absorb shocks, meaning minor or localised failures can rapidly escalate into widespread operational and customer disruption.

**Case Study: North Hyde Substation (Heathrow) Fire March 2025**

At 23:23 on the evening of 20 March 2025, the London Fire Brigade were alerted to a fire at the North Hyde substation in Hayes, which resulted in a blackout at Heathrow and loss of power to 60,000 homes and businesses. The site had K11 switchgear similar to that used on the WCML.

On 20-21 March about 25,000 litres of oil caught fire, with live high-voltage equipment further complicating the task of bringing such a large oil-fuelled fire under control. That the fire was still burning 16 hours after the first emergency call underlines the immediate safety risks of an event like this.

These risks are compounded by the age of the assets in NW&C as well as the increasing volumes of traffic that place a higher load on the equipment. Like the North Hyde incident, catastrophic failures have been known on railway infrastructure including Dunton Feeder Station (2009) and Cheadle Hulme Feeder Station (2001).

## C.04.01 Weaver – Crewe:

The section of the West Coast Main Line (WCML) between Crewe and Weaver Junction is approximately 27 km (17 miles) in length, forming part of the Carlisle Grand Junction Line (ELR: CGJ1). This corridor is one of the most intensively used mixed-traffic sections of railway in the UK, carrying:

- High-speed intercity services
- Regional passenger flows

- Stopping services serving Winsford and Hartford
- Heavy freight movements to/from the Merseyside and North Wales corridors
- Diversionary traffic during blockades on the Trent Valley or Liverpool routes

Weaver Junction Auto Transformer Feeder Station (ATFS) feeds north to Euxton Junction as an AT system utilising modern switchgear, as well as to Liverpool as a part booster classic system using mostly modern switchgear. It feeds south to Crewe Neutral Section as a booster classic system using legacy bulk oil switchgear (K11) that is beyond asset life.

The Crewe-Weaver section contains TSCs at Hartford and Winsford Junction, which allow the feeding to be stopped to specific areas. The effect of failure of this equipment is central to this study because any failure puts considerable strain on the other assets in this part of the network.

The electrical assets on the WCML in the Weaver-Crewe area, in particular the switchgear, were installed in 1959. When installed these assets had an expected life of 50 years with a maximum life of 60 years.

*In 2026 these assets are now seven years beyond their maximum life*

Recent asset assessments show progressive deterioration, primarily due to age-related wear and sustained operational demand. Each time an asset fails it is stressed, this in turn reduces the assets life and causes it to deteriorate faster.  In response, this equipment has been placed under the highest tier of monitoring protocols and is subject to maximum maintenance scheduling to mitigate risk and ensure continuity of service.

In addition, this legacy equipment is housed in buildings that contain asbestos and are deteriorating, particularly at Hartford. This adversely impacts the switchgear. Access is further complicated by the necessity of track access to reach the site as it involves crossing the tracks. With the significant decrease in red zone working, access to the sight is more limited than when the equipment was first installed

**N-1 Power Resilience**

"N" stands for Normal, in essence the total number of critical components needed to operate the railway. Essentially N equates to a single electrical supply with no redundancy, if that supply fails, the equipment it feeds will lose power. N-1 contingency criterion is a reliability standard used in power system planning and operation. It assesses the system to ensure it is able withstand the loss or failure of any single major component—such as a transformer, switchgear, cable or substation—without causing service disruption.

The North Hyde (Heathrow) Substation fire in March 2025 highlighted the importance of recognising early warning signs of potentially high-consequence events.  Similar risk indicators are now present on areas of the WCML, reinforcing the need for proactive measures in the event of a catastrophic failure of the K11 switchgear at Weaver, Hartford, Winsford or Crewe

*Below: Dunton catastrophic failure.*

| Category | Explanation | Resilience level |
|---|---|---|
| N | One supply only. No backup. | Low |
| $N_1$ | Two independent supplies, but only one is needed to run the load. | Medium |
| $N_2$ | Two independent supplies, in addition to the main supply. | High |

**Passenger Timetable Development Challenges:**

As part of the December 2025 timetable development process, AWC submitted bids for four services per day (with contingent rights) to operate between London Euston and Liverpool Lime Street. These consisted of three services in one direction and one in the other, which were identified as unable to be safely accommodated using electric traction due to power system constraints. Mitigation options were presented to the operator, resulting in a partial compromise with services terminating at Crewe (as opposed to Liverpool Lime Street) whereby two of the four services were withdrawn. However, AWC subsequently advised that the removal of these services would also prevent the operation of two additional services between Euston and Liverpool, due to operational interdependencies and resource constraints.

In total, six services are affected:

- Four services withdrawn, including two originally identified as unsupported and two additional services deemed unviable by the operator
- Two services remain in an amended format. Two of the original four services remain in operation but are affected by the compromise.

This outcome highlights the broader network and performance implications of constrained power availability and the limited flexibility in service planning under current infrastructure conditions.

**Freight Timetable development Challenges:**

As part of the May and December 2025 Timetable development freight services with full rights anticipated to operate in electric following the roll-out of new class 99 fleet were included in the Power model of the timetable. These were not additional or new services but existing services which regularly operate. In total, six services are affected. These were all GBRf services Network Rail wrote to GBRf in 2025 seeking to work with them to find a resolution. Options are still being explored.

This outcome highlights the broader network and performance implications of constrained power availability and the limited flexibility in service planning under current infrastructure conditions.

It should be noted that in April 2026 a further one freight train was identified to be impacted by the limited power capacity between Weaver and Crewe.

# Part D: Methodology

## D.01 Data sources (timetable, performance, TPRs, asset capability)

This analysis draws on:

- May and December 2026 Working Timetable (WTT) data
- Timetable Planning Rules (TPRs) 2025 V2 and 4, 2026 V2 and 4
- Sectional Running Times (SRTs) 2025 V2 and 4, 2026 V2 and 4
- Asset capability and signalling data taken from relevant existing asset strategies
- Performance metrics (e.g., delay attribution, headway adherence)
- Periodic [power] tripping analysis for relevant sites
- Monitoring and Metering Data
- Severity Risk Exposure – Corporate Risk Assessment Matrix (CRAM) Score
- Maintenance team reports of building condition.

## D.02 Analytical techniques (e.g., TPR evaluation, capacity utilisation, diagrams, modelling)

The May 2026 timetable (provided by Franchise and Access Management Team) has been modelled across 3 variations.

- Track Access Contracts (TAC) – Fully reflects agreements with TOCs and FOCs.
- Normalised – Reflects closer to real life with reduced train lengths to match more likely service patterns and expected freight loads (e.g. empty stock when applicable).
- Normalised without freight – Normalised with complete removal of Freight services.

Modelling has been undertaken using Vision/Oslo Simulator and results assessed against BS EN 50163, BS EN 50388, and NR/L2/ELP/27275. Assessment of these results has enabled identification of peaks in power draw (Power Loading Peaks) and 10 minute average current through key assets (as required by BS EN standards).

In reviewing modelling outputs, Power Loading Peaks were assessed to ensure any error or duplication removed, any unused services or standby ECS moves were excluded.

### D.02.01 Modelling

Whilst power modelling provides a robust and evidence-based understanding of how the electrical system performs, it is important to acknowledge that a model is, by its nature, a representation of a complex real-world environment. Models cannot capture every operational variable, such as driver behaviour, localised voltage fluctuations, or unplanned network events. Absolute precision therefore cannot be guaranteed. However, despite these inherent limitations, the modelling outputs consistently offer a reliable and meaningful indication of system behaviour. When interpreted alongside engineering judgement and operational context, these results provide a sound basis for understanding network performance, identifying emerging constraints, and supporting informed decision making.

Network Rail has undertaken regional power modelling since 2022, and the power modelling has produced consistent results, providing a clear trend of steadily worsening power constraints as additional services and newer rolling stock have been introduced to the network. The progressive tightening of available electrical headroom shown in the modelling aligns closely with operational evidence, particularly the increased frequency of power related issues, the growing number of trips, and the pressure placed on ageing assets despite ongoing maintenance efforts. Taken together, the modelling outputs and observed performance trends present a coherent picture: the system is becoming increasingly constrained, and the results from the model reliably reflect the real-world deterioration in network performance.

Power modelling is undertaken using Vison/Oslo simulator. It models realistic train movements, power demand and voltage behaviour. The system is also designed to include alternate feeding arrangements.

Power modelling assesses a specific timetable, with defined rolling stock types and lengths over a full day, allowing for greater accuracy. The model is based on all services operating to time, which is often a very optimistic situation when contrasted against the perturbations that commonly occur. Metered data from grid supply points taken over long periods is used to help validate modelling outputs. Modelled results that are within 10-15 % of the metered data can be considered an appropriate prediction.

The power infrastructure in the model is derived from asset data. Electrical infrastructure parameters are assessed against BS EN 50163, BS EN 50388, and NR/L2/ELP/27275. The proposed timetable is then assessed against asset capability in line with these parameters.

Electrical Assets such as switchgear and cables exist in different forms with different design limits. One of the most critical assets is oil filled switchgear which is life-expired with no maintenance (OEM) support and very limited spares available, with high rates of degradation already measured and managed through enhanced maintenance. As such, rating exceedance in oil filled switchgear is considered intolerable, representing both significant safety and performance risk.

All modelling is assured by qualified engineers, externally approved where required, and finally reviewed and signed off by senior regional engineering leadership. By using a consistent team and incremental timetable updates, Network Rail maintains a stable, repeatable and robust modelling approach. Network Rail works closely with TOCs and FOCs to validate timetable, fleet and operational data, ensuring freight growth assumptions, ECS movements and service patterns are accurately represented. This includes industry testing to confirm that real world behaviours are correctly captured in the modelling so that outputs reflect genuine operational conditions. This includes, for freight, the use of Y Paths, variations in electric operation, or services running empty and therefore lighter than their timed trailing load. For passenger services the modelling references services with rights (firm, contingent and new) and works alongside the Sale of Access Rights Process (SOAR) and bid applications to ensure accurate data. *See Supplementary information* [i]

## D.02.02 Capacity Assessment

A traction power capacity assessment investigates the power consumption at a feeder station against the contractual limit in place, which is called the Firm Service Capacity (FSC). This is set through an agreement with the Distribution Network Operator (DNO) or Transmission Network Operator (TNO), also referred to as supplier or energy supplier.

## D.02.03 Switchgear and Cable Rating Assessment

10-minute average current draw of the train service through the assets is used to assess how the train service will affect the asset condition and safe operation of switchgear and cables. Should these ratings be breached, asset degradation can accelerate, and there is an increased risk of asset failure as well as the creation of unsafe conditions for staff using the equipment. This averaging time is aligned with BS EN 50388 Annex A for Thermal Loading of assets.

## D.02.04 Negative Phase Sequence

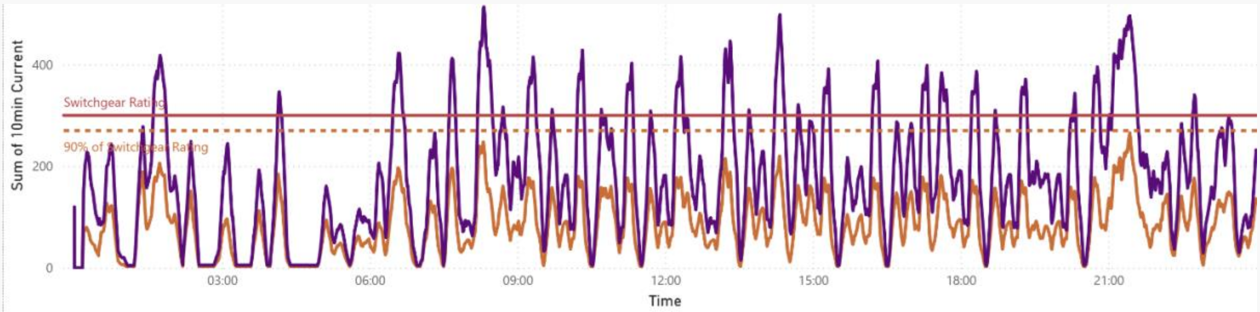
Negative Phase Sequence is a measure of imbalance that Network Rail export onto the DNO and TNO network. Network Rail are legally obliged to remain within the imposed limits. When this is breached there is a risk of affecting non-railway infrastructure, in particular that which uses rotating machines.

## D.02.05 N-1 Arrangements

N-1 arrangements describe abnormal feeding arrangements, these can be due to failure of a supply point or failure of any single piece of equipment as well as planned maintenance works conducted by Network rail or the DNO/TNO. Network Rail uses Alternative Feeding Diagrams to plan for supply failures. Network Rail licence conditions stipulate the rail system should be able to support a full timetable in N-1 feeding arrangements. This is also stipulated in NR/L1/ELP/27000 Policy Requirements for Electrical Power Assets.

Upon reviewing the outputs from the power modelling of the May 2026 timetable (as bid), Network Rail highlighted power loading peaks where asset ratings in the Weaver Feeding area were predicted to exceed 100 % of their design rating in N-1 feeding arrangements. As this area experiences N-1 scenarios almost daily (for varying durations lasting from a few minutes to the entire day) during which point the oil filled switchgear is at a high risk of failure and the asset degrades faster it was agreed that the power load within these peaks should be reduced where practicable.

These peaks span the full day with the first peaks appearing at c.01.30 in the morning with the last peaks at c.22.30. However, peaks above 90 % (industry standard full capacity levels start at around 01:00 and finish at around 21.30. (Below December 26).



# Part E: Analysis Required by Regulation 27(2) / NR CoP 3.6.2

## E.01 Characteristics of the congested infrastructure (layout, signalling, line speed, gradients) – Reg. 27(2)(a) / NR CoP 3.6.2(a)

### E.01.01 3.6.2.a General Overview – Load on the NW&C Regional Power System.

#### Increasing Electrical Demand

Over recent years, electric traction has grown rapidly due to service expansion and replacement of diesel fleets with electric or bi-mode rolling stock. This growth and change have outpaced investment in power infrastructure. Planned upgrades in Control Period 4, 5 and 6 were deferred due to funding constraints.

Specifically, the WCML Power Supply Upgrade finished initial design in CP4 (2009-2014) and major design was underway by CP5 before elements including a new power supply near Preston, Auto Transformer feeding on the WCML from Weaver to Crewe to Whitmore and the WCML South were deferred. This project was intended to increase power supply to the WCML and replace the aging K11 switchgear and the older booster transformation 'classic' 25kV system now constraining power capacity.

#### Lessons from Past Incidents

The North Hyde (Heathrow) fire incident highlighted the importance of recognising early warning signs and the potential impact critical power failures. Similar risk indicators are now present on areas of the WCML, reinforcing the need for proactive measures.

### General Overview - Power Assets and Failure Risk.

Across the NW&C network, power assets are a single point of vulnerability in a region that carries around 246.5 million passenger journeys every year—roughly 675,000 journeys every day. Any failure in traction power, switchgear, transformers, or feeder cables can therefore have an immediate and disproportionate impact on passenger movement, service reliability, and economic activity.

The power system is designed to supply traction power at 25kV. When the system voltage falls significantly below the nominal 25kV, particularly below (approximately) 19kV, train performance and service delivery are directly affected.

**Technical Specifications for Interoperability**

Under the Technical Specifications for Interoperability (TSIs), UK electric rolling stock is required to operate within the defined voltage range set out for the 25 kV AC subsystem. TSI-compliant trains are designed and tested to function safely and reliably only when the OLE voltage remains within the permitted limits, with 17.5kV recognised as the lower boundary at which full traction performance can be assured. Below this threshold, onboard protection systems restrict power draw to prevent equipment damage, leading to loss of traction. As a result, TSI-compliant fleets and cannot be relied upon for normal timetable delivery at <19kV.

At these reduced voltages, train power systems are typically forced to limit or reduce power draw to protect onboard equipment and maintain compliance with applicable standards. This manifests as slower acceleration, reduced maximum speed on rising gradients, and extended journey times. In more severe cases, onboard protection systems may intervene, leading to traction power being temporarily lost and trains stopping or trains being unable to restart without operator intervention.

From a network performance perspective, operation at voltages below 19kV (which is considered the lowest permitted permanent Voltage) can result in:

- Slower acceleration and therefore longer sectional running times, creating a performance reduction.
- Knock on delays to following services particularly on intensively used or mixed traffic routes like the WCML.
- An increased risk of service cancellations
- A reduced ability to recover from perturbation
- The inability for TSI compliant trains to operate, or operate at significantly reduced performance

While short duration Voltage dips are tolerable for the majority of services, persistent or repeated operation at voltages below 19kV indicates that the traction power system is not providing the expected 'quality' of power through the OLE system to trains. For a modern electrified railway, maintaining system Voltage within the specified range is therefore not only a technical requirement but an enabler of reliable, punctual and resilient train services.

## E.01.02 Alternate feeding and power resilience

Being able to operate a railway in the event of a loss of a key piece of equipment is essential to maintaining services levels, performance and deliver a safe running railway. This level of resilience is referred to as N-1.

Network Rail uses Alternate Feeding Diagrams to plan how the railway's traction power system reroutes electricity to keep trains moving when a primary piece of power infrastructure becomes unavailable. This could be for planned maintenance by Network Rail or the power supplier (e.g. National Grid), planned projects, unplanned disruption or asset failure. It is a core resilience feature of modern rail networks.

In normal operation, each section of railway is supplied from its nearest traction substation. Under an alternate feeding scenario, that same section can instead be supplied from a neighbouring substation or an independent feeder route. This ensures continuity of service even if a single asset fails.

> **Alternate Feeding Example**
>
> If Substation A loses a transformer, the railway section it normally powers can be fed from Substation B instead. Passengers notice no difference; trains continue running because the system has built-in flexibility to "borrow" power from the next location along the route.

### Safe By design

As part of its Network Licence Conditions, Network Rail secures the operation and maintenance of the network, whilst taking regard of best practice and funding. The expectation to maintain the full timetable in the event of a single failure aligns with the intent of Condition 1, especially where it affects safety, reliability, or service delivery. This is also stipulated in NR/L1/ELP/27000 Policy Requirements for Electrical Power Assets.

Other legal and regulatory frameworks include:

- **Railways and Other Guided Transport Systems (Safety) Regulations 2006 (ROGS)** requires a safety management system and risk-based control measures for infrastructure and operations.
- **Electricity at Work Regulations 1989** imposes duties to prevent danger from electrical systems. This includes proper protection, fault clearance and safe continuity of supply.

- **ORR Targets** the ORR sets regulated targets for performance which it expects NR to meet in order to provide a reliable service to customers.
- **ORR guidance and Railway Group Standards** are guidance on infrastructure risk, power supplies and control systems expects robust, fault tolerant design consistent with good engineering practice and relevant EN standards.

These following railway EN standards are used when designing and operating the power system – See Appendix H.02.01/02. In relation to managing resilience and N-1 capability the following specifically cover design parameters for how sections deliver N-1 supply security, feeders and paralleling are arranged to tolerate a single outage.

- **EN 50119 – Railway applications – Fixed installations – Overhead contact lines**
- **EN 50126 series (RAMS)**

## Insurance Risk

Failures of power equipment and subsequent costs and losses would normally be covered by Network Rail's business insurance however it should be considered that for a claim to be covered under an insurance policy, the loss must be fortuitous, in the circumstances outlined, Network Rail are aware of the likelihood of a loss occurring and the proximate cause which may therefore lead to insurers repudiating policy coverage. *See supplementary information*[ii].

## E.01.03 Power Assets and Failure Risk Weaver- Crewe.

K11 bulk oil switchgear, widely installed on the West Coast Main Line from 1959 into the 1960s, is now operating beyond its original design life. Recent asset assessments show progressive deterioration in principle electrical switchgear, primarily due to age-related wear and sustained operational demand. In response, this equipment has been placed under the highest tier of monitoring protocols and is subject to maximum maintenance scheduling to mitigate risk and ensure continuity of service. This relies on regular oil sampling, dissolved moisture analysis, and breakdown voltage testing. Where moisture levels exceed acceptable thresholds, the oil is fully replaced, restoring dielectric strength. The traction power load placed on the system directly affects to the number of trips and therefore also the safety and railway performance impact of the K11 equipment.

Disruption has a knock-on-effect across the network. In February 2025 a feeder Station on the WCML was out of action for 3 minutes – this triggered 90 minutes of overall delay.

### Case Study: High Moisture Levels in K11 Oil-Filled Switchgear

One of the most significant age-related degradation mechanisms of K11 bulk-oil switchgear is moisture ingress into the insulating oil. Over decades, seals harden, gaskets lose elasticity, and tank welds experience micro-cracking. These pathways allow atmospheric moisture to diffuse into the oil, gradually reducing its dielectric strength. The large oil volume and the absence of modern moisture-barrier systems mean that even small ingress rates accumulate over time.

High moisture levels directly affect asset performance. Moisture lowers the oil's breakdown voltage, increasing the likelihood of internal flashover during switching or fault conditions. It also accelerates the degradation of cellulose insulation and metallic components, creating sludge and gas that further compromise reliability. Because K11 units rely on oil for both insulation and arc-quenching, any reduction in oil quality has a disproportionate impact on safety and operational resilience. These events would remove the switchgear and the section of the railway it supports from use. As there are very limited spares it is likely the equipment would be out of action from 6 months to 2 years.

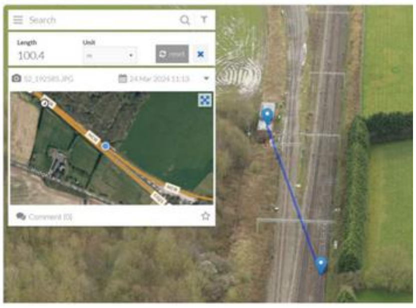
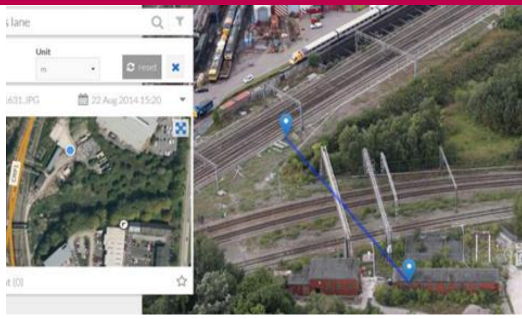
Failures in K11 switchgear can be severe. When moisture-degraded oil fails to withstand electrical stress, an internal arc can form. The arc rapidly vaporises oil, generating high-pressure gases within the sealed tank. If the pressure rises faster than the tank can vent or withstand, the result can be an explosive rupture, ejecting oil and debris. These events are rare (Dunton in Anglia and North Hyde (Heathrow) being two prominent examples), but well-documented and whilst replacement of the oil reduces the risk of catastrophic failure it does not alleviate the root cause and as such the risk remains.

## Short term Impact of a significant switchgear failure on the WCML

The Weaver to Crewe Feeding area comprises four Feeder Sites; Weaver, Hartford, Winsford and Crewe. Taking data from past incidents, it would be reasonable to assume a significant failure – like Dunton or Primrose Hill (right) would impact up to a 100m radius. *See supplementary information* [iii]

The January 2026 Primrose Hill incident particularly highlights the vulnerability of the West Coast Main Line where a single infrastructure-adjacent fire caused national intercity disruption.

In the event of a similar failure, there are contingency plans in place that set out the actions for loss of signalling or lines - the impact will be highly disruptive. The table below illustrates the potential impact to the NW&C Region railway and lineside neighbours. See Appendix H.02.03.

| Hartford | Winsford | Crewe |
|---|---|---|
|  |  |  |
| Hartford has the potential to damage OLE equipment and track assets. Any failure would be expected to compromise the building entirely and as such all electric provision from the site. | Winsford is within 100m of a main road, a housing estate and Winsford Station itself. With a catastrophic failure posing a significant risk to railway and non-railway users | Crewe FS is within 100m of significant amounts of infrastructure, including grid supply DPDs, signalling equipment rooms and the WCML and Crewe-Manchester line. A significant failure poses a raised risk of disruption to the railway and travelling public. |

Using Moira data inspector (based on ticket sales data) there are an estimated 10,513,238 journeys per annum over the Crewe-Winsford arc.  This is all passengers on services travelling through the Weaver to Crewe feeding area with journeys including Liverpool-Euston, Glasgow-Euston, Glasgow/Edinburgh-Euston (via Birmingham) and Liverpool-Birmingham.

This equates to circa 29,000 passengers per day (both directions) or 1,600 per hour (assuming 18 hours per day will have services running). This informs the level of passenger disruption that could be expected in the event of a significant failure that damages lineside infrastructure.

Appendix H.02.03 Recovery of Traction Distribution Equipment Following Catastrophic Failure -states the process in place to manage the technical aspects of a catastrophic failure.

## Longer-Term Impact of a significant switchgear failure on the WCML

There is currently no European based manufacturer of K11 equipment and very limited spares across the UK. Depending on the level of failure, the K11 equipment could be out of action from 6 months to 2 years. This would trigger an extended disruption plan. The longer-term impact of a sustained planned disruption on the WCML between Weaver to Crewe is expected to be to a scale consistent with

- 1 long distance Manchester - Euston TPH in each direction cancelled
- Euston - Glasgow services diverted via Manchester with an extended journey times.
- Euston to Liverpool – diverted via the independent lines – likely 20 minute journey time penalty
- Euston to Holyhead – runs Chester to Holyhead only.
- No electric EMR trains - in particular the existing Birmingham to Liverpool service in each direction would likely be terminated at Crewe
- TfW no electric services
- Weekday freight would also be significantly disrupted, routing of some services via the Bolton Line and through Manchester would be an option outside core times – which would likely lead to some freight cancellations.

## Existing Monitoring and Maintenance regime.

At present, circuit breaker trips are occurring more frequently than the standard maintenance regime expects, averaging 17 times per month across the Weaver-Crewe section. This is adding unsustainable labour and cost to ensuring that switchgear can operate safely because every trip requires a physical inspection of the equipment.

In conjunction with this, the design standard for the maintenance of K11 to manage risk is a 2-yearly inspection, strip-down and oil change, known as a 'B service' to maintain safe operations and reduce risk of failure. This involves the removal, replacement and disposal of circa 135 litres of hazardous waste. After 30 trips, this full service must be done regardless of the time within that two-year cycle. Owing to the risk imported by the K11 population, Technical Authority updated the standards governing maintenance in December 2024 to include 'partial discharge' measurement because of the suspected degrading asset population. This had not always been a requirement. At the moment, this means that some of the circuit breakers are receiving T30 services every 6-9 months.

Safe disposal of mineral insulating oil on the UK railway follows strict environmental rules: the oil must be sampled for PCB content, stored securely as hazardous waste, and removed only by a licensed waste contractor. The process is tightly regulated because insulating oil is classified as hazardous waste even when PCB levels are low. This has further human safety and railway disruption impact, particularly at Hartford due to the constrained site and difficulty of access.

## E.01.04 Key Equipment Failures (N-1) Weaver to Crewe Alternate feeding and power resilience

In the Weaver-Crewe section of the WCML there are a number of alternate scenarios for power regulation and management in the event of a loss of a key piece of equipment. The most onerous of these, a situation that the region faces circa monthly, is the Hairpin feeding arrangement.

The Hairpin feed addresses an N-1 state where a switch, breaker or other asset is out of use at Hartford TSC. *See Supplementary information*[iv]

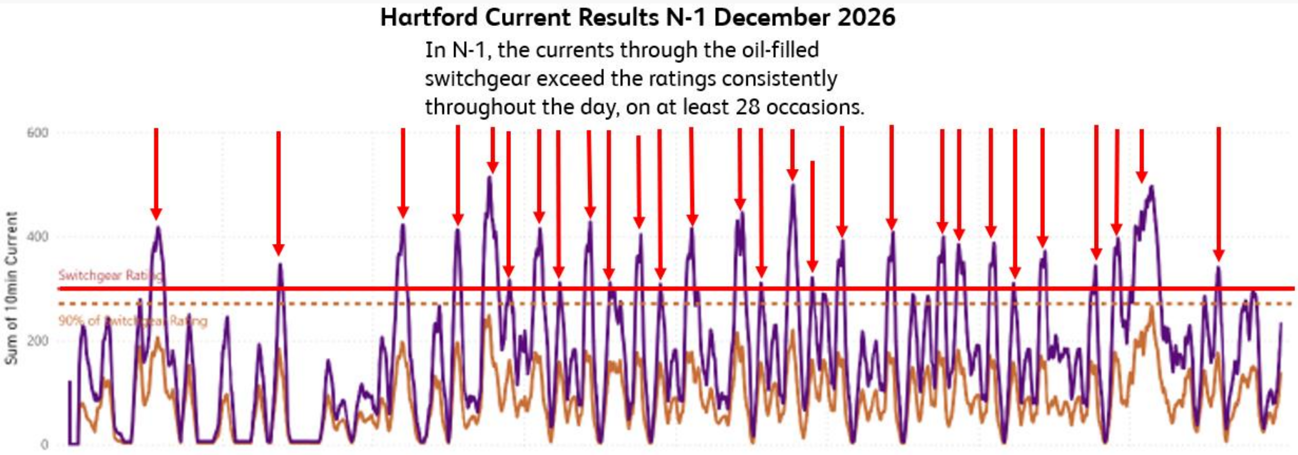
As shown in the table below, operation in the Hairpin configuration can place the assets under significant stress when sustained at high load levels, particularly where asset condition is degraded. Under these circumstances, prolonged operation would increase the risk of breaching licence conditions.

| Model | Location | Voltages <19kV for 2mins or more | Voltage Instances under 17.5kV | Voltage Instances 17.5kV - 19.5kV | 20min Avg. Current between 250A & 270A for 2mins | 20min Avg. Current Instances between 270A & 300A | 20min Avg. Current Instances Over 300A |
|---|---|---|---|---|---|---|---|
| Hairpin (Classic) | Weaver OLE | 0 | 0 | 0 | 3 | 130 | 95 |
| | Hartford Breakers | 0 | 0 | 4 | 0 | 119 | 49 |
| | Hartford OLE | 1 | 48 | 164 | 0 | 0 | 0 |
| | Crewe OLE | 1 | 34 | 196 | 0 | 0 | 0 |

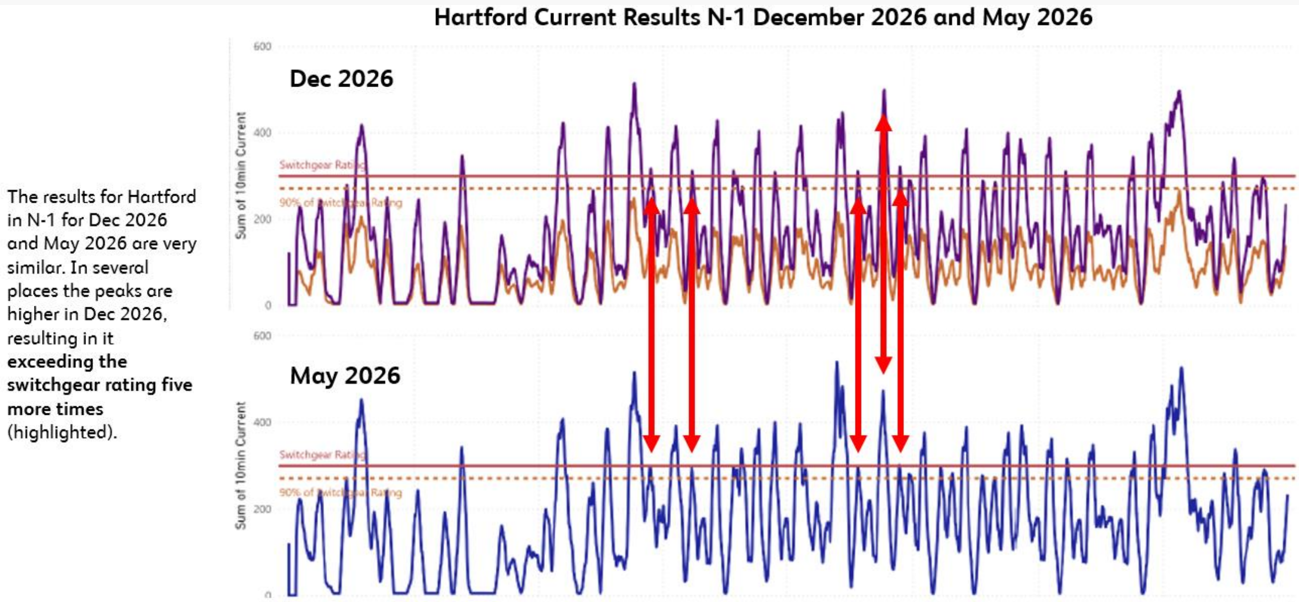
The Hairpin feeding arrangement remains a safe and compliant operating configuration when used within its design parameters. Where base demand is managed and loading remains within acceptable limits, the arrangement provides a viable contingency solution. Extended use beyond short durations (greater than 24 hours) is undesirable, as it is expected to result in reduced performance and accelerated asset degradation, rather than an immediate safety concern.

## E.01.05 Power Modelling Results for Weaver-Crewe (including Hartford and Winsford)

Modelling for N-1 scenarios in the December 2026 timetables shows switchgear ratings being consistently exceeded throughout the day. The consequences of which are increased and faster asset degradation, triggering more frequent failures, performance impacts and an increased risk of fire or catastrophic failure. Each peak represents the asset under conditions that exceed its design parameters, resulting in increased thermal stress.



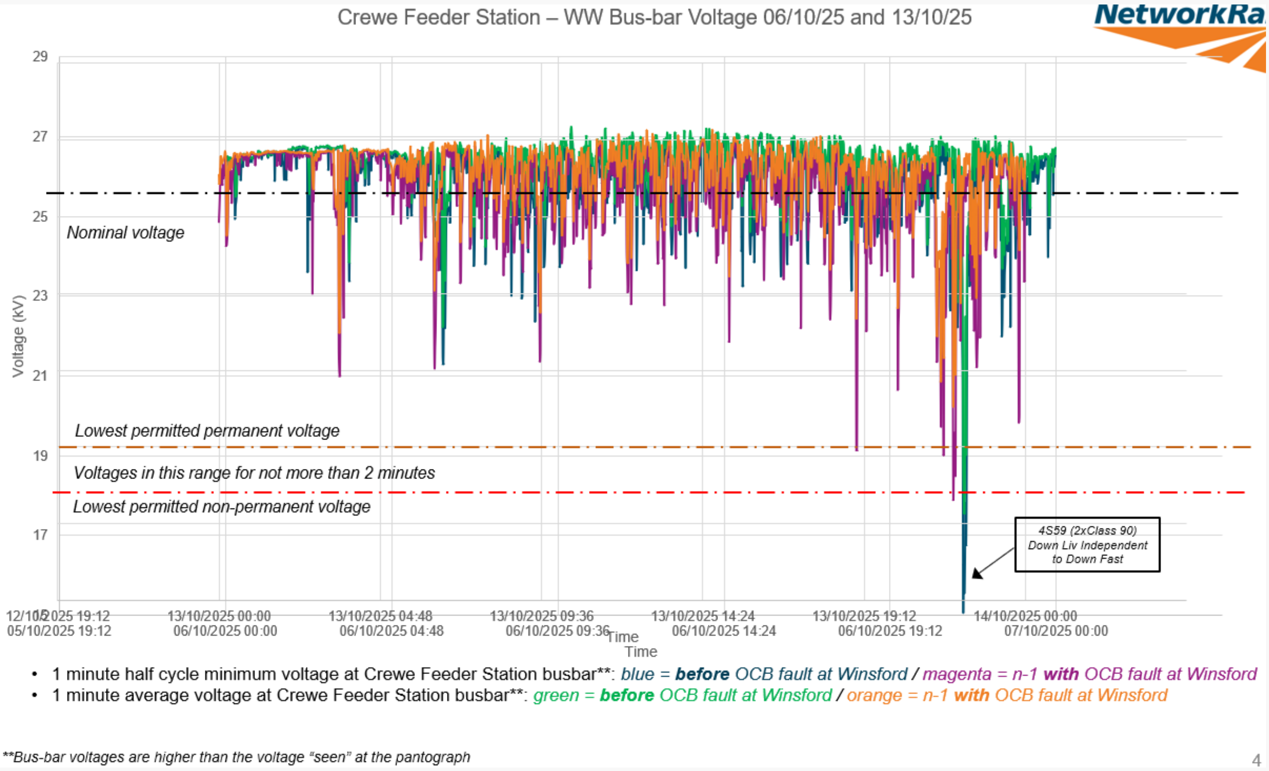

This is an increase in power loading peaks from the May 2026 timetable model. This is triggered by minor changes including retiming and the return of a temporarily paused service.




The supply south to Crewe neutral section, and west to Liverpool, suffers from poor voltage regulation. This can lead to low voltages (<18kV) which affects acceleration and may cause trains to stop for short periods. *For more information see* [v]

Using Crewe Feeder Station data this chart shows the impact of a powerful freight train 4S59 (in this case a double headed Class 90) on the power system in normal operations (blue and green lines). When this planned service coincides with other services, it draws the voltage level below 17.5kV. This is the point where some trains will not operate and the majority will suffer very poor acceleration for several minutes.

The graph also shows the impact to voltage under N-1 conditions without the additional freight train (orange and magenta lines).




## E.01.06 Technical Authority independent CRAM Risk Assessment

The Network Rail Technical Authority (TA) have completed Corporate Risk Assessment Matrix (CRAM) assessments based on normal feeding and N-1 contingency feeding of electrical plant at grid infeed points. against:

- Thermal load rating of equipment
- Contractual load limit (Firm Service Capacity)
- Unintended loss of traction supplies due to load tripping
- Power quality (negative phase sequence (NPS)) exceedances
- Poor train voltage (note this does not assess or indicate poor train running times)

The full CRAM report is attached as Appendix H.02.06, which details the full parameters of the assessment. *For more information see* [vi]

## CRAM Risk scoring Weaver-Crewe

**Present day traction power constraints**

| Rank (Top 10) | Geographical Area | Region | Train service | Train Service delivery CRAM (Impact + Likelihood) | Political & Stakeholder CRAM (Impact + Likelihood) |
|---|---|---|---|---|---|
| 1 | Weaver Junction | NW&C | Now (2022) | 2 + 5 = 7 | 2 + 5 = 7 |
| 9 | Crewe | NW&C | Now (2022) | 1 + 5 = 6 | 2 + 5 = 7 |

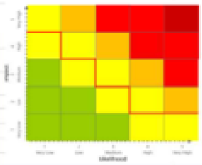
**CRAM score (impact + likelihood)**

1 to 4 = Minor Risk (Green)

5 to 6 = Significant Risk (Yellow)

7 = Major Risk (Amber)

8 to 10 = Critical Risk (Red)



| | | CRAM impact score | | |
|---|---|---|---|---|
| Impact area | Sub-category | 1 | 2 | 3 |
| Train service delivery | Network disruption (single event) | Disruption, <1 day, single route | Disruption for >1 day and <3 days on a single route | Disruption > 3 days < 7 days, single route |
| | Network disruption (long-term) | Missed train service delivery targets for > 1 period - single operator | Missed train service delivery targets for multiple operators over a period or a single operator for multiple periods. | Missed train service delivery targets for - 3 months, multiple operators, 1 year single operator |
| | Service delivery | Poor performance, negligible/ minor customer disruption | Poor performance causing moderate customer disruption as a result which may continue intermittently for up to 1 week. | Poor performance, negligible/ minor customer (one or more customers) disruption for <1 week |
| Political & Stakeholder | Media and stakeholders | Short-term negative local stakeholder reaction | Negative local media coverage over a medium- term period driving localised stakeholder concern. | |
| | Legal | Minor legal issues, non-compliance or breach of regulation. Minor out of court settlement. | Breach of regulation with investigation or report to authority with prosecution and/or moderate fine possible. Limited to parties involved but outcome uncertain. | |
| | Regulatory | No ORR action | Risk scores 1 – 2 on the ORR regulatory escalator. | |
| | Government | Short term loss of morale with poor performance of non-critical activities. | Risk event drives local government interest. | |
| | Internal | Minor disengagement. Effectiveness / efficiency compromised with service failures in non-critical activities. | | |

| Likelihood - CRAM likelihood score and descrition | |
|---|---|
| 4 | ≥50%, ≤70%. Risk would occur between 1 and 5 times a year. High likelihood the risk will occur |
| 5 | ≥75%. Risk would occur 5 times a year or more. Very high likelihood the risk will occur |

# E.01.07 The impact of depots on the power system

Each depot and freight terminal between Crewe, Liverpool and Wigan impacts on, and is dual-dependent with, both the 25kV traction power system and the local distribution network. Traction substations at Crewe, Weaver, Warrington, Liverpool and Wigan provide the access to the main line. What makes the depots critical is that they are the origin and destination of ECS moves, which present units at the right place and time for the working timetable. The first and last movements of the day (and often off-peak berthing) create concentrated bursts of power demand as multiple units draw high current simultaneously while accelerating from standstill onto the main line. This is very different from a single train running through the area at line speed: acceleration from low speed is where traction current is highest, so clustered ECS departures and arrivals can drive short-duration power peaks on the 25kV system.

In practical terms, this means that depot operation is a power-critical activity, not just a logistical one. If traction power is constrained or a substation is out of service, the railway may still be technically “open”, but the inability to power ECS moves can prevent units from reaching their starting stations. Conversely, well-coordinated ECS planning and an understanding of these acceleration-driven peaks are key to managing substation loading, avoiding nuisance trips, and maintaining a resilient service pattern across the Crewe–Liverpool–Wigan corridor.

### Depots that impact on the Weaver- Crewe power system

There are 14 depots relative to WCML Weaver-Crewe feeding area. Six support passenger services;

1. Wigan Springs Branch Depot – Wigan
2. Allerton Depot – South Liverpool
3. Edge Hill Depot – Liverpool
4. Kirkdale Depot – North Liverpool (Merseyrail)
5. Crewe LNWR Depot – Crewe
6. Crewe Carriage Sidings – Crewe

Whilst a further eight support freight services:

1. Warrington Arpley Yard – Warrington
2. Bank Quay Sidings – Warrington
3. Ditton Freight Terminal – Widnes

4. Garston Freightliner Terminal – Liverpool
5. Seaforth Intermodal Terminal – Port of Liverpool
6. Liverpool Bulk Terminal (Seaforth) – Bulk freight
7. Basford Hall Yard – Crewe
8. Gresty Bridge (DB Cargo Depot) – Crewe

# E.02 Operating procedures used (rules, margins, traffic management) – Reg. 27(2)(b) / / NR CoP 3.6.2(b)

## E.02.01 3.6.2.b General Overview Power Operational controls

### Operational Controls Available Under Traction-Power Constraint and Their Impacts

When the 25kV traction power system approaches its operational limits due to asset failure, extended feeding arrangements, or high concurrent electrical load, Network Rail and TOCs may use operational controls to maintain system stability. These controls can reduce instantaneous power draw but typically introduce performance trade-offs. The following outlines the principal measures, their operational effect, and the associated impact on passengers, timetable robustness, and network performance.

### Notching Back (Traction Power Reduction)

Notching back is a targeted intervention where electric trains operate with reduced traction power, particularly during acceleration phases. Typically, this would be a reduction down to 75 % of full power.

Operational effect:

- Reduces instantaneous current draw at feeder stations and intermediate substations.
- Limits acceleration rate and caps traction output during power-critical periods.

Impact on services:

- Slower acceleration: trains take longer to reach and maintain line speed.
- Longer sectional running times: journey-time extensions, particularly noticeable on high-frequency or mixed-traffic main lines.
- Compression of timetable margins, increasing the risk of reactionary delay if multiple trains notch back concurrently.
- The WCML currently has the lowest punctuality rate in UK rail a position that would be worsened with this mitigation.

Overall, whilst notching back helps manage short-term power peaks, it degrades timetable performance and will reduce network resilience during perturbation. *See also running shorter formations in Section F.*

### Restricting Certain Electric Services

In some constrained scenarios, specific flows (e.g., contingent rights or diversionary services) may be asked not to operate in electric mode or to avoid electric operation through constrained sections. *See also operating bi-mode trains in diesel in section F.*

**Operational effect:**

- Reduces peak electrical load on highly stressed feeder areas.

- Supports resilience when in N-1 scenarios, perturbation or extended feeding arrangements are already in place.

**Impact on services:**

- This may create performance improvements as fewer services are operating, however surrounding services will be more crowded which could trigger additional delays.
- Reducing the ability to integrate with other services impacting network flexibility and strategic growth.
- Reduces connectivity and service offering, as certain routes or formations may lose their operational optimum, leading to disbenefits for customers and reduced revenue.

### Service Re-Spacing or Controlled Dwell Extensions (Soft Controls)

In some contingency situations, minor timetable adjustments may be applied tactically. Given the criticality of traction power supply, operational control would be significantly strengthened by the introduction of a simple forecasting tool to indicate when power limits are likely to be exceeded, potentially informed by real-time operational data. Delivery of such a capability would require targeted funding for asset metering, data integration, and resourcing to present usable information within Electrical Control Rooms to support the timely issue of operational notices. At present, controls are based solely on planned service levels, with no capability to monitor actual real-time demand, real time degraded working (N-1), or flag emerging risk, particularly during disruption when service bunching and simultaneous power draw create the highest risk to system resilience.

**Operational effect:**

- Reduces simultaneous acceleration events that cause short-duration power spikes.
- Helps stagger electrical load without major timetable change.

**Impact on services:**

- Can introduce small reactionary delays.
- Reduces timetable flexibility for conflict resolution at key junctions.

These controls are typically last-resort and highly localised.

### Overall Performance Considerations

In all cases, the operational controls that reduce electrical load have a consistent set of impacts:

- Lower acceleration leads to longer running times.
- Extended acceleration phases leads to sustained power draw over a longer duration, even if peak load is reduced.
- Bunched traffic becomes more likely, especially on mixed traffic, two track sections such as Weaver-Crewe.
- Headway utilisation worsens, reducing available capacity for recovery or additional services.
- Performance risk increases, as slower, less predictable acceleration makes it harder to maintain junction timing and pathing precision.

These controls therefore provide temporary relief for the traction power system but materially affect timetable performance and passenger experience. They are only suitable for deployment in contingency conditions, and their use requires coordinated industry consultation and operational discipline.

# E.02.02 3.6.2 b Existing Operating Controls Weaver-Crewe

Recognising the vulnerability of the assets in the Weaver-Crewe Feeding area the Electrical Control Operations (ECO) at Crewe has an Electrical Control Room (ECR) Instruction which tells them the track feeding circuit breakers between Weaver and Crewe may not be opened to permit (traction power) maintenance activity - effectively a ban on a specific type of (N-1) operation.

Because of unsustainable levels of power system trips when there are powerful freight moves into Crewe, a permanent operational control is in place in order to support continued freight capacity under existing conditions (this control does have a detrimental impact on annual performance). *See supplementary information xi.*

*Network Rail already has Operational Controls in place on the WCML between Weaver- Crewe owing to the power infrastructure condition, these annually impact train performance.*

Network Rail is developing an operational control framework for deployment when the WCML Weaver feeding area enters a high-risk extended feeding arrangement (Hairpin feeding) following the loss of a key piece of electrical equipment. Under these conditions, traction power resilience is significantly reduced, and the risk of overloading remaining assets increases. As part of this proposed control, a GSM-R instruction would be issued to all bi-mode fleets capable of extended diesel operation, directing them to operate in diesel mode for the duration of the contingency. In parallel, WMT services would be asked to operate in shorter formations to reduce peak electrical load, and AWC's Liverpool contingent services would be requested not to operate in electric traction. For remaining electric services, targeted notching-back may be considered to manage localised power demand. This package is at proposal stage and will be subject to structured engagement and consultation with operators, the Technical Authority, and wider industry stakeholders before any final operating procedure is adopted.

In addition to the above, in 2024 Network Rail:

- Applied operational length restrictions on new WMT services;
- Placed an objection to the Vehicle Change for electric freight Class 93s due to power concerns;
- Issued an Early Warning Notice for Likely Congested Infrastructure for the Weaver-Crewe feeding area;
- Four AWC Contingent Rights and new Open Access applications were not supported by Network Rail due to power limitations.

In 2025 Network Rail:

- Issued two additional Early Warning Notices for Likely Congested Infrastructure, one in the Crewe Area, adjacent to the Weaver-Crewe feeding area;
- Did not support new applications made by Open Access operators;
- Continued to be unsupportive of four AWC Contingent Rights and new Open Access applications were not supported by Network Rail due to power limitations;
- Did not support additional/ service extensions related to the Glasgow- Blackpool/ Euston service.

# E.03 Characteristics of Rail Services allocated (mix, stopping patterns, dwell times, freight parameters) – Reg. 27(2)(c) / NR CoP 3.6.2(c)

## E.03.01 General Overview 3.6.2c of Power Characteristics of Rail Services

Electric trains place uneven demands on the power system because they draw the most electricity when accelerating. Leaving stations, restarting after signals, or pulling away from junctions creates power spikes as trains take maximum current. When several trains accelerate together, especially after disruption, these combine and put stress on feeder stations and other power equipment.

Weather also affects how well the system performs. Hot conditions reduce how much current the wires can safely carry, while storms, high winds or heavy rain increase the risk of faults on overhead lines and substations. These factors make the system more fragile and increase the need for strong resilience and reliable backup feeding arrangements.

Some trains regenerate energy when braking, but only a small amount can actually be reused. The power system cannot store energy, and regeneration only helps if another train in the same electrical section is accelerating at that moment. Otherwise, the energy is released as heat. Because of this, regenerative braking does not meaningfully reduce the extra power needed when trains run or accelerate more often. Equally battery storage units would not offer the needed capacity in this instance as the current would still need to flow through the legacy switchgear. *See supplementary information on power characteristics of rail services* [vii]

### Weaver – Crewe: 3.6.2 c) Characteristics of the infrastructure

The section of the West Coast Main Line (WCML) between Weaver Junction and Crewe is approximately 27 km (17 miles) in length, forming part of the Carlisle Grand Junction Line (ELR: CGJ1). This corridor is one of the most intensively used mixed-traffic sections of railway in the UK, carrying:

- High-speed intercity services
- Regional passenger flows
- Stopping services serving Winsford and Hartford
- Heavy freight movements to/from the Merseyside and North Wales corridors
- Diversionary traffic during blockades on the Trent Valley or Liverpool routes

The combination of service types, differing speeds, and high utilisation results in a corridor that routinely operates at or near its practical capacity.

# Part F: Measures to Ease Congestion (Short and Medium Term)

## F.01 Re-routing of services – Reg 27(3)(a) / NR CoP 3.6.3(a)

### F.01.01 3.6.3a Weaver Junction - Crewe Rerouting trains

#### Limitations of alternative routes to the WCML Weaver-Crewe

The 27km (17 miles) between Weaver Junction and Crewe forms the primary north–south rail artery for services operating between the Midlands, North West England, Scotland, and North Wales. This corridor is the only double-track electrified main line available for through-running services in this part of the network. As a result, there is no alternative route of comparable capability, journey time, or operational suitability that can be used to divert traffic during disruption.

#### Lack of a parallel electrified main line

There is no electrified relief route running broadly parallel to the Weaver Junction -Crewe corridor. All other rail lines in the area either:

- do not provide a continuous north–south connection,
- are not electrified,
- have significantly lower line speeds,
- or are not designed to accommodate long-distance intercity or high-frequency mixed-traffic flows.

This means that electric services cannot be diverted without either removing electric traction capability or introducing substantial operational delay.

#### Alternative routes involve significant additional mileage and extended journey times

The nearest potential alternate route options require substantial deviation from the direct WCML alignment, thereby allowing services to avoid the section of the WCML between Weaver-Crewe. In all cases, diversionary options introduce increases in journey time, require complex re-timing, and are not capable of absorbing the volume of traffic normally routed via the WCML.

**Via Chester and the North Wales Coast Line**

- Adds approximately 45–55 km of additional mileage.
- Line speeds are lower, with extended sections limited to 60–90 mph.
- Journey times increase by 25–40 minutes depending on service type.
- The route is not designed to accommodate high-frequency WCML traffic and has limited capacity for additional trains.
- Part of this section is not electrified and could not therefore support electric traffic.

**Via Manchester, Stoke-on-Trent and Kidsgrove**

- Does not provide a through connection to Weaver Junction or the Liverpool corridor.
- Requires reversal or complex re-pathing at Crewe or Manchester.

- Adds 20–30 minutes to typical northbound journeys.
- Capacity is constrained by existing regional and freight services.
- Power constraints exist in the Kidsgrove feeding Area.

**Via Warrington Bank Quay avoiding lines**

- No continuous diversionary path exists that bypasses the Weaver- Crewe section while maintaining access to the Liverpool or Preston corridors.
- Available freight-only or low-speed lines are unsuitable for passenger diversions at scale.

### Capacity limitations on alternate routes

Even where physical diversionary paths exist, they do not have the capacity to accept the volume of trains that operate on the Weaver Junction – Crewe section. On a typical weekday this corridor carries:

- 260–280 passenger trains, and
- 40–60 freight trains.

No alternative route in the region has the infrastructure capability—either in terms of signalling headways, junction layouts, or line speeds—to accommodate this level of traffic without displacing existing services or causing significant performance degradation.

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*Re-routing trains to avoid the Weaver-Crewe Junction section of the WCML is not a viable operational option.*

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Given the absence of a parallel electrified main line, the substantial additional mileage and journey time associated with diversionary routes, and the limited capacity of alternative corridors. The corridor therefore represents a single-point dependency within the national network, and its constraints must be recognised within the context of a congested infrastructure declaration.

# F.02 Re-timing of services – Reg. 27(3)(b) / NR CoP 3.6.3(b)

## F.02.01 3.6.3b General Overview Constraints on retiming services to resolve power capacity

A power peak is measured against a 20 minute margin and as such to resolve a power loading peak would require moving a service or sometimes several services at least 10 minutes. This may resolve the intended peak but as the power capacity is operating at close to full capacity across the day it is likely to create another peak either at the main location or further along the train route.

This is complicated by the flexibility afforded to freight services from the options to use any approved rolling stock, ±30 minutes timing flexibility, variable loads and 24 hour path options.

*See supplementary information Freight and Passenger Train Timetable Variability and Power Load*[viii]

Passenger services are planned and modelled to operate to precise timings, but in reality, delays of up to 3 minutes are common. When multiple services experience small deviations simultaneously, train movements can become compressed, driving power peaks, demand surges during disruption scenarios. Planners must incorporate delay sensitivity into power simulations to reflect operational reality. *See supplementary information Freight and Passenger Train Timetable Variability and Power Load*[ix]

*Even minor timetable deviations can amplify power draw, meaning actual peak loads often exceed modelled scenarios.*

It should also be noted that freight path punctuality is highly volatile, with adherence to planned timings frequently falling below 50 % . This variability means that freight-driven power loading peaks cannot be accurately predicted or managed through retiming, reinforcing the need for sufficient and consistent power capacity to be available at all times rather than reliance on timetable intervention alone.

## F.02.02 3.6.3b Retiming trains – Weaver Junction– Crewe Corridor

### High Train Volumes and Tight Planning Margins Weaver -Crewe

The section of the WCML between Weaver Junction and Crewe accommodates a very high number of daily train movements. On a typical weekday, analysis of the working timetable and live service data indicates that this section accommodates around 260–280 passenger train movements per day (both directions combined) and approximately 40–60 freight trains, depending on the timetable period and freight demand. This level of utilisation means that, for much of the operational day, the corridor is running close to its practical capacity, with multiple operators sharing the same two-track railway. Although exact real-time counts vary by day and timetable period, the corridor typically supports:

- Fast intercity services operating at up to 125 mph
- Regional and commuter services with lower line speeds and more frequent stops
- Freight trains with significantly slower acceleration and braking profiles

To accommodate circa 300–340 train movements per weekday on just two tracks, the timetable is constructed with tight pathing and junction margins. Faster services must be carefully threaded between slower passenger and freight trains, and there are limited opportunities for overtaking. Junction margins at both Weaver Junction and Crewe are minimal, and there are no parallel relief lines on this section to segregate flows by speed or service type.

As a result, there is very little embedded slack in the working timetable. Small variations in running times can quickly propagate, as there is limited scope to recover time without impacting other services.

### Constraints on re-timing services from network capacity Weaver-Crewe

Given this high baseline utilisation and tight planning, the ability to reroute services during disruption is severely constrained:

- **Limited spare paths:** With around 260–280 passenger and 40–60 freight trains already planned on a typical weekday, there are few truly spare paths available in the core of the day. Those that do exist are reserved as performance buffers to provide timetable resilience.
- **Junction conflicts:** Weaver Junction and Crewe are both heavily-used flat junctions due to being high-intensity nodes. Rerouting trains through either location requires additional track capacity (which is very limited) for:
    - Additional/ longer junction margins
    - Re-timing of conflicting movements
    - Re-pathing through already-constrained flat junctions
- **Mixed-traffic interactions:** Freight services, which are essential to the regional and national economy, cannot easily be removed or re-timed without wider network impacts, further limiting flexibility.
- **Performance risk:** Moving existing trains within this corridor presents a risk of:

    - Missed junction slots or junction timing conflicts downstream towards Manchester, Liverpool and WCML South.
    - Reducing resilience and the ability to recover and increasing the impact of reactionary delay
    - Platforming conflicts at Crewe and at end destination locations including Liverpool Lime Street, Manchester and Euston
    - Downstream congestion towards London, Warrington, Liverpool, and Manchester
- **Freight Train Timetable Flex and Power Planning Mitigation Approach:** Unlike passenger services, many freight paths are planned with a timing tolerance of ±30 minutes, meaning a train can run anywhere within a one-hour window around its booked slot. This flexibility is essential for freight operators to manage loading, terminal operations, and network conditions, but it introduces complexity for power planning:
    - Planners must model freight paths as probabilistic windows rather than fixed times, using scenarios to ensure the network can absorb variations without breaching N-1 resilience or stressing assets.

In practice, this means that rerouting trains over the Weaver Junction -Crewe section is rarely feasible without cancelling or severely delaying other services and cannot be relied upon as a routine mitigation strategy.

# F.03 Alterations to line speed – Reg. 27(3)(c) / NR CoP 3.6.3(c)

## F.03.01 3.6.3 c General Overview Alterations to the speed of trains within existing [power] infrastructure capability

Higher train speeds place significantly greater demand on the electrical power system because trains must accelerate harder, draw more current, and overcome much higher air resistance as speed increases. This creates larger power peaks, increases the strain on feeder stations, and raises the likelihood of several trains drawing high power at the same time. Although some rolling stock can regenerate energy during braking, the benefits are limited by voltage conditions and older infrastructure, meaning it cannot offset the extra power required at higher speeds. Running trains faster might release limited track capacity, but it also puts more strain on the electrical system, especially the older equipment like K11 switchgear. In busy areas like the WCML or West Midlands, this extra load can build up quickly and lead to power trips or equipment failures. Overall, running trains faster substantially increases traction energy use and electrical loading, which the current power system cannot support without reinforcement. *See supplementary information* [x]

Connected Driver Advisory System (CDAS) has been suggested as an intervention with the potential to manage power peaks. CDAS does this by giving drivers real-time advice on the optimal speed to keep moving rather than having to stop at red signals. By using lower speeds to keep trains moving, the power peaks caused by heavy acceleration are avoided. Crucially, the system is only advisory and drivers would not be obliged to follow the recommendation to drive below line speed. This option has not been progressed following a cost vs benefit assessment, summarised as follows:

1. it is highly unlikely to resolve the high power peaks seen on the NW&C Infrastructure (see notching back above)
2. the cost of delivering new infrastructure both lineside and in the cab,
3. the associated driver training required due to considerable changes to methods of working

# F.04 Infrastructure improvements – Reg. 27(3)(d) / NR CoP 3.6.3(d)

## F.04.01 3.6.3d General Overview Infrastructure improvements

A range of built infrastructure options exist to improve the infrastructure and remove the notice of Congested Infrastructure. However, as the issue is complex, few single interventions resolve all aspects of the challenge.

Power infrastructure interventions are time consuming to deliver (typically with a 6-10 year duration after funding is committed). They often require engagement and works from National Grid (TNO) or the local Distribution Network Operator (DNO), which is subject to complex commercial processes. They are generally disruptive as power needs to be switched off to the railway whilst works are completed.

When defining the preferred solution, Network Rail have considered future growth in electric traction, compliance with modern electrical standards, and the operational consequences of both construction and long-term maintenance. The power system is inherently interconnected, so proposals must avoid simply relocating constraints elsewhere and instead reflect whole system thinking. Final scoping should also align with committed and emerging strategic programme interfaces, such as TRU, HS2, Northern Powerhouse Rail, and future passenger and freight operator fleet decarbonisation to ensure that today's investment supports tomorrow's railway.

Power infrastructure upgrades require a balance between enhancing existing asset capability and increasing capacity. Renewals funding is intended to maintain steady-state infrastructure and does not support growth scenarios; funding for growth and change is provided through enhancements. While the railway seeks to deliver intelligent renewals—incorporating future-proofing where feasible and avoiding reinstatement of obsolete, unsupported, or unsafe equipment—renewals budgets do not include specific provision to accommodate significant capacity growth.

## F.04.02 3.6.3d Weaver-Crewe Infrastructure Improvement Options

As described in section C.03, Weaver Junction Auto Transformer Feeder Station (ATFS) feeds north to Euxton Junction as an AT system utilising modern switchgear. It feeds south to Crewe Neutral Section as a booster classic system using legacy bulk oil switchgear (K11) that is beyond asset life, as well as north to Liverpool as a booster classic system using mostly modern switchgear. This area experiences N-1 scenarios 17 times per month.

Power supply generally becomes weaker the further you get from the source, so trains near the southern end of the system (towards Crewe) have to draw more electricity to maintain the same level of performance. This extra demand puts pressure on the older electrical equipment that supplies the railway, which was designed to handle much lower levels of current than modern systems (typically systems were designed to supply 300A whereas modern switchgear will typically be rated 1250A to 2000A).

**No Investment Option**

If no funding were available to resolve the underlying power supply constraints, the majority of electric train services would need to be capped at their December 2026 levels. This would effectively create a one in one out situation for electric services. Similarly, if an operator wished to run an electric train using a current diesel path, the equivalent electric capacity would first need to be freed. In practice, for more powerful, longer passenger and freight services to be included, this could mean that multiple electric passenger services would need to be withdrawn to support a single additional electric freight or high-powered longer passenger path.

Modelling shows that, on busy days, this equipment would be pushed beyond its design limits, sometimes several times a day. This strain is even greater when part of the system is out of service (N-1), when the peaks in demand can reach up to 175% of what the equipment is rated for.

The older switchgear, in particular, is already past its intended life and needs intensive maintenance. Overloading it in this way carries a high risk of failure, which in the worst cases could lead to fire or an explosion.

A solution would need to either reduce load or improve the asset capability and increase power system capacity to meet committed planned demand. Options such as doing nothing, increasing maintenance, or reducing train services have not been included because they do not address the underlying causes of congestion and therefore do not provide a viable resolution. If the power capacity constraints are not addressed electric services will be predominately capped at December 2026 levels.

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*Options such as doing nothing, increasing maintenance, or reducing train services have not been considered because they do not address the underlying causes of congestion and therefore do not provide a viable resolution. If the power capacity constraints are not addressed electric services will be capped at December 2026 levels.*

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The list of options are:

1. Like for like modern renewal of the switchgear
2. Power system minor upgrade
3. Like for modern equivalent renewal and upgrade (Auto transformer and modern switchgear)
4. Increase Power Supply

## 1 - Like for similar switchgear renewal

K11 technology is now obsolete and parts are no longer manufactured meaning it cannot be replaced exactly like for like. It is also known to present a significant failure risk, and maintenance is expensive requiring heavy testing and oil disposal. Alternate switchgear could be used to replace the existing switchgear, as well as refurbishing mothballed WCPSU equipment at Winsford and Hartford. This option would not increase the traction power capacity, meaning operating restrictions would persist. It would reduce the safety risk to an acceptable level.

## 2 - Power system minor upgrade through booster transformer removal

Decommissioning booster transformers between Winsford and Weaver would not resolve the safety and performance risks created by legacy equipment elsewhere in the area. Neither would this remove the constraint to capacity because it would not permit more power to be feed to the railway.

## 3 - Auto Transformer upgrade of the existing electrical system

This would upgrade the full power system including switchgear and power delivery mechanism. Full upgrade to 25kV AT can be split into the following packages:

a. AT Liverpool-Weaver – this is needed in the longer term to support further growth to Liverpool docks and Liverpool lime Street
b. AT Weaver-Winsford – this covers the 3 highest safety risk locations
c. AT Weaver-Crewe – this covers the top 4 safety risk areas including Crewe Feeder Station
d. AT Weaver-Whitmore – single stage intervention that affords economy of scale through a single programme and removes all aging K11 switchgear on the WCML.

A combination of these options would allow increase in capacity beyond the next five years. It would also remove the safety risks.

### Increase the power supply

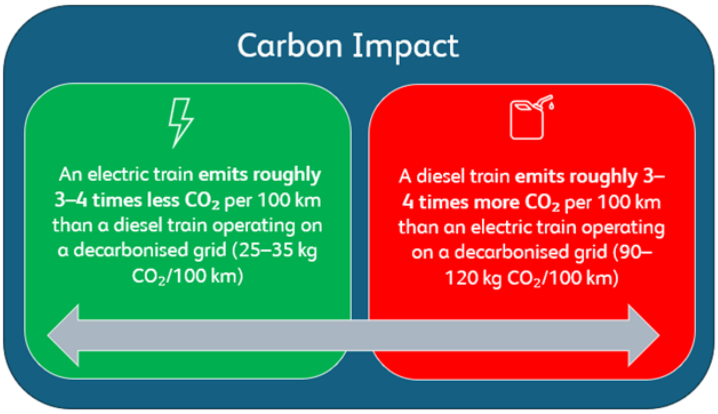
This could be done through any of the following: a new or upgraded Distribution Network Operator (DNO) connection, Grid Supply Point (GSP) or Static Frequency Converter installation. These solutions would provide more power, but would not resolve the constraining factors. In particular, it would not alleviate the risks from continued use of legacy K11 switchgear and would require significant works to the OLE.

### Preferred option

Only an option that upgrades the power delivery system and the switchgear would resolve the safety issues and remove the capacity constraints today and in the medium to long-term future. To resolve the area addressed by this congested Infrastructure report the optimal solution would be to deliver Auto Transformer feeding between Weaver and Crewe –Option 3c. This Solution was originally part of the WCPSU programme and was endorsed by the DfT. Latterly the Business case was revisited and shown to be positive and initial design has been completed. Contribution renewal funding has enabled detailed design to commence on the first 3 locations (option 3b) whilst full funding is sought.

## F.05 3.6.3g General Overview Reduction or combination of services to release [optimise] capacity NR CoP 3.6.3(g)

This declaration of Congested Infrastructure is intended to support industry decision making around options for reducing or combining services to alleviate capacity constraints. However, current rail industry priorities, reinforced by regional authorities and local mayors, are focused on retaining and growing connectivity rather than reducing services. Franchise agreements and strategic growth plans for corridors such as Liverpool–Manchester and London–Scotland reflect this commitment to service expansion (see DfT Rail Enhancements Pipeline, 2023).




Growth is being driven by several national strategies and policy objectives ultimately underpinned by passenger and freight demand:

- Decarbonisation Policy: The Transport Decarbonisation Plan (DfT, 2021) and Net Zero Strategy (BEIS, 2021) underpin investment in new rolling stock and electrification. Commitments to new fleets for TransPennine Trains and Northern Trains Limited support modal shift and emissions reduction.
- Passenger Growth Commitments: Franchise obligations and regional transport strategies aim to increase connectivity and frequency, particularly in the North of England and on long-distance routes.
- National Freight Growth Strategy: The government's Rail Freight Growth Target (DfT, 2022) seeks a 75 % increase in freight by 2050, requiring additional capacity on key corridors.
- Regional Economic Growth: Local authorities and combined mayoral regions advocate for rail expansion to enable economic development and meet levelling-up objectives.

To date, the rail industry has actively sought to maximise rail travel and connectivity, while supporting government-led decarbonisation initiatives. Against this backdrop, reducing services is not considered a viable or sustainable method of managing congested infrastructure. Instead, solutions must focus on optimising capacity through infrastructure enhancements, operational efficiencies, and technology improvements.

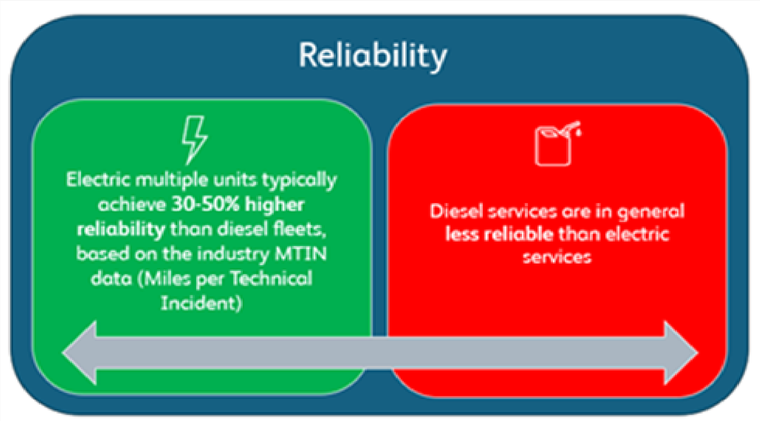
## Why Combining Services Can Disbenefit Power Planning

From a power perspective, operating fewer but longer or heavier trains does not reduce overall traction demand. On the contrary, it can concentrate electrical load into shorter timeframes, resulting in higher instantaneous power peaks. While operating a greater number of shorter trains may, in theory, offer benefits in terms of smoothing power demand, allowing power considerations to drive this outcome would impose a substantial increase in industry costs and would materially elevate performance and operational risk:

- **Better Load Distribution**: Two shorter trains spread across the timetable allow power draw to be distributed more evenly, reducing peak stress and improving network stability.
- **Acceleration Load Profile**: A single long or heavy train requires substantial power during acceleration, exceeding the combined peak of two shorter trains operating at staggered times.
- **Substation Stress**: Concentrated demand can overload local feeders and substations, increasing the risk of a trip or failure and triggering alternate feeding arrangements or breaching N-1 resilience.

This means that even if services were combined, the infrastructure cannot easily absorb concentrated power demand without reinforcement. Furthermore, the industry's growth objectives driven by passenger demand, regional connectivity, and decarbonisation means there is limited operating surplus capacity. Removing a train reduces connectivity and undermines modal shift goals. *See supplementary information*[xi]

## Optimising Capacity Through Rolling Stock and Traction Choices




Network Rail has worked with operators to optimise rolling stock deployment by using trains with lower traction power requirements, to reduce peak electrical demand. This has included AWC's use of the bi-mode Class 805 fleet and ongoing discussions with freight operators. Using diesel traction (or bi-modes running in diesel mode) provides a short-term solution where electrical power is constrained, but it does not create additional capacity. Electric traction delivers stronger acceleration and better performance on gradients, whereas diesel operation does the opposite; slower acceleration and lower speeds increase pathing pressures and the risk of knock- on delay.

## Optimising Capacity Through Rolling Stock deployment

Network Rail has worked with operators to review rolling stock deployment, attempting to maximise the use of units with lower traction power requirements where possible to reduce peak electrical demand. This has often been complicated by overall train planning, fleet and operational constraints, but it has been considered and actioned where possible in particular with AWC use of bi-mode 805 fleet and is being reviewed by freight operators.

However, availability of bi-mode fleet, slower diesel running speeds and decarbonisation initiatives limit how effective this solution is or the long-term applications. The trade off in power usage delivers slower acceleration from stops or junctions and poorer hill or gradient performance, which increases bunching, elongates sectional times, and degrades overall path utilisation on mixed-traffic lines like the WCML and West midlands.


Electric services perform optimally in comparison to diesel units and can be up to 60 % more powerful than equivalent length trains and more reliable failing less frequently.

While diesel operation could, in principle, be used to alleviate electrical power constraints, doing so would deliver a detriment to short-term train performance and long-term sustainability, increasing carbon emissions and running counter to established decarbonisation objectives. *See Performance and Sustainability supplementary information*[xii]

# F.06 Conclusion

This report, while authored by Network Rail, reflects extensive engagement across the rail industry, including with passenger and freight operators. The issues, risks and constraints described are consistent with operational experience and represent a shared understanding of the current and emerging impact of power capability on network capacity.

*This report shows that power capability is increasingly defining not just how many services the railway can operate, but how reliably, safely and credibly it can do so.*

Electrical power supply is no longer a localised technical constraint; it is now a system-critical determinant of network capacity. Across the network, available power headroom has been exhausted to the extent that the system is effectively operating on a *one-in, one-out* basis for electric traction. Any additional load—whether a new service, a lengthened train to address overcrowding, a freight path supporting growth or decarbonisation targets, or the replacement of diesel services through committed fleet transitions—can only be accommodated by displacing existing capability.

*There is, at present, insufficient power capacity to reliably support the commitments of today, let alone planned or aspirational growth.*

As a consequence, a proportion of proposed and committed electric services, including planned fleet introductions and service enhancements associated with major programmes, are at risk without power system intervention. To maximise the benefits of major programmes, investment in power capacity is required. This applies not only to services operating directly over constrained routes, but also to associated empty coaching stock movements, depot access, adjacent routes and diversionary routing. For existing contingent and firm access rights, including proposals to lengthen or strengthen services, power availability is now a binding constraint irrespective of demand, rolling stock availability or timetable aspiration.

The current position also presents a safety risk. Sustained operation of electrical assets at or beyond their intended capability reduces resilience and tolerance to disruption, increasing the likelihood of in-service failures. Credible risk scenarios include stranded trains, passenger detraining, exposure of maintainers to hazardous conditions during fault response, and increased risk to neighbouring communities adjacent to lineside infrastructure. While operational mitigations are currently in place to manage these risks, they rely on intervention rather than inherent system capability and will become increasingly fragile as the system operates prolonged high levels of electrical loading.

Failure to address the advice and evidence set out in this report would place the railway in a heightened risk position. In such circumstances most critically, continued operation without addressing the underlying power constraints would elevate the likelihood of a serious safety incident, arising either from in-service failure or from the conditions under which assets must be operated and maintained. Equally, the network would be increasingly unable to meet its performance and cancellation metrics. Under the present time-table performance is expected to deteriorate further as asset condition declines under sustained heavy loading, and the addition of further electric load would exacerbate this position, increasing the probability of service disruption and unplanned operational intervention.

While the majority of this report is based on modelled analysis, real-time and historic operational data corroborate the findings and indicate that the modelling presents an optimistic view of system capability. Observed asset behaviour under live operating conditions demonstrates reduced margins and resilience beyond those assumed in modelling, reinforcing both the immediacy and seriousness of the constraint.

Solutions have been developed to manage immediate safety risk and to provide capacity for short-term commitments, known fleet changes, and medium to long-term planned and aspirational growth, including that enabled through committed projects and programmes. However, power infrastructure projects have long lead times and are dependent on both funding approval and external engagement, including with National Grid. While Network Rail has commenced design development for optimal solutions identified in this report, funding remains outstanding and the constraint will persist until interventions are delivered.

In the absence of timely investment, power capability will increasingly determine outcomes by default constraining capacity, reducing reliability, limiting the effective use of rolling stock investment, and capping future timetable ambition. Conversely, strengthening power capability presents a clear opportunity to restore operating headroom, improve resilience, and enable growth ambitions to be delivered safely and credibly. Power is therefore a critical failure point and blocker to electric traction growth, and addressing it is fundamental to the sustainable operation of the railway.

**The End**

# Part G: Governance and Consultation

## G.01 Stakeholders consulted (Secretary of State/Scottish Ministers) during the preparation of this analysis

Completion of this report has involved consultation with the following:

- Office of Rail and Road.
- Department for Transport.
- Transport Scotland.
- Train Operating Companies.
- Freight Operating Companies.
- Major programmes including TRU, MRH, MNTP, HS2, EWR.
- Network Rail Route and Regional Electrification and Plant Engineers
- Network Rail Advanced Timetable Team

## G.02 Dependencies and related initiatives (enhancements, performance plans etc)

The railway is a strategic national asset and growth industry, underpinning economic activity across the UK. Demand on the West Coast Main Line continues to grow, with long-distance passenger journeys now approaching and in some cases exceeding pre-pandemic levels. At Crewe Passenger volumes have doubled since the early-2000s and Crewe station handled approximately 3.4 million passenger journeys in 2024/25, representing almost 8 % growth year-on-year with the Liverpool–London's route being one of the busiest long-distance rail markets.

In recognition of this growth and the importance of the corridor, Government has committed approximately £8.5bn of funding to the North West & Central (NW&C) region in Control Period 7 (2024–2029), supporting operations, renewals and major enhancements across the backbone of the network.

Significant dependencies also arise from rolling stock change. Operators including Northern Trains (NTL) TransPennine Trains (TPT) and GB Railfreight (GBRf) are currently investing in newer, higher-performance fleets, to meet efficiency and decarbonisation objectives. These changes align with Government policy to decarbonise rail and the wider transport system, alongside industry direction that rolling stock manufacturers will no longer produce diesel-only trains by 2040, driving a shift towards electric, electric bi-mode and battery traction. CrossCountry Trains operates a fleet dominated by Voyager units introduced in the early-2000s and now over 20 years old, with replacement required within the next decade to address obsolescence and compliance; Chiltern Railways, which has one of the oldest fleets in the country (average age c.29 years), has published its "Right Route 2030" vision and is already securing replacement trains to remove its oldest diesel stock, including future battery-electric capability. Power capability will be integral to enabling these full-electric and electric bi-mode fleets, and to supporting any battery operation, including the ability to reliably charge battery trains while operating under the wires.

Alongside fleet change, a series of nationally funded enhancement and renewal programmes introduce further dependencies on congested infrastructure. Major enhancement schemes such as Manchester North Transformation Programme (MNTP), TransPennine Route Upgrade (TRU), HS2, East West Rail (EWR), Northern Powerhouse Rail (NPR) and Midlands Rail Hub (MRH) sit alongside major renewals including the West Coast North (WCN) Transformation Programme, with cumulative public funding of tens of billions of pounds committed across these programmes over successive control periods. The new, longer and faster services released by these schemes will interact directly and indirectly with the Conventional Rail Network, particularly across the WCML. Whether benefits are expressed through capacity, performance or reliability, some benefits are directly enabled by enhanced power capacity, while others can be delivered independently but are materially amplified where the power network can support higher-performance operations.

This report therefore represents one step in a wider programme to modernise an aging traction power system, much of which was designed between the late-1950s and 1970s for a very different railway: slower services, fewer passenger trains, lower auxiliary loads and no provision for today's digitally enabled, air-conditioned or battery-equipped rolling stock. The interventions identified here provide essential building blocks towards greater power capability and resilience, supporting future schemes and operational growth at locations such as WCML South to Handsacre, and WCML North towards Lancaster and Heald Green to support Manchester, ensuring that the network can sustain future demand and investment outcomes.

# Part H: Appendices

## H.01 Maps, diagrams, train graphs and charts

### H.01.01 AFDs alternate feeding diagrams

IDU/LNWS/AFD [ Issue: 13 ] LNW Alternative Feeding Diagrams (Rugby ECR)

## H.02 Industry Documents

### H.02.01 BS EN 50119:2020

Link: BS EN 50119:2020 - Railway applications. Fixed installations. Electric traction overhead contact lines

### H.02.02 BS EN 50126

Link: BS EN 50126 - Railway applications. The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS)

### H.02.03 NR/L3/ELP/27240/NR.DIST C30c

Link: NR/L3/ELP/27240/NR/DIST C30c [ Issue: 1 ] Recovery of Traction Distribution Equipment Following Catastrophic Failure

### H.02.04 Early warning of congested infrastructure

NWC-Early-Warning-of-Congested-Infrastructure-–-Crewe-Feeder-Area-26-November-2025.pdf

### H.02.05 Declaration of congested infrastructure

Weaver-Feeder-Area-–-Declaration-of-Congested-Infrastructure-–-26-November-2025.pdf

### H.02.06 CRAM risk assessment Weaver – Crewe (commercially sensitive)

## H.03 Data tables and model assumptions

Modelling inputs

NR/GN/ELP/27312 [ Issue: 1 ] Impedances of 25 kV a.c. overhead lines for Classic system

BS EN 50641 Requirements for the validation of simulation tools used for the design of electric traction power supply system.

## H.04 Stakeholder consultation log

TP-RAM August 2025

ORR/ DfT September 2025

RIRG December 2025

PIG Dec 2025

RIRG March 2026

TCRAG March 2026

PIG Feb 2026

ORR/DfT April 2026

# H.05 Supplementary Information (technical detail)

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### [i] General Power Modelling.

Vision Oslo is the mandated tool used in Network Rail procurement and modelling. It is used for power modelling because it brings infrastructure, train performance, timetables and electrical behaviour into a single, integrated environment, allowing planners to understand how the whole system behaves rather than analysing each element in isolation. It should be understood that in the real-world timetables can fluctuate. Freight in particular has a large window of operation. These fluctuations are accommodated through train 'driver style' in the software. Metered data from grid supply points taken over long periods is used to help validate modelling outputs. Using metered data is, however, just a series of averages across large time frames, and specific feeding arrangements are not known to the meter.

The power infrastructure in the model is derived from asset data and updated following project and renewal work, which is maintained by Network Rail Asset Managers.

10-minute average current draw of the train service through the assets is used to assess how the train service will affect the asset condition and safe operation of switchgear and cables. Should these ratings be breached, asset degradation can accelerate, and there is an increased risk of asset failure as well as the creation of unsafe conditions for staff using the equipment. This averaging time is aligned with BS EN 50388 Annex A for thermal loading of assets.

Electrical switchgear and cables come in different forms,  meaning that each type comes with different risks when in the same situation. Particular interest should be taken in the difference between oil filled assets and gas insulated or vacuum insulated assets under exceedance of thermal ratings. In this event, due to the design, construction, and flammable nature of oil and its by-products from arcing; a failure of oil filled switchgear that encompasses the building is more likely and more severe when compared to gas insulated or vacuum switchgear.

All modelling undergoes formal assurance, with a qualified engineer (BEng) reviewing work completed either by Network Rail's internal ESDD design teams qualified to MEng in Electrical and Electronic engineering or equivalent (who maintain up to date competencies) or by externally licensed suppliers, both of whom are subject to independent approvals. Final reports are then reviewed by the Regional Head of Engineering PhD and signed off by the Director of Engineering Asset Management (E&P).

### [ii] Insurance Considerations:

For a claim to be covered under an insurance policy, the loss must be fortuitous, but in the circumstances outlined, Network Rail are aware of the likelihood of a loss occurring and the proximate cause.
In the event of a first party property loss (physical damage and business interruption to Network Rail assets) which becomes the subject of an insurance claim, as a direct result of the power system being run beyond its capability, then any damage will almost certainly not be covered under Network Rail's Property Damage and Interruption Policy. Insurers will most likely repudiate policy coverage. It's also important to remember that sub-deductible losses (ie. £75m for Property) are treated as insured losses, and claim payments will only be made out of these pots should policy coverage attach in the same way as losses met by insurers (both Network Rail's Captive insurer and the external insurance market).

Should damage or injury be suffered by a third-party, as a result of the system being pushed beyond its capability, then Network Rail will pick up the legal liability, and insurers may also repudiate policy coverage under the Network Rail Liability Policy, preventing Network Rail from being able to present the claim under the Policy, thus stuck with paying any third-party damages and representatives costs. Again, internal insurance funds will only pay losses below insurance deductible levels where the loss would have been met by insurers as the policy wording is triggered, otherwise wider Network Rail group funds bear the risk.

### [iii] Primrose Hill:

An example of a rail related significant incident similar to that of a catastrophic failure is the fire above the railway at Regent's Park Road, Primrose Hill (Camden), close to the West Coast Main Line, on 30 January 2026. Because the fire was directly adjacent to and above live railway infrastructure, Network Rail halted trains for safety reasons, particularly during the morning peak and into the afternoon. The fire required a major emergency response (around 10 fire engines and 70 firefighters), meaning services could not resume until the site was declared safe. This incident highlights the critical vulnerability of the West Coast Main Line with a single infrastructure-adjacent fire causing national inter-city disruption.

While train services gradually restarted later in the evening, disruption lasted throughout most of the day, affecting long-distance, commuter and London Overground passengers nationwide.

Services most affected

- London Euston services were severely disrupted, with trains to and from Manchester, Liverpool and Glasgow suspended for large parts of the day.
- Avanti West Coast and London Northwestern Railway were the operators most heavily impacted, reflecting their reliance on the West Coast Main Line.
- There was major disruption between Euston and Watford Junction, effectively blocking a key southern section of the route.
- Several Overground lines were also affected, notably: Mildmay line and the Lioness and Suffragette lines

### iv Weaver – Crewe Hairpin feeding arrangement.

The most onerous outage scenario that is likely to happen on a ‘regular’ basis, tested by the NW&C Region, is the Hairpin feeding arrangement. The Hairpin feed addresses an N-1 state where a switch, breaker or other asset is out of use at Hartford TSC. Previous N-1 assessments, including that used when Whitmore-Weaver Auto-Transformer conversion was descoped following WCPSU, have only considered loss of a feeder at Weaver Junction.

In this case the ability for an OLE feed directly from Weaver Junction Feeder Station is removed, meaning the feed must go through Hartford TSC to Winsford TSC and return via the OLE. This could be due to asset failure (complete or due to a minor fault) or because of a tripping event. Under Hairpin (Classic) OLE voltages drop below compliant values at the feeding area midpoint (Crewe) and current draw through Hartford TSC assets exceeds asset ratings. Additionally, current is at times double the norm compared to the Normal (Classic) feeding arrangement.

### v Weaver-Crewe Low Voltages.

The supply south to Crewe neutral section and west to Liverpool suffers from poor voltage regulation at the far end owing to the booster transformers and the two track areas. This can lead to very low voltages (<18kV) which affects acceleration and may cause trains to stop for short periods. This part of the network also has a long stretch of track fed from relatively few power supply points, which means that voltages decrease in equipment further from the feed — particularly around Liverpool and Crewe. Each train needs a large amount of power, and when several draw power at the same time, the voltage along the system can fall even further. This effect becomes more noticeable when trains are running close together or catching up after delays, because several high power demands occur at once and place extra strain on the system.

### vi General CRAM (Corporate Risk Assessment Matrix )

The CRAM scores and rankings are based on the following impact areas:

- Low voltage affecting train performance
- Automatic protection, which isolates the traction power supply from 'unhealthy' parts of the network - a consequence of this are higher impact and likelihood scores for train service delivery and political & stakeholder
- Breaching (or expectation of breaching) the electricity supply contractual load (firm service capacity) limits
- Poor (or unrealistic) train service specification, poor application (or interpretation) of train service specification

## [vii] General Characteristics of electric rail services.

Electric rail services place highly variable and dynamic demands on the power system. Acceleration from a standstill produces short duration but high peak loads as traction units draw maximum current. When services are held during incident management and then released together, the simultaneous acceleration of multiple trains can create sharp coincident load spikes, stressing feeder stations, autotransformer sections and upstream grid connections. These behaviours drive voltage fluctuations, influence negative phase sequence levels, and shape the overall electrical capacity required to support reliable and resilient operations.

Railways in Britain experience a mix of weather conditions that directly affect electrical performance and asset resilience. Hot summer weather increases conductor temperatures, reducing current carrying capacity and causing greater voltage drop along long sections. High winds and storms raise the risk of OLE damage, vegetation strikes and transient faults, leading to protection operations and supply interruptions. Heavy rain and lightning can increase fault rates, affect earthing performance and introduce additional stress on substations and switching equipment. Together, these conditions require robust design margins, proactive maintenance and operational flexibility to maintain system stability across the region. This is one of the reasons alternate feeding scenarios and power system resilience are considered so critical in the management of power systems. Auto-transformer feeding is more weather resilient than classic or booster classic feeding, this is a consideration in option selection in Section F.

A number of types of rolling stock operating on the WCML can regenerate power. Regenerative braking converts a train's kinetic energy into electrical energy, but only a small proportion can be used by the rail system. Braking events are short and highly variable, making them difficult for the system to utilise. It is only effective when another train in the same electrical section is accelerating and able to absorb the energy; otherwise, the train reverts to rheostatic braking and dissipates the energy as heat. The 25kV network is designed for power delivery rather than storage, cannot bank energy, and does not export power back to the grid. Voltage protection limits also restrict how much reverse power can be accepted.

## [viii] General Freight Train Timetable Variability and Power Load

Freight services introduce unique challenges for power planning due to their operational flexibility:

- **Timing Tolerance:** Freight paths are planned with ±30 minutes flexibility, meaning trains can run anywhere within a one-hour window.
- **Variable Load Profiles**: Power demand is linked to train movements. When freight services shift within their tolerance window, the timing of traction load changes, making it harder to predict peak demand accurately.
- **Impact on Contingency Planning**: If multiple freight trains flex into the same period, localised power draw can spike unexpectedly, increasing the risk of overload or triggering alternate feeding arrangements.
- **Rolling Stock Variability**: Under Timetable Planning Rules, freight operators may use any vehicle from the approved catalogue provided it meets the Sectional Running Time (SRT). This means actual trains may differ from those assumed in planning. Substitution of different locomotives or wagon configurations can introduce more onerous traction loads than expected, increasing the risk of unplanned demand peaks.

## [ix] General Passenger Train Timetable Variability and Power Load

Modelling tests a perfect timetable in real life there is a high quantum of passenger (and freight services) per day and often these do not operate to time this has a negative impact on the power system:

- **Compression of Movements**: Trains that were planned to be evenly spaced may bunch together, reducing headways and increasing simultaneous traction demand.
- **Higher Real-World Peaks**: Power models assume ideal spacing, but real-life delays can create overlapping acceleration phases, driving short-term spikes in load beyond modelled expectations.

- **Network Stress Under Disruption**: If delays cascade across multiple services, localised substations may experience demand surges, challenging N-1 resilience and contingency plans.

## x General: Why Faster Operations Increases Power Demand

The electrical load drawn by modern EMUs on the WCML is directly related to the speed at which they accelerate. Traction power demand increases nonlinearly with speed due to aerodynamic drag, rolling resistance, and the higher traction effort required to accelerate to and maintain elevated line speeds. As a result, operating existing services at higher speeds may release limited track capacity but will increase electrical loading on the 25kV AC traction system and raise the likelihood of high current conditions through legacy K11 switchgear. In areas where traffic density is high, these effects compound and lead to power trips or asset failures.

### Traction Effort and Acceleration

To achieve higher average speeds, trains must accelerate harder and for longer. This results in an increased power load on the assets:

- Higher peak currents during acceleration
- Increased thermal loading on feeder stations
- Greater cumulative energy consumption over a journey

### Aerodynamic Drag

Aerodynamic drag increases approximately with the square of speed. The power required to overcome drag therefore increases roughly with the cube of speed.  An example of this is that increasing speed from 100 mph to 125 mph does not increase power demand by 25 % , it increases it by closer to 95 %  increase due to the cubic relationship. Put simply, when a train increases speed from 100 mph to 125 mph, the power needed to overcome air resistance almost doubles.

### Regenerative Braking Limitations

Although a number of trains operating on the WCML can regenerate power (including the Pendolino and Class 730 units), the ability to return energy to the network is constrained by:

- Local Voltage conditions
- Network receptivity
- Protection settings on older switchgear

As a result, regeneration does not offset the increased power drawn at higher speeds.

### Increased Current Through Feeder Stations

Higher train speeds lead to:

- Higher instantaneous current draw
- Higher sustained current levels on busy sections
- Increased likelihood of coincident peaks when multiple trains accelerate simultaneously

### Comparison of traction power demand at faster speeds

To illustrate how higher speeds increase traction power demand, the table below compares two regularly used rolling stock types on the WCML and shows the approximate traction energy for a Class 390 Pendolino and a Class 730 EMU over a 25 km run on level track, for two scenarios:

- accelerating from 0–100 mph and then cruising, and
- accelerating from 0–125 mph and then cruising (the 125 mph case for Class 730 is a theoretical comparison only).

These values are illustrative, orderofmagnitude estimates, based on typical train masses and power ratings, and are intended to show the *relative* increase in energy and power demand with speed rather than provide exact consumption figures.

Train energy and distance information

| | Energy | | Distance | |
|---|---|---|---|---|
| **Vehicle Type** | **0-90 mph** | **0-125 mph** | **0-90 mph** | **0-125 mph** |
| **Class 390 11 Car** | 153 kWh | 327 kWh | 2.8 km | 8.0 km |
| **Class 730 5 Car** | 80 kWh | N/A | 3.8 km | N/A |
| **Class 805 10 Car** | 135 kWh | 274 kWh | 2.4 km | 6.9 km |

For both train types, the 0–125 mph case requires substantially more energy than the 0–100 mph case over the same 25 km distance. This reflects the nonlinear increase in power demand with speed.

### Elevated Stress on K11 Switchgear

K11 oil filled switchgear was not designed for the sustained highcurrent operation associated with modern highpower EMUs running at elevated speeds. This is true for today's timetable but more so in relation to the consideration of further increasing service speeds to resolve capacity issues. Higher speeds lead to higher currents which result in:

- Thermal stress within the oil tank
- Risk of internal arcing under fault conditions
- Overall likelihood of catastrophic failure modes associated with ageing oilfilled equipment

### Reduced Electrical Headroom

Running trains faster reduces the available electrical headroom for additional services, perturbation recovery and/or engineering or diversionary operations. This is particularly relevant on constrained sections of the WCML where power supply margins are already limited.

### Conclusion

While increasing train speeds may offer limited benefits in terms of track capacity and journey time, the electrical consequences are significant. Analysis shows substantially higher power demand at higher speeds due to aerodynamic and tractioneffort effects. On the WCML, where electrical headroom is constrained and legacy K11 switchgear remains, operating existing services at higher speeds would:

- Increase instantaneous and continuous current draw.
- Reduce power system resilience.
- Heighten the risk of highcurrent conditions through K11 equipment.
- Potentially compromise the safe and reliable operation of the traction power system.

For these reasons, increasing train speeds cannot be considered a viable intervention from a power system perspective and would introduce additional safety and performance risk to already constrained electrical infrastructure.

## [xi] General Service Spread, Not Consolidation

Distributing services reduces power loading peaks and supports growth objectives. This concept was tested and undertaken with WMT operating services to Liverpool as a precursor to declaring Congested Infrastructure.

Power modelling analysis demonstrated that two 4-car units an hour could be supported within the existing power capability, whereas a single 8-car formation could not.

Network Rail also implemented length restrictions on several WMT services from Birmingham to Liverpool to ensure they can be safely accommodated within the limits of existing power capacity as opposed to rejecting the service introduction.

However, as passenger demand continues to grow, shorter formations are reaching capacity, creating pressure to lengthen trains. Extending these services is not feasible with the existing power infrastructure, highlighting the constraint between operational flexibility and electrical capability.

## General Conclusion optimising capacity through combination of services:

Reducing or combining services is not a practical solution for congested infrastructure. It conflicts with growth and decarbonisation objectives and introduces technical challenges: longer or heavier trains concentrate electrical load, increasing peak power demand. Diesel operation as a fallback compromises performance, reliability, and carbon targets while consuming more track capacity. Network Rail has applied mitigations such as length restrictions and rolling stock optimisation where practicable.

## [xii] General: Performance and Sustainability

Electric vs Diesel performance: Operating in electric traction is materially superior for both capacity and performance. A Class 390 Pendolino draws up to ~5.9 MW under 25kV AC, giving strong acceleration and hill-climb capability on the WCML; by contrast, a bi-mode Class 800 in diesel mode is limited by under-floor engines (typically 3–5 × MTU 12V1600 per unit), giving an installed diesel power of ~1.68–3.5 MW depending on formation and software limits. In power-to-weight terms, published figures indicate around 10–11 kW/t for electric operation versus ~6–9 kW/t in diesel mode for Class 800 variants this affects journey times, acceleration from stops such as stations or red signals.

Electric vs Diesel Reliability: Diesel services are in general less reliable than electric services. With the Industry MTIN (Miles per Technical Incident) data typically showing electric multiple units achieving 30–50 % higher reliability than diesel fleets, reflecting fewer mechanical components and simpler traction systems.

Carbon Impact: A diesel train emits roughly 3–4 times more $CO_2$ per 100 km than an electric train operating on a decarbonised grid—around 25–35 kg $CO_2$/100 km for electric versus 90–120 kg $CO_2$/100 km for diesel, depending on load and duty cycle. Therefore, for this section of track each return journey of circa 56km would be the equivalent of circa 55-60kg $CO_2$.

## [xi] Crewe-Weaver Operational Control

Due to unsustainable levels of tripping on Down Slow when operating in n-1 a permanent operational control is in place to manage double headed Class 90 freight trains. This is due to the cable asset condition at Crewe. This makes the operation of freight services on the Down Slow significantly more risk-intensive for both the asset and overall system performance. The specific wording is: “Any down direction freight trains hauled by multiple class 90 traction (i.e.. more than 1 class 90) must be routed via the down fast from Crewe coal yard to Winsford south junction. where necessary trains should be held on the down slow or the down Liverpool independent until a margin to run on the down fast becomes available". In the last year alone this caused circa 1500 delay minutes.