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Value for Money in UK Railway Electrification Programmes

A Critical Review of Cost Drivers, Delivery Efficiency and Strategic Opportunity

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Patras, Greece, September 2026

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This dissertation was completed during a particularly meaningful period. My wife and I are preparing for the arrival of our first child. I would like to thank my wife for her patience and support.

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Abstract

This dissertation examines value for money in UK railway electrification programmes, focusing on cost drivers, delivery efficiency, and strategic opportunity. Electrification is widely recognised as an important pathway for rail decarbonisation. Nevertheless, its delivery in the UK has often been associated with high costs, programme uncertainty, and inconsistent political confidence. The study investigates whether these cost challenges arise mainly from electrification technology itself, or from wider delivery conditions such as governance, access, scope maturity, standards, procurement, and programme continuity.

The research adopts a qualitative approach. It combines a review of published industry and policy evidence with semi-structured interviews with experienced railway electrification practitioners. The findings indicate that value for money is not adequately captured by upfront capital cost alone. Practitioners associated value with whole-life performance, operational reliability, maintainability, system flexibility, and the ability to deliver efficiently across a stable programme of work. Furthermore, the research found that unit-cost variation is strongly influenced by route complexity, access constraints, late scope change, fragmented governance, technical client capability, standards application, and the treatment of wider system costs such as traction power, signalling interfaces, and civil or multidisciplinary interventions required to achieve electrical clearances.

A key contribution of the dissertation is the clarification of how single-track kilometre cost comparisons can be misleading when scope boundaries are inconsistent.

It concludes that improving value for money depends less on reducing the cost of the wires alone and more on stable long-term planning, mature project development, proportionate governance, integrated delivery, and retention of specialist capability through a rolling programme of electrification.

Keywords

UK Railway Electrification

Value for Money

Cost Drivers

Delivery Efficiency

Βέλτιστη Αξιοποίηση Πόρων στα Προγράμματα Ηλεκτροκίνησης Σιδηροδρομικού Δικτύου του Ηνωμένου Βασιλείου

Κριτική Ανασκόπηση Παραγόντων Κόστους, Αποδοτικότητας Παράδοσης και Στρατηγικών Ευκαιριών

Νικόλαος Γεωργακοπούλος

Περίληψη

Η παρούσα διατριβή εξετάζει την αξία έναντι κόστους (value for money) στα προγράμματα ηλεκτροκίνησης σιδηροδρόμων στο Ηνωμένο Βασίλειο, με έμφαση στους παράγοντες κόστους, την αποδοτικότητα και τη στρατηγική ευκαιρία. Η ηλεκτροκίνηση αναγνωρίζεται ευρέως ως βασική οδός για την απανθρακοποίηση των σιδηροδρόμων. Παρ' όλα αυτά, η υλοποίησή της στο Ηνωμένο Βασίλειο έχει συχνά συνδεθεί με υψηλά κόστη, αβεβαιότητα προγραμμάτων και ασυνεπή πολιτική εμπιστοσύνη. Η μελέτη διερευνά κατά πόσον οι προκλήσεις κόστους προκύπτουν κυρίως από την ίδια την τεχνολογία ηλεκτροκίνησης ή από ευρύτερες συνθήκες υλοποίησης, όπως η διακυβέρνηση, η πρόσβαση, η ωριμότητα του αντικειμένου, τα πρότυπα, οι προμήθειες και η συνέχεια των προγραμμάτων.

Η έρευνα υιοθετεί ποιοτική προσέγγιση. Συνδυάζει ανασκόπηση δημοσιευμένων στοιχείων της βιομηχανίας και πολιτικών κατευθύνσεων με ημιδομημένες συνεντεύξεις έμπειρων επαγγελματιών στον τομέα της σιδηροδρομικής ηλεκτροκίνησης. Τα ευρήματα δείχνουν ότι η αξία έναντι κόστους δεν αποτυπώνεται επαρκώς αν περιοριστεί στο αρχικό κεφαλαιουχικό κόστος. Οι επαγγελματίες συσχέτισαν την αξία με την απόδοση σε όλο τον κύκλο ζωής, τη λειτουργική αξιοπιστία, τη δυνατότητα συντήρησης, την ευελιξία του συστήματος και την ικανότητα αποδοτικής παράδοσης στο πλαίσιο ενός σταθερού προγραμματισμένου όγκου έργων. Επιπλέον, διαπιστώθηκε ότι η μεταβλητότητα του μοναδιαίου κόστους επηρεάζεται έντονα από την πολυπλοκότητα της γραμμής, τους

περιορισμούς πρόσβασης, τις καθυστερημένες αλλαγές αντικειμένου, τον κατακερματισμό της διακυβέρνησης, την τεχνική ικανότητα του εντολέα, την εφαρμογή των προτύπων και τον τρόπο με τον οποίο αντιμετωπίζονται τα ευρύτερα κόστη του συστήματος, όπως η ηλεκτρική ισχύς, οι διεπαφές σηματοδότησης, οι πολιτικές παρεμβάσεις και τα περιγράμματα/ελεύθερα όρια.

Βασική συμβολή της διατριβής αποτελεί η αποσαφήνιση του τρόπου με τον οποίο οι συγκρίσεις κόστους ανά μονή γραμμοχιλιομετρική μονάδα μπορεί να είναι παραπλανητικές όταν τα όρια του αντικειμένου δεν είναι συνεπή.

Συμπεραίνεται ότι η βελτίωση της αξίας έναντι κόστους εξαρτάται λιγότερο από τη μείωση του κόστους των αγωγών ηλεκτροκίνησης καθαυτών και περισσότερο από τον σταθερό μακροπρόθεσμο σχεδιασμό, την ώριμη ανάπτυξη έργων, την αναλογική διακυβέρνηση, την ολοκληρωμένη υλοποίηση και τη διατήρηση εξειδικευμένης τεχνογνωσίας μέσω ενός κυλιόμενου προγράμματος ηλεκτροκίνησης.

Λέξεις – Κλειδιά

Ηλεκτροκίνηση Σιδηροδρομικού Δικτύου

Βέλτιστη Αξιοποίηση Πόρων

Παράγοντες Κόστους

Αποδοτικότητα Υλοποίησης

Table of Contents

List of Figures

List of Abbreviations and Acronyms

ATF	Auto-Transformer Feeder
BCR	Benefit-Cost Ratio
GBR	Great British Railways
CBA	Cost-Benefit Analysis
CBGDP	Carbon Budget and Growth Delivery Plan
CSM-RA	Common Safety Method - Risk Assessment
DfT	Department for Transport
ECC	Electrification Cost Challenge
GVA	Gross Value Added
HM Treasury	His Majesty's Treasury (Finance Ministry)
HS2	High Speed 2
LTRS	Long-Term Rail Strategy
MCDA	Multi-Criteria Decision Analysis
NAO	National Audit Office
NPPV	Net Present Public Value
NISTA	National Infrastructure and Service Transformation Authority
OCS	Overhead Contact Systems (Electrification engineering discipline)
ORE/OLEMI	Empirical foundation design method for Overhead Contact Systems (see Glossary of Terms)
ORR	Office of Rail and Road
OVfM	Office for Value for Money
PVB	Present Value [of] Benefits
PVC	Present Value [of] Costs
RIA	Rail Industry Association
TDNS	Traction Decarbonisation Network Strategy
TPS	Traction Power Systems
UK	United Kingdom
VfM	Value for Money

List of Units and Symbols

AC	Alternating Current
CO_2	Carbon Dioxide
DC	Direct Current
Hz	Hertz
kV	kilo Volt
mm	Millimetre
m	Metre
V	Volt
£	Pound Sterling

Glossary of Terms

Autotransformer Feeder (ATF):	A 25 kV AC railway electrification power supply arrangement that consists of 25 kV OLE and 25 kV autotransformer feeder conductors to improve power transmission and voltage regulation along the route.
Access (Railway)	The arrangements that permit engineering work to be carried out on the railway, including possessions, isolations, blockades, and other access windows during which train services are restricted or suspended.
Blockade	A planned period during which a section of railway is fully closed to train services to allow intensive engineering works to be undertaken safely and efficiently.
Bi-mode train	A train capable of operating using electric traction where electrification infrastructure is available, and switching to other power sources (typically diesel or battery traction) when electric traction is unavailable or not in use.
Common Safety Method - Risk Assessment (CSM-RA)	CSM-RA is a European legislation about safety for railways. It provides a structured way to identify and manage risks. CSM-RA has been retained in the UK law despite Brexit.
Factory Train	A train used to deliver electrification construction works that combines several construction activities into one mechanised process, with the aim of increasing productivity and reducing the number of possessions required.
High-output electrification	A construction approach to railway electrification that aims to deliver large volumes of work efficiently by using mechanised equipment (see factory train), and repeatable processes to maximise productivity during limited access periods.
ORE/OLEMI method	An empirical foundation design approach historically used in UK railway electrification projects, which was developed by the Office for Research and Experiments (ORE). The method

	relies on empirical design from previous schemes to determine foundation sizes for overhead contact system masts.
Possession	A planned period during which a section of railway is temporarily closed to train movements so that maintenance or construction work can be carried out safely.
Rail Enhancement vs Renewal	Rail enhancement is a project that adds new capability, for example, electrifying an existing railway or extending a line. Rail renewal replaces or refurbishes existing life-expired assets to maintain the current railway capability.
Rail Method of Measurement	RMM is a standardised way of categorising railway project costs so that different projects can be compared on a like-for-like basis.
Rolling Programme	A rolling programme refers to a continuous, long-term approach to railway electrification, in which a consistent volume of single-track kilometres is electrified over successive years.
Rules of the Route	A Network Rail document that defines the operational constraints for a specific railway route. This document includes permitted access times, possession rules, traffic patterns, and engineering access windows. These rules influence when and how infrastructure work can be carried out.
Supply-Chain	It refers to organisations that provide services, products, and expertise to design, build, and operate the railway.
Single-Track Cantilever	A single-track cantilever is the simplest support structure used in railway electrification. It consists of a mast and a cantilever frame. The cantilever frame supports the wires serving one track only.
Single-Track Kilometre (or metre)	The measure of electrification. Electrifying one kilometre (or metre) of two track railway is two STK.

Shortlisting	The stage of options selection in which a reduced set of feasible options is taken forward from the longlist for more detailed appraisal, typically based on affordability, deliverability, and value-for-money considerations.
Longlisting	The initial stage of options development in which a wide range of potential schemes or interventions is identified and screened at a high level against strategic objectives and constraints, before more detailed appraisal is undertaken.

1 INTRODUCTION

1.1 Background

Following the 2015 Paris Climate Agreement, the United Kingdom (UK) has committed to reducing greenhouse gas emissions and achieving net-zero by 2050. Transport contributes about a third of the UK's total emissions, therefore decarbonising the railways is an integral part of the national climate strategy.

The Traction Decarbonisation Network Strategy (TDNS) published by Network Rail confirms that widespread electrification is the primary pathway in order to decarbonise the most intensively used areas of the railway network. Outside these areas the deployment of battery and hydrogen rolling-stock on both an interim and permanent basis will be critical in achieving decarbonisation. For areas of the network with significant freight flows or long-distance high-speed services, electrification is the only technology currently able to support these service types. TDNS emphasises that electric trains have lower emissions, lower operating and maintenance costs and offer greater capacity and reliability than diesel trains.

Recent progress in railway electrification has been modest. The Office of Rail and Road (ORR) states that, as of 31st March 2024, Great Britain had approximately 6,130 km (3,809 miles) of electrified lines. This is about 39% of the network. Between the years 2023 and 2024, 141.4 km (87.86 miles) of new electrification was delivered through projects such as the Core Valley Lines Electrification, the TransPennine Route Upgrade and Glasgow to Barrhead Electrification. These figures indicate that decarbonisation will require an accelerated and sustained electrification programme over the coming decades to meet the government goals. The TDNS identified a requirement to electrify approximately 13,000 additional STK. However, later RIA analysis suggests that wider deployment of battery-electric trains could reduce the required amount of electrification to approximately 66% of the network.

The political climate during 2024 and 2025 has been shaped by fiscal constraints and competing infrastructure priorities. In a speech to the Railway Industry Association in late 2025, the transport secretary stated that full electrification of the railways is "not affordable right now" and that pausing some schemes had allowed the government to make other commitments.

Decarbonisation policy is framed by wider political commitments to economic growth, regional levelling-up (particularly in the North-West region) and productivity improvements. Rail investment is a key instrument to meet these objectives. The railway industry contributes around:

- £41.2 billion of gross value added (GVA),
- and supports 640,400 jobs across the UK economy.

Cost-benefit analysis indicates that for every £1 invested in railways, between £2.50 and £4.00 is generated in the wider economy.

Rail enhancements improve capacity for both passenger and freight services, reduce journey times, and increase reliability. However, successive programmes (such as the Great Western Electrification Programme) have suffered from cost increase and schedule elongation, leading policymakers to focus on governance, budgeting, and value-for-money.

1.2 National Policy and Infrastructure Content

Railway electrification is not limited to capital expenditure (i.e. installation of equipment or procurement of rolling stock). It is influenced by climate change policy, fiscal constraints (arising from the significant initial financial capital required), regulatory frameworks, institutional and governance changes, and political priorities.

In November 2025, the Government introduced the Railways Bill, which introduces the Great British Railways (GBR), that replaces Network Rail. GBR will be a state-owned organisation responsible for both the railway network and rolling-stock, ending the current fragmented system. The Department for Transport highlights that GBR will provide unified leadership and accountability. Moreover, the Secretary of State for Transport will issue the Long-Term Rail Strategy (LTRS), which is the first strategy of its kind. The Long-Term Rail Strategy will set out strategic objectives for the railways over a 30-year period. As a result, it will inform GBR about the government's priorities, helping GBR to make long-term choices, which influence the whole rail sector. The Railways Bill indicates that the UK will move away from short franchising cycles, and towards more strategic management of infrastructure and services.

Infrastructure policy has also evolved. The Autumn Budget 2024 introduced the Office for Value for Money (OVfM), an independent time-limited body, which supported the decisions making in the Spending Review 2025. The Spending Review 2025 explained that the OVfM has undertaken cross-departmental studies on mega-project governance and procurement, assessing departments' technical efficiency targets, and recommending thematic value-for-money reviews and annual efficiency targets of at least 1%. The review commits to implement continuous improvement practices and to improve budgeting across governmental projects.

The Carbon Budget and Growth Delivery Plan (CBGDP) is a governmental strategy outlining emissions targets, which are legally enforced. CBGDP highlighted that railway electrification is a key policy to replace older diesel trains with pure electric. The plan notes that electrification introduces reduction in CO_2 emissions per vehicle-kilometre, with notable examples the TransPennine Express and Northern (two Train Operating Companies) by approximately 11% and 17% respectively. In addition, the CBGDP states that electrification schemes reduce costs as electric trains are cheaper to operate, maintain and buy than diesel trains. Further to this, electric trains are lighter, thus, they cause less damage to the track and subsequently the network requires less operating and maintenance costs. Lastly, CBGDP notes that electrification increases capacity and reliability. It lists the Midland Main Line to Leicester project, Wigan to Bolton Electrification project and the TransPennine Route Upgrade project as upcoming projects; and indicates that future schemes will be identified and assessed for the period 2037 – 2050.

Investment announcements by Transport Scotland move towards this direction. Particularly, in September 2025, the Scottish Government announced that it will invest £342 million to deliver approximately 140 km (86.99 miles) of electrification for the Fife and Borders lines. In addition, the Scottish Government announced that it will procure 69 battery-electric trains. Such statements demonstrate momentum and the role of devolved administrations, particularly Scotland, in delivering electrification.

Long-term infrastructure planning is presented in the *UK Infrastructure: 10 Year Strategy*, which was published in June 2025. This strategy, the first of its kind, prioritises long-term outcomes over short-term announcements. In addition, it aims to reduce stop-start investment cycles (which have historically increased costs) and to cut costs by 10-25% through a stable project pipeline. The strategy recommends the creation of the National Infrastructure and Service Transformation Authority (NISTA) to oversee the implementation of the *UK Infrastructure: 10 Year Strategy*. More notably the strategy states that the government is committed to invest £35.5 billion for rail enhancements between 2026-27 and 2029-30, including £2.5 billion to continue the delivery of the East West Rail mega-project, to unlock economic growth along the Oxford-Cambridge arch.

Evidence presented by the NISTA indicates that transport unit costs are not statistically different between the UK, EU and other OECD countries (see figure 1-1). Additionally, NISTA states that UK electrification projects are 30-60% more expensive than comparable schemes in Germany. This suggests that the challenge is not simply that infrastructure in the UK is always more expensive, but that rail electrification is affected by specific inefficiencies.

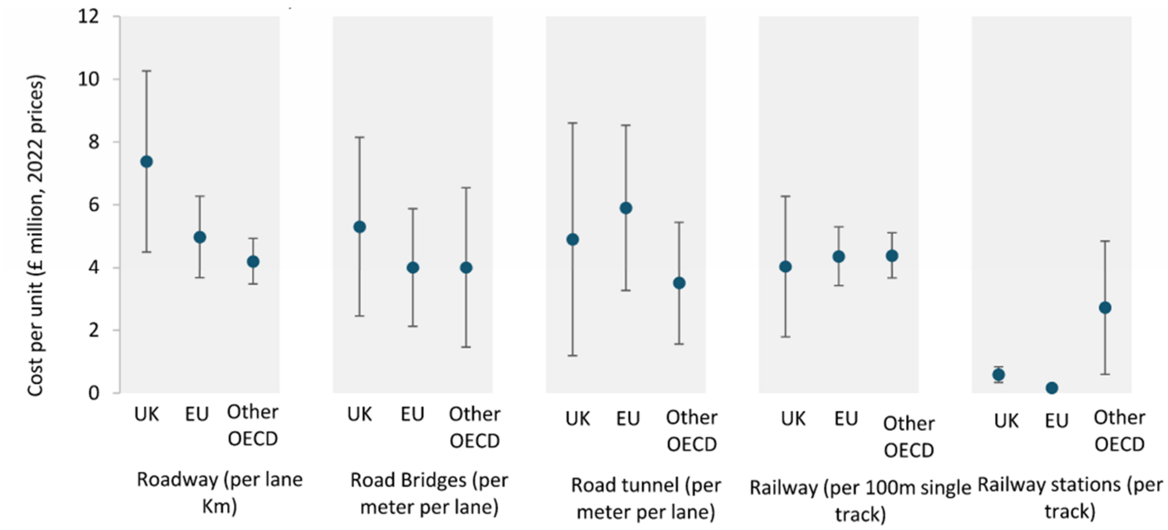

Figure 1-1: Transport unit costs between UK, EU, and other OECD countries
Source: NISTA

1.3 The Case for Electrification

Railway electrification offers several advantages in comparison to diesel traction. Electric trains are more energy-efficient, produce no emissions at the point of use, and can use electricity from renewable sources. The CBGDP explains that replacing diesel trains with electric rolling-stock reduces lifecycle CO_2 emissions, lowers operating and maintenance costs, and improves capacity and reliability. A rolling programme of electrification is also essential to develop and retain skills, standardise design and access, and avoid remobilisation costs that are introduced from start-stop projects. Rail Industry Association (RIA) states that when electrification is delivered as a continuous pipeline through a rolling programme, it can be 33-50% cheaper per kilometre than stop-start programmes. RIA justifies this cost reduction because of:

- supply-chain learning and skills development, with the new skills being able to be retained by having a consistent workforce,
- stable utilisation,
- consistent standards.

Nevertheless, the UK's electrification rate remains low despite substantial advantages that would be gained. Approximately 39% of the railway network is electrified and the past average annual electrification additions are approximately 70-100 km (43.5-62.14 miles) over the past decade. In order to achieve the net-zero emission goals described in the TDNS, several thousand kilometres will need to be electrified over the next 20-25 years. Not committing to a rolling programme of electrification will introduce higher costs, skill shortages, and delays.

An additional strategic benefit is energy security and national resilience. Electrification reduces railway dependence on diesel fuel. Therefore, it reduces exposure to fossil-fuel price volatility and by extension to geopolitical supply disruption. This broadens the case for electrification beyond emissions reduction and operating cost. This is relevant to value-for-money because some benefits of electrification may not be fully captured through narrow capital-cost or project-level appraisal.

1.4 Understanding Value for Money

From the UK Government's investment strategy perspective, value-for-money is not simply about reducing cost. The Green Book, published by HM Treasury, defines how to appraise projects, programmes, and policies. The Green Book Review 2025 defines value-for-money as a balanced judgement about the best use of public resources to deliver policy objectives. Moreover, it states that value-for-money should be based on:

a) monetisable benefits and costs, which can be reflected in benefit-cost ratios
b) un-monetisable benefits and costs, risk and uncertainty, and other important unquantifiable parameters.

The Green Book Review 2025 highlights that a project with a benefit-cost ratio (BCR) below one should not be treated by default as having more costs than benefits and by extension being unworthy of further consideration. Rather, it means that the monetised benefits captured in the BCR are lower than the monetised costs. A project could still provide value-for-money. This could happen when substantial un-monetised benefits are present (such as network resilience, air quality, improved energy security, freight capacity, system reliability, social connectivity, or wider economic confidence). The review also states that arbitrary BCR thresholds should not determine funding decisions.

The National Audit Office (NAO) is the UK's independent body responsible for monitoring public expenditure and publishes approximately 60 value-for-money reports each year. NAO evaluates whether programmes or projects offer good value-for-money through the three Es:

- Economy,
- Efficiency, and
- Effectiveness.

The NAO defines *Economy* as minimising the cost of resources while maintaining quality. Furthermore, it defines *Efficiency* as achieving the same or better outputs with fewer resources. Finally, it defines *Effectiveness* as the metric to where objectives are met. The NAO reports that value-for-money is the optimal use of resources to achieve the intended outcomes. In a similar manner, the Northern Ireland Audit Office defines value-for-money an evidence-based investigation that considers whether Economy, Efficiency and Effectiveness have been achieved.

For railway electrification, value-for-money requires a comprehensive appraisal of whole-life social costs and benefits. This includes quantifiable impacts (such as journey time savings, reduction in diesel fuel use, lower maintenance costs, and increased capacity) and wider benefits (such as reducing greenhouse-gas, reducing air-pollutant emissions, noise reduction, modal shift to rail, and regional economic development). Furthermore, consideration should be given to additional benefits affecting different groups in society, such as increased connectivity of poorer regions, these benefits should also form part of the value-for-money judgement.

1.5 Research Aim and Objectives

The aim of this dissertation is:

- To investigate how value-for-money is defined and achieved in UK railway electrification programmes.
- To identify practical actions that improve delivery efficiency and stakeholder value.

To meet the above aim, the dissertation pursues four key objectives:

1. **Review how value-for-money is defined, achieved, and measured in UK railway electrification, across publicly funded programmes.** This objective will examine decarbonisation strategies, relevant policy, and infrastructure planning frameworks to understand how electrification contributes to value-for-money.
2. **Identify the key drivers of cost variability and delivery efficiency**. This objective will explore how programmes, procurement, railway access, standards and internal delivery capabilities influence value-for-money outcomes, drawing on the Green Book Review 2025 and NAO.
3. **Synthesise published evidence with insight from industry.** Semi-structured interviews with industry experts will be undertaken and analysed thematically to understand practical barriers and enablers to value-for-money. These interviews will complement published data and insights from recent governance and budgeting reforms.
4. **Develop actionable recommendations to improve design efficiency, cost performance, and stakeholder value in future UK electrification programmes**. These recommendations will be based on recent electrification schemes, analysis of unit-cost variability and efficiency savings, and lessons learnt from case studies such as the TransPennine Route Upgrade and Midland Main Line, considering whether rolling programmes and specific design, procurement and access strategies can deliver 33-50% cost reductions.

1.6 Research Questions

The objectives above lead to the following research questions:

1. **How should value-for-money be defined and manifested in railway electrification in the UK?** This question investigates the Green Book definition of value-for-money and how monetised and non-monetised benefits are measured against costs.
2. **Which project governance and budgeting factors most strongly affect value-for-money in UK railway electrification programmes?** The response to this question aims to present how project governance, funding structures and client-led assurance processes influence cost, schedule, and outcomes. This response will consider recent reforms such as the Railways Bill (that introduced GBR) and OVfM.
3. **What are the main drivers of unit-cost variation in UK electrification, and to what extent can a rolling programme, standardisation and capability retention reduce costs?** The response to this question aims to present the cost drivers and examines whether a continuous rolling programme can deliver 33-50% cost reductions, which is what RIA suggests.
4. **What practical design, procurement and railway access choices matter most for delivering value-for-money on complex railway corridors such as the TransPennine Route Upgrade?** The response to this question is focused on identifying lessons from recent projects and how these can inform and subsequently improve future electrification schemes.

1.7 Scope and Limitations

This dissertation is focused on the UK mainline rail network. It is concentrated on heavy-rail electrification that uses 25 kV AC at 50 Hz overhead contact systems including interfaces with Electrical Track Equipment (e.g. 750 V DC third rail). In addition, it considers battery-electric and hydrogen rolling stock where they complement electrification on lighter-used railway lines. Railway networks outside the heavy-rail sector, such as metro systems (e.g. London Underground), tramways (e.g. Metrolink), privately financed networks, and freight-only railway routes are not included in this dissertation. International comparisons will be made selectively to benchmark costs and governance practices.

1.8 Structure of the Dissertation

The below presents the structure of this dissertation:

- **Chapter 1 - Introduction** (this chapter). It sets the scene of UK railway electrification. It defines the dissertation's aim, objectives, research questions, and scope.
- **Chapter 2 - Literature Review**. It reviews the literature on railway decarbonisation, electrification policy, cost drivers and appraisal methods. Furthermore, chapter 2 presents the insights from the RIA Electrification Cost Challenge (ECC) report.
- **Chapter 3 - Methodology**. This chapter explains the research methodology, which will be based on data from semi-structured interviews and data from several organisation such as: ORR, NAO, Network Rail, RIA.
- **Chapter 4 - Findings**. It presents the results from the semi-structured interviews, assesses any other collected data. Lastly, it highlights perceptions of cost drivers, governance influences, and delivery practices affecting value-for-money.
- **Chapter 5 - Discussion**. It provides a critical discussion of the findings, linking cost drivers, governance and delivery choices to overall value-for-money (economy, efficiency, and effectiveness).
- **Chapter 6 - Conclusions**. The last chapter presents recommendations for policymakers, industry and future researchers.

2 LITERATURE REVIEW

2.1 Value for Money in UK Infrastructure and Railway Projects

The concept of value-for-money is pivotal to investments on public infrastructure in the United Kingdom. It also defines how projects are appraised and prioritised. Generally, value-for-money is about securing the best outcomes for public resources. As described in Chapter 1, the NAO defines value-for-money as the optimal use of resources to achieve the desired outcomes and goals. This definition is based on the traditional '3 E's (economy, efficiency, and effectiveness) and underlines the NAO's position that public spending should not simply be minimised but also achieve the desired policy outcomes and objectives in the most effective way.

In the UK transport industry, and subsequently in the railway sector, value-for-money is applied through the Department for Transport's 'Value for Money Framework'. The DfT's guidance document titled 'Value for Money: Supplementary guidance on categories' outlines a hierarchy of categories based on the expected Benefit-Cost Ratio or Net Present Public Value. These categories are widely used by the decision-makers on local and central governments as they provide clearly defined benchmarks.

While economic metrics derived from Cost-Benefit Analysis (CBA) are central to UK transport industry appraisals, it should be noted that the literature presents additional approaches, such as Multi-Criteria Decision Analysis (MCDA) and Benchmarking. These approaches will be discussed further in Section 2.2.

Additionally, the DfT's guidance highlights that where significant non-monetised benefits are present (such as environmental or social benefits) analysts should consider whether the BCR or NPPV are sufficient indicators to determine the value-for-money category. Furthermore, the DfT's guidance suggests that such factors could lead to change a value-for-money category and that sensitivity analysis should be used to explore how changes in these factors can affect the value-for-money assessment. This approach articulates that the simple BCR or NPPV analysis may not determine an accurate result in terms of value-for-money categorisation and subsequently introduces a degree of professional judgement. Moreover, it acknowledges that any value-for-money category judgements should be transparent in order the decision-makers to understand the uncertainties involved and the basis on which categories have been determined or adjusted. In conclusion, the BCR or

NPPV may be the main indicators to determine the value-for-money categories, however the DfT 'Value for Money Framework' provides flexibility for wider considerations.

The NAO, which uses its own definition of value-for-money as described in Chapter 1, focuses on the relationship between resources and outcomes, and does not assess the benefits of the underlying policy objectives themselves. This approach reinforces the idea that value-for-money is not based on pure economic analysis but also involves investigating other factors such as governance, management, and delivery effectiveness.

Furthermore, the House of Commons Library (UK Parliament's independent body) presents evidence that although transport appraisal involves "balancing a series of economic, social and environmental benefits the economic case, especially the benefit-cost ratio, tends to dominate thinking on transport projects". This dominance is described as problematic since not all aspects of a project can be easily monetised, and particularly non-economic benefits such environmental impacts tend to carry less weight in the decision-making process. The paper concludes that project with strong environmental or social benefits often are sifted out as local authorities exclude projects with low BCR.

These criticisms align with broader academic debates on the limitations of CBA as an appraisal tool. Researchers argue that monetising environmental and social benefits is challenging, subsequently leading to undervaluation of these benefits, for example carbon reduction, improved health, and social inclusion. Moreover, the House of Commons paper notes that some commentators support a reform of the appraisal process to consider climate and societal goals. Even the DfT's guidance highlights that non-monetised benefits may shift a value-for-money category, which indicates acknowledgement of these concerns. Nonetheless, the current value-for-money framework focuses on quantifiable economic returns.

The literature shows both consensus and disagreement. Public bodies agree that value-for-money means achieving the best outcomes from public spending in accordance with the NAO's '3 Es'. Additionally, there is agreement that the CBA has useful indicators for comparing economic returns across projects. Disagreement arises about the weight on the decisions of such economic indicators. Critics argue that reliance on the CBA oversimplifies complex decisions and undervalues non-monetised benefits. The DfT's use of sensitivity testing and consideration of non-monetised effects suggests a partial move towards a more balanced approach. Nevertheless, the literature suggests that adopting such approach is still a challenge for UK transport projects.

2.2 Methods for Assessing Value for Money in UK Infrastructure Projects

In order to assess whether public infrastructure investment is value-for-money several methods are being used in the UK. The following three methods are prominent in the railway industry:

- Cost-Benefit Analysis
- Multi-Criteria Decision Analysis
- Benchmarking

The strengths and limitations of these methods, and their use in the UK railway environment, are discussed below.

2.2.1 Cost-benefit analysis

CBA is the main appraisal approach in accordance with the HM Treasury's Green Book and the DfT's guidance document titled 'Value for Money: Supplementary guidance on categories'. CBA assesses the value of costs and benefits, and ultimately produces a value-for-money category for each option, enabling decision-makers to compare proposals. The CBA is based on the BCR and NPPV. The BCR and NPPV are defined as below:

$$BCR = \frac{PVB}{PVC} \quad (2.1)$$

$$NPPV = PVB - PVC \quad (2.2)$$

Where:

- BCR = Benefit-Cost Ratio
- NPPV = Net present Public Value
- PVB = Present Value [of] Benefits
- PVC = Present Value [of] Costs

In standard cases, where the PVC is positive as the costs exceed the revenues, figure 2.1 illustrates these categories. In cases, where the PVC is negative as the costs are less than the revenues, figure 2.2 illustrates these categories. In cases where the PVC is zero, figure 2.3 illustrates these categories.

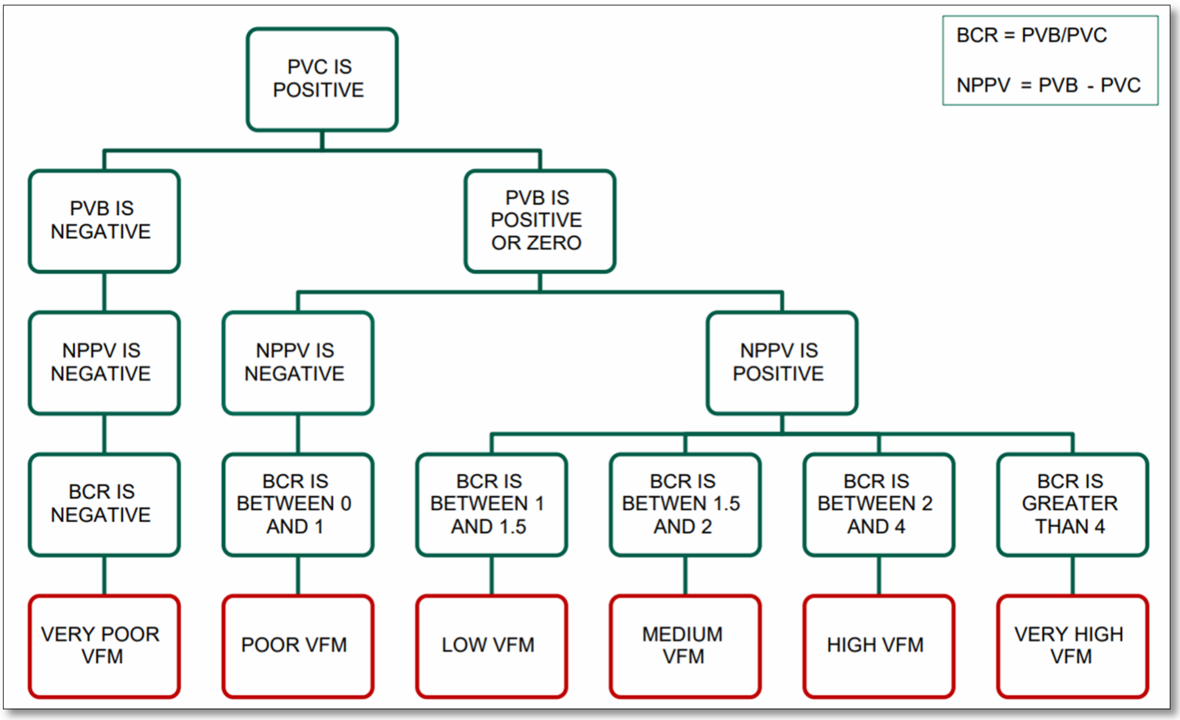

Figure 2-1: Value-for-money categories, when PVC>0
Source: Department for Transport (2022), Value for Money: Supplementary guidance on categories

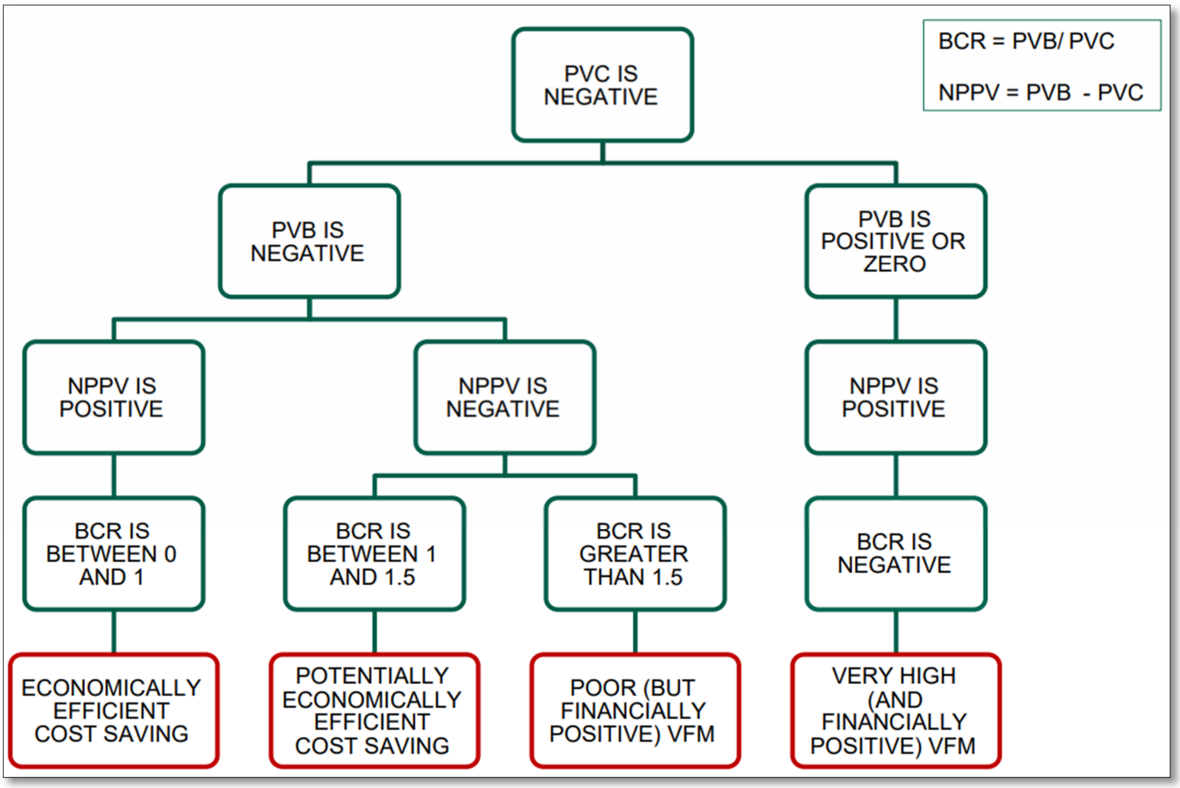

Figure 2-2: Value-for-money categories, when PVC<0
Source: Department for Transport (2022), Value for Money: Supplementary guidance on categories

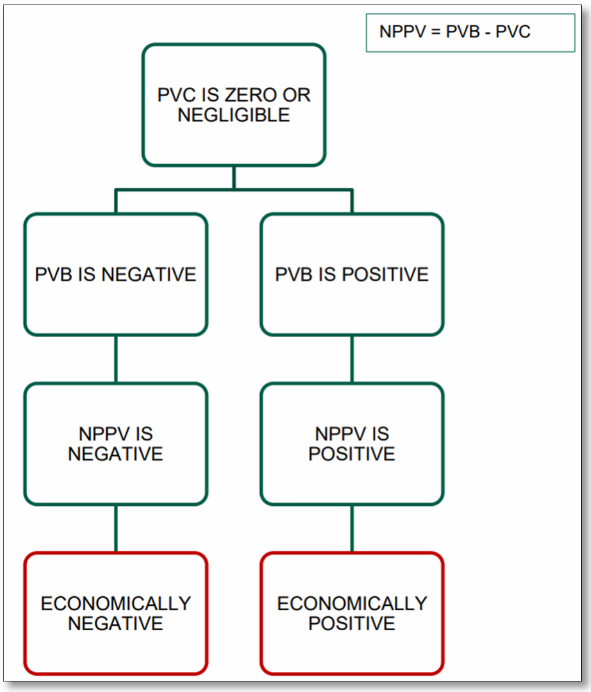

Figure 2-3: Value-for-money categories, when PVC=0
Source: Department for Transport (2022), Value for Money: Supplementary guidance on categories

The House of Commons Library in the document titled 'Transport appraisal and evaluation' notes that, in practice, a BCR of 2: 1 is regarded as high value-for-money, while a BCR of 4: 1 regarded as very high value-for-money (a BCR of 2: 1 means a return of £2 for every £1 invested). This means that transport projects with a BCR less than 2: 1 are usually sifted out at early development stages as decision-makers perceive that they will struggle to obtain the necessary funding.

The House of Commons Library highlights that transport industry appraisals aim to balance economic, social, and environmental factors. However, the BCR and subsequently the economic factors dominate the decision-making.

Reliance on the BCR provides a clear categorisation of the different options and is seen by officials as transparent metric that supports accountability in public expenditure decisions. For railway electrification projects, CBA allows the economic quantification of journey-time reduction, operating cost reductions, and environmental benefits, while discounting capital and maintenance costs over the life of the assets. Thus, it offers a single metric of economic efficiency, which can be used to judge value-for-money across competing infrastructure proposals.

Several criticisms have been identified in the literature. Firstly, the CBA is sensitive to assumptions about demand, discount rates, and monetisation of intangible benefits. The House of Commons Library briefing highlights that heavy reliance on BCR could lead to oversimplifying complex decisions. Moreover, environmental and social factors may be undervalued or excluded entirely, leading to a biased approach towards projects whose benefits are easier to monetise. Secondly, the same briefing notes that because the CBA requires mathematical modelling the decision-makers sometimes do not fully understand CBA results. Thirdly, the Green Book notes that the CBA output and subsequently the value-for-money categories should be interpreted cautiously since significant non-monetised factors, and optimism bias may warrant adjustments. Nevertheless, the CBA method's mathematical clarity makes it an enduring, but imperfect, tool for appraising projects.

2.2.2 Multi-criteria decision analysis

MCDA is a suite of techniques designed to compare options against multiple conflicting objectives. Government guidance notes MCDA is used when:

- factors cannot be easily compared,
- there are several stakeholder perspectives, or
- other methods are unsuitable.

MCDA combines quantitative and qualitative components. The qualitative component involves stakeholder engagement to capture their requirements. The quantitative component involves modeling both the stakeholders' requirements and the performance of different proposals.

The Green Book notes that MCDA could be used at the longlisting to sift out options, but CBA should be used at shortlisting. Thus, MCDA has a limited function in infrastructure appraisal and is used to complete CBA rather than replacing it.

The Government Analysis Function's guide notes that MCDA is not a descriptive approach but rather normative. Therefore, MCDA is used to develop appraisal summary tables or to illustrate how options perform across criteria, and the final decision making is based on economic appraisal.

2.2.3 Benchmarking

Benchmarking appraises value-for-money by comparing the cost performance of projects against previously specified benchmarks. For railway electrification, RIA has used benchmarking to demonstrate that electrification can be delivered affordably in comparisons with recent high-profile projects. In the RIA ECC report, it is concluded that:

- simpler projects should be delivered between £0.75 - £1.0 million per single-track kilometre (approximately £0.9 - £1.3 million in 2026 prices)
- complex projects should be delivered between £1.0 - £1.5 million per single-track kilometre (approximately £1.3 - £1.9 million in 2026 prices).

Benchmarking these unit costs against past UK and international projects allows policymakers to identify inefficiencies and set realistic cost targets. The same report notes that a rolling programme of electrification could progressively lower costs by retaining skilled teams and reducing re-mobilisation costs.

Furthermore, the ORR uses annual benchmarking of Network Rail's maintenance and renewals costs, controlling cost drivers such as track length and traffic levels. The ORR analysis aims to identify areas performing above or below expected cost ranges, and as a result revealing potential efficiencies.

Therefore, benchmarking complements CBA as it is focused on cost efficiency rather than cost-benefit valuation. It provides information about cost performance when costs are compared with previously specified benchmarks. However, benchmarking faces methodological challenges. Accurate comparisons require standardised cost definitions and accounting for differences in scope, geography, and design standards. Railway electrification projects with extensive civil engineering interventions or heritage constraints may legitimately cost more than simpler schemes, therefore superficially high unit costs do not necessarily indicate poor value-for-money. RIA warns that "unit costs should be used with caution. They are not an estimating tool.". RIA notes that a common "rail method of measurement" would improve comparability, but such standards are still developing.

2.2.4 Strengths and limitations of methods for assessing value-for-money

The three methods reviewed address different aspects of value-for-money.

CBA's main advantage is that it allows for a direct comparison of the different investment options by converting diverse factors into a single economic measure. However, because CBA is mainly focused on economic benefits, it undervalues the environmental and social benefits of a proposal. Additionally, CBA is a mathematical tool with intrinsic complexity, which can mislead non-technical decision-makers.

MCDA addresses some of these limitations by considering qualitative and non-monetary criteria, along with quantitative criteria. Therefore, MCDA presents a more holistic reflection as it considers social and environmental factors. Nevertheless, its normative nature and the need to assign subjective weights make it less accepted for formal appraisals. As a result, policy guidance restricts its use, and it is not considered as a meaningful measure of value-for-money. This leads to the MCDA being used at longlisting stage to sift out proposals, while CBA dominates the shortlisting stage and the final decisions.

Benchmarking assesses cost performance (and offers data about cost-efficiency) by comparing unit costs across projects. It identifies outliers and could highlight lessons learnt from best practice. For example, the RIA ECC report notes that with appropriate design, access strategies, and a rolling programme; electrification costs can be kept within an efficient range. Thus, benchmarking informs both decision-makers about realistic cost expectations. However, its reliability depends on the availability of comparable data and the ability to adjust the data for project complexity, access conditions, and technical standards. Therefore, Benchmarking may misrepresent value-for-money without such adjustments. Moreover, Benchmarking provides no direct measure of benefits. It must be combined with another appraisal method for this purpose.

In summary, CBA, MCDA, and benchmarking methods contribute to value-for-money appraisal. CBA method provides an economic assessment focused on monetised benefits. MCDA method considers a wider number of qualitative and quantitative components. Lastly, benchmarking method can provide empirical evidence of cost efficiency through comparison with similar projects. The key is that understanding the advantages and disadvantages of each method could lead in developing an appraisal process that is both analytically robust and sensitive to the multifaceted nature of value-for-money in railway electrification.

2.3 Cost Drivers in UK Railway Electrification and Causes of Cost Variability

Cost escalation in railway electrification programmes arises from a combination of factors such as technical, managerial, legislation, and market. NAO highlights that costs on the Great Western Route Modernisation increased significantly because early cost estimates relied on unrealistic assumptions and an immature understanding of scope.

2.3.1 Infrastructure constraints

Infrastructure-related cost drivers stem from the physical characteristics of a route and the extent of civil (and other non-electrification engineering disciplines) interventions needed. Many civil structures on UK's railway were built during Victorian times, and they were not designed for electrification. In order to achieve the electrical and mechanical clearances for Overhead Contact Systems (OCS), overline structures may require track realignment/lowering, bridge raising, or reconstruction. Furthermore, it may be necessary to modify lineside structures and overline assets such as such as station awnings, signal cages, bridges. These works may include increasing parapet heights, providing screening, or introducing new bridges over the railway. The main purpose of those works is to prevent contact with live equipment. It should be noted that recent initiatives, mainly the Cost-Efficient Electrification, have reduced the magnitude of the interventions needed through the application of Voltage Control Clearances (VCC).

2.3.2 Standards and legislation requirements

RIA ECC report notes that cost escalation in Great Western was exacerbated by a change from UK clearance standards to European Technical Specification for Interoperability (TSIs), which required more onerous clearances. In particular:

a) It required a 270mm clearance (from live OCS to overline structure soffit) unless justified through a risk assessment complying with CSM-RA, while the previous UK practice allowed for a reduced clearance of 150mm. This resulted in overline structures (mainly bridges) that would previously have been considered clear, requiring an intervention.

b) It required adopting a 3.5m clearance (from standing surface to live OCS) instead of the historic UK “9-foot rule” of 2.75m. This change introduced extended and expensive OCS adjustments and bridge modifications.

It should be noted that since the RIA ECC report was published in 2019, there have been updates to standards (e.g. NR/L2/ELP/27716 and BS EN 50122-1:2022+A1:2025) which have aimed to rebalance safety, quality, and cost by reducing some of the more onerous requirements. However, the literature suggests that these later standard updates did not reduce the costs of projects that had already established their design decisions during early design development.

Therefore, the RIA ECC report recommends that implementing a “standards freeze” for the duration of a project to ensure that it will be completed against the standards on which they were tendered.

2.3.3 System design maturity and proven technology

The RIA ECC report notes that at the Great Western programme, designers adopted a conservative limit-state approach which was the BS EN EC7. This approach led to higher loads and longer piles instead of the well-established empirical method (ORE/OLEMI). Moreover, conservative assumptions about soil stiffness resulted in pile lengths up to 12-15m. These piles were often positioned away from tracks to avoid buried cables, which further increased loading and length requirements. While the ORE/OLEMI method, which is applicable to most locations, would typically lead to pile lengths of a 3-6m for a single-track cantilever.

The new ‘factory train’ struggled to drive the long piles, leading to poor productivity and rework as piles had to be cut down or repositioned. There was also an issue with the foundations being located further away from the track than had been assumed, so the crane was operating outside of its safe lifting radius.

The Great Western programme attempted to design a new and unproven OCS system (aka Series 1) and high-output plant concurrently with project delivery, a decision that the NAO and RIA identify as a key source of risk and cost overrun. By commissioning a new ‘factory train’ and Series 1 system while construction was underway, Network Rail introduced untested technology into a live programme; productivity assumptions were not achieved, and the resulting slippage could not be recovered.

The RIA ECC report recommends that future projects should adopt "proven systems that comply with relevant standards and avoid developing and obtaining approval for new systems as part of a project".

2.3.4 Railway access, possession and the impact to logistics

The RIA ECC report describes how the rules of the route provided minimal midweek access to the Great Western programme. However, the Stirling-Dunblane-Alloa project negotiated an extended regime that offered possession for six nights per week, complemented by blockades. Similar access arrangements on the Midland Main Line and Preston-Blackpool projects increased productivity. However, the Great Western programme attempted to rely on a high-output plant working within short night possessions, but the limited access and the teething problems with the factory train reduced performance. Therefore, the literature emphasises that a balanced approach between access strategy (continuous blockades or extended possessions) and technology can support efficient construction, but they may disrupt services. However, short railway access windows do not disrupt services but restrict productivity.

Additionally, another factor of access noted in the RIA ECC report is the availability of road-rail access points, which are typically located at 5 km (3.11 miles) intervals. Insufficient access points increase travel time during possessions and reduce productive work hours. Thus, railway access is not only about possessions but also about logistics and site accessibility

Lastly, material procurement affects costs. Long lead times and inflexible ordering systems on the Great Western programme prevented unused materials from being returned to stock, causing delay and waste.

2.3.5 Scheduling, supply chain capability, and skills retention

The significant increase in the UK of single-track kilometres of electrification post 2012 (as it can be observed in Figure 2-4) highlights the risks of planning.

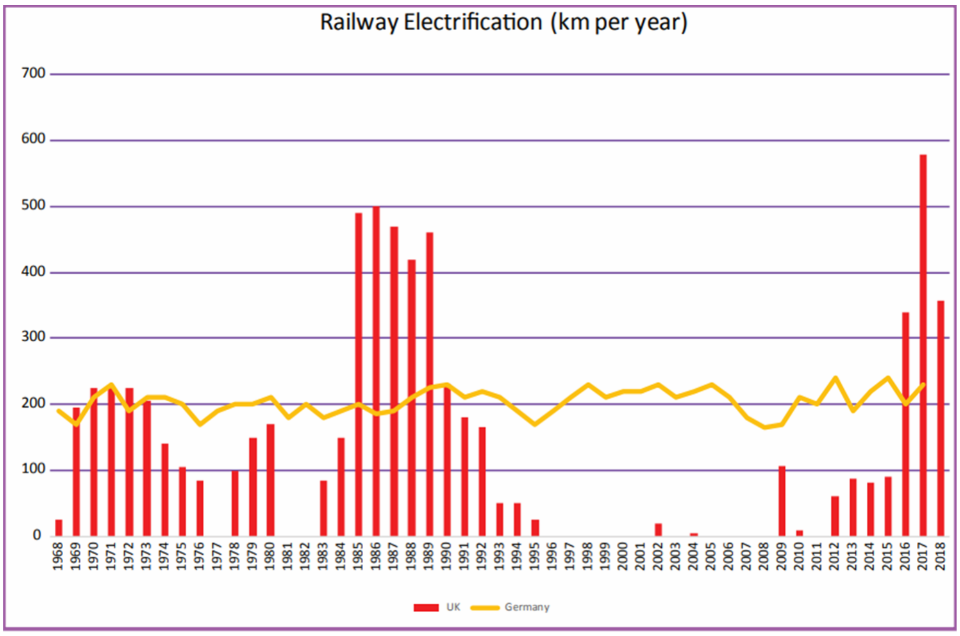

Figure 2-4: Railway Electrification in single-track kilometres in the UK and Germany
Source: Noel Dolphin, Campaign to Electrify Britain's Railway

A useful international reference is Germany, where electrification has been pursued through a rolling-programme. Germany has maintained delivery at around 200 km (125 miles) per year and aims to increase this towards 400 km (250 miles) per year. The objective is to electrify around 70% of the network. This illustrates how programme continuity, strategic planning, and a network-level approach can support delivery efficiency and capability retention.

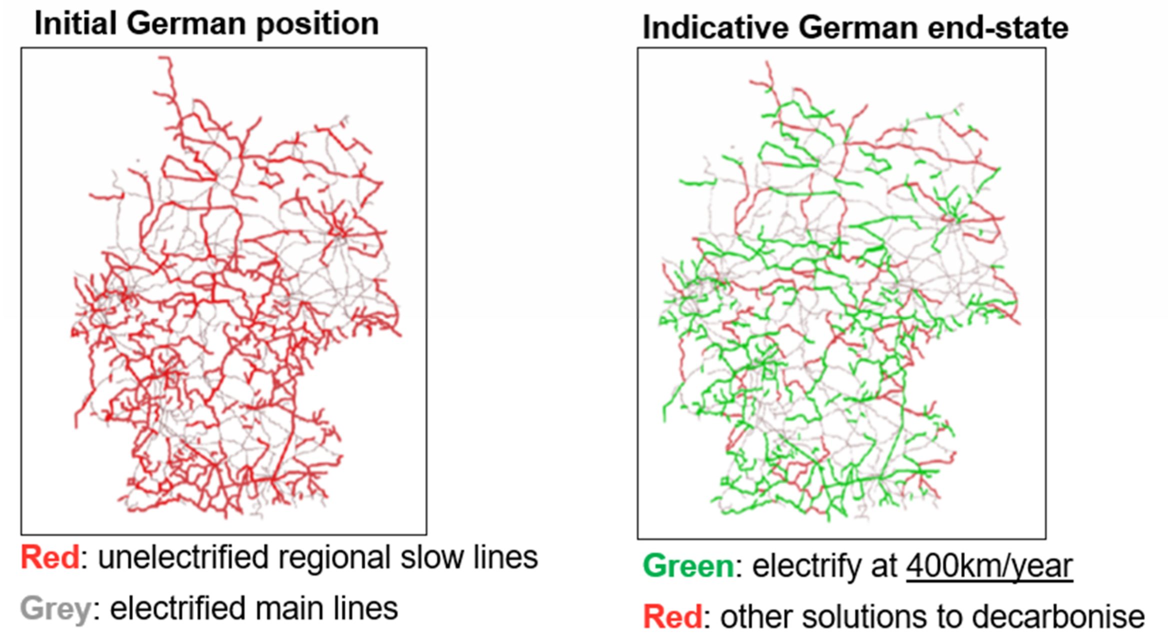

Figure 2-5: German rail electrification programme: initial position and indicative end-state
Source: Adapted from Campaign to Electrify Britain's Railways, 2025.

Before the Great Western programme, it was twenty years since the last major UK electrification programme, so expertise had been eroded. However, the Great Western programme formed part of a 2,000 km (1250 miles) nationwide programme launched across multiple routes.

Several projects commenced simultaneously, competing for the same pool of specialist labour and equipment. This shortage of experienced resources contributed to productivity shortfalls and learning curves that manifested as cost overruns.

This "feast and famine" cycle of investment means that installation contractors increase capacity quickly and then faced a sharp decline when funding was cut or projects were paused.

Additionally, the development of new technology during project delivery created dependencies on single suppliers and limited market competition. Such fragmentation allowed each supplier to optimise their own part of the work without regard to overall efficiency, exacerbating cost variability.

The NAO concluded that Network Rail did not establish a critical path before starting Great Western electrification and began construction works before the designs were mature.

The RIA ECC report notes that unrealistic schedules and inexperienced resources led to learning on the job. When the Great Western programme encountered difficulties, the DfT responded by cancelling or curtailing other electrification projects; as a result, suppliers were left with little visibility of future work.

The RIA ECC report suggests that electrification should be delivered through a rolling programme rather than discrete projects. Furthermore, a continuous pipeline will provide suppliers with confidence to invest in plant and training, which by extension will reinforce supply chain capability.

2.3.6 Risk allocation and consent readiness

The NAO found that electrification works in Great Western commenced before necessary consents were secured and before designs were completed. Network Rail was too optimistic about obtaining consents and underestimated the time and cost implications of planning and environmental approvals. When risks materialised, the client often retained responsibility rather than transferring risk to parties best able to manage it. The RIA ECC report notes that risk allocation should be reviewed and that the Network Rail standards should move towards output specifications, ensuring that risks are held by those with control over them.

2.3.7 Explaining cost variability between projects

Not all electrification projects experience this type of cost escalation. In the RIA ECC report, it is concluded that:

- simpler projects should be delivered between £0.75 - £1.0 million per single-track kilometre (approximately £0.9 - £1.3 million in 2026 prices)
- complex projects should be delivered between £1.0 - £1.5 million per single-track kilometre (approximately £1.3 - £1.9 million in 2026 prices).

Complexity relates to several factors such as:

a) the number of structures and particularly bridges and tunnels, which could introduce the need for major civil works,
b) limited access windows, and
c) the adoption of novel systems.

On one hand, projects that achieved efficient delivery shared certain features:

a) realistic schedules,
b) robust management of requirements

c) proven technology,

d) mature designs,

e) collaboration between infrastructure owner, client, and suppliers, and

f) good access arrangements.

On the other hand, projects with delivery difficulties often combined several of the following factors:

a) immature design with new technology,

b) limited access,

c) unrealistic schedules,

d) fragmented responsibilities, and

e) weak integration between design and construction.

Thus, cost variability is not only based on the geographical complexity of the route but also on the effectiveness of governance. The RIA ECC report suggests there is an efficient cost range and that UK unit costs could be further reduced. A long-term rolling programme would allow lessons learnt from one scheme to be applied to the next one; and thus reduce variability and improve value-for-money.

2.3.8 Distinguishing cost escalation, cost overrun, and scope-driven cost increase

There are mainly three different types of cost increases:

1. Cost escalation refers to increases in unit costs due to market conditions, learning curves or delivery constraints. For example, the increased spending from 2012-2018 on electrification created an overheated market and the productivity fell.
2. Cost overrun refers to actual costs exceeding budgeted costs because of estimates that were unrealistic or risks were not managed. For example, the NAO highlights that in the Great Western scheme, unrealistic assumptions and poor schedule management led to repeated design work and subsequent delays.
3. Scope-driven cost increase refers to when new requirements are introduced or an existing requirement changes. For example, in the Great Western scheme the adoption of the more onerous European (TSI) clearance standards substantially increased the infrastructure interventions to achieve compliance.

It is important to identify the type of cost increase, as this will help identify the relevant solutions. For example, cost escalations may be addressed through market management and a rolling programme. Cost overruns can be addressed through better estimation and risk management. Lastly, scope-driven cost increase can be addressed early clarity on standards and requirements. The combination of these factors explains why costs vary between UK electrification schemes.

2.4 Governance, Procurement Models, and Delivery Structures

Effective governance and appropriate procurement strategies are key to delivering value-for-money in railway electrification. The OVfM notes that mega-projects often “aren’t set up for success” because early cost estimates are unreliable and decision-making structures are convoluted. Political pressures to “live within annual budgets” and a failure to adjust project governance, when circumstances change, lead to scope changes and delays.

2.4.1 Programme governance and client capability

The OVfM identifies common governance problems in mega-projects. Sponsors often rely on early cost estimates that are difficult to be met accurately at later dates. However, these early estimates become political commitments. Weak assurance processes and overlapping oversight bodies dilute accountability, this results in programmes proceeding despite having immature designs.

To address these issues, recent government reforms require:

- A command paper at project inception and key milestones,
- Streamlining the decision-making processes.
- Feasibility studies to support incremental funding in order to better reflect uncertainty at the early development stages. early uncertainty.
- Projects will be given fixed capital envelopes with the flexibility to move budgets between financial years. This will enable projects to accelerate work when it is advantageous in order to “buy out” risk rather than deferring tasks to stay within annual budgets.
- Additionally, the reforms should allow projects to recruit specialist skills without civil service pay constraints. This acknowledges that capability gaps have contributed to poor value-for-money outcomes.

Railway electrification projects reveal how inadequate governance can affect value-for-money. The RIA ECC report notes that electrification is rarely viable as a standalone investment. It should be part of a route-wide upgrade along with a rolling stock replacement. For example, on the Great Western scheme the DfT did not treat interdependent projects as a single programme. This led to uncoordinated decisions and competing demands for scarce resources. In contrast, East Coast Main Line electrification was delivered through an integrated programme with clear leadership. The literature highlights that DfT's approach to managing interdependence of different projects varied. For example, the Thameslink benefited from agreed governance from the beginning of the scheme, while Great Western lacked integrated governance until early 2015. This variability suggests that value-for-money depends on consistent, programme-level coordination.

Insufficient client capability also undermines governance and subsequently value-for-money. The OVfM points to blurred responsibilities between sponsor and shareholder roles, differing organisational priorities, and churn at senior levels. All these impair unified decision-making. In the case of HS2, frequent scope resets, moving objectives and immature designs resulted in cost escalation. Contracts created "the wrong incentives," and the organisation lacked the capacity to manage them. Budgeting mechanisms were inconsistent. Attempts to protect HS2 funds were undermined by DfT's annual budget cycle, leading to deferrals that increased phase costs by about £1.25 for every £1 of work postponed.

2.4.2 Procurement models and contracting approaches

The way in which electrification is procured significantly affects any value-for-money outcome. Network Rail's "hub-and-spoke" model for Great Western allocated separate work packages to different suppliers. At the same time, Network Rail kept the overall programme management in-house. The RIA ECC report notes that this structure left Network Rail responsible for coordinating all interfaces and holding most programme risk. Additionally, suppliers were incentivised to focus on individual deliverables rather than shared outcomes. Moreover, the NAO concluded that a more integrated approach could have reduced interfaces and encouraged collaboration.

The RIA ECC report notes that an integrated "design-and-build" contract might have eliminated the split between designer and construction suppliers, this would have result in improving productivity. This framework would ensure that a single contractor would take responsibility for the design, construction, and integration. This would bring incentives together and reduce the risk of rework.

In contrast, collaborative contracting models appear in literature, such as alliances. The RIA ECC report presents the Staffordshire Alliance and Ordsall Chord as examples. The integrated and collaborative approach of these alliances resulted in shared incentives and minimal interfaces; and subsequently delivered better results than the "hub-and-spoke" model. In an alliance, the client and suppliers operate as a single team. Therefore, there is collective responsibility for cost, schedule, and performance. By bringing together risk and reward, such models encourage innovation and align the interests of all parties towards value-for-money.

Additionally, the RIA ECC report builds on this with input-based specifications and requirements**,** where the client defined detailed design solutions and selected technologies (in the case of Great Western, unproven technologies). This approach limits suppliers' ability to propose proven alternatives and can introduce inefficiencies. Output-based specifications and requirements are the proposed solution. Instead of dictating equipment or methods, the client specifies desired performance outcomes (e.g. journey times, reliability, emission reduction) and allows the supply chain to optimise solutions. Evidence from Denmark and from the PSU2 Alliance on the East Coast demonstrates that output-based specifications can achieve significant cost savings (up to 60% compared with original estimates in the PSU2 power upgrade). To support this recommendation, the RIA ECC report suggests establishing a technical authority within Network Rail to provide objective advice and ensure that output-based specifications consider whole-system implications.

The literature presents other contract types such as target cost or framework agreements, but these are discussed less extensively. However, the key underlying message is that the contract type and the governance method must be matched to project complexity and risk allocation. For electrification schemes with multiple interdependencies and technological uncertainties, purely transactional models can exacerbate fragmentation. By contrast, integrated models or alliances appear better suited in managing complexity and promoting value-for-money. Ultimately, the success of any model depends on the client's ability to manage and incentivise suppliers effectively. This reinforces the importance of governance and capability.

2.4.3 Programme and funding cycles

It has been noted in section 2.3.5 that RIA recommends that electrification should be delivered through ten-year rolling programme rather than discrete projects, and the reasons behind this recommendation.

The effects of fragmented delivery are starkly illustrated in HS2. OVfM notes that deferring work to remain within annual budgets increased Phase 1 (London to Birmingham) costs. for every £1 of work deferred into a future annual budget, the total cost rose by an additional £1.25 due to demobilisation and remobilisation. HS2's experience shows that delivering mega-projects through a series of annualised decisions can be counter-productive. Therefore, the OVfM recommends fixed capital envelopes with flexibility to move funds across years.

2.5 Scope Decisions and Interaction Effects on Value for Money

Decisions about the extent and the timing of electrification are normally called scope decisions by the railway industry. These are not purely technical, they are being influenced by other factors such as interactions with standards, access, and governance models. The literature demonstrates that the scope decisions can affect cost drivers and subsequently value-for-money.

2.5.1 Determining the scope of electrification

Scope decisions about the extent of the electrification could also be impacted by the economic case of alternative technologies or network planning as described below.

The NAO notes how BCR can be affected when complementary investments (such as new rolling-stock or high-speed lines) alter the expected benefits of the initial BCR estimate. For example, at the Cardiff-Swansea section of the Great Western route, the BCR was reduced from 0.6: 1 to 0.3: 1 after costs rose from £295 million to £433 million and the government ordered bi-mode trains that could operate on diesel or electricity. The procurement of bi-mode trains removed the immediate need to electrify that section, leading to further reduction in the benefits.

Another example is on the Midland Main Line, where for the north of Kettering electrification, the BCR was assessed at 0.8: 1. Following consideration of the HS2 drawing passengers off the route the BCR was affected, and the case for electrification was weakened.

The above two examples highlight that scope decisions are strongly shaped by wider network planning and the selection of rolling-stock. Decisions such as the introduction of bi-modes can reduce electrification investment.

However, the main issue is that when the scope is reduced, there are costs that cannot be recovered. These costs negatively affect value-for-money. Cancelling the Cardiff-Swansea and other schemes produced short-term savings but left unrecoverable costs of £14 million and risked undermining the coherence of the wider Great Western programme. The RIA ECC report highlights that electrification delivers the greatest value when it is part of a coordinated route upgrade. Fragmented scope can lead to multiple interfaces, duplication of mobilisation costs, and inconsistent technical solutions across adjacent segments.

Similarly, the NAO notes that poor coordination between interdependent projects contributed to delays and cost increases on the Great Western programme. Thus, scope decisions erode value-for-money when projects are delivered in isolation rather than as part of an integrated programme.

2.5.2 Interfaces with scope, standards, access, and contract approaches

The literature identifies several interfaces between scope, standards, access, and governance. These interfaces influence value-for-money outcomes in railway electrification The decision about the extent of electrification interfaces with standards and access in complex ways. As described in earlier sections, earlier revisions of standards for electrical clearances and requirements for foundations can substantially increase the cost of civil engineering. The adoption of onerous requirements may tip the economic balance against the case of electrification. Particularly, on sections that are on the edge of being cost-effective. Conversely, a risk-based approach to standards, which could incorporate derogations or adopting proven design methods, may reduce intervention costs. This could lead to making full electrification more viable.

Additionally, scope decisions interface with access arrangements. For instance, electrifying only part of a route may limit opportunities to coordinate possessions or to negotiate extended blockades. This could lead to reduced productivity during possession and increase disruption of the operational railway.

Contract approaches affect governance and subsequently impact the value-for-money on electrification projects. The RIA ECC report notes that the benefits of electrification are realised most effectively when projects are managed as part of a single programme. Furthermore, the NAO notes that delays and cost overruns were exacerbated by a lack of coordinated decision-making. Additionally, once bi-mode trains were procured to mitigate delays, the scope of electrification was curtailed; this decision was a response to both technical risk (uncertain delivery of infrastructure) and political pressure to demonstrate progress. Such interactions highlight that scope cannot be determined in isolation; it must be aligned with standards, access, and supported by robust governance.

These interactions provide an important context for the analysis of practitioner perspectives in later chapters, where their implications for delivery are examined in more detail.

2.5.3 Delivery risk and timing

Late changes to scope, and particularly, scope reduction can introduce risk to the delivery. The NAO's notes that:

- On one hand, cancelling projects can reduce future expenditure. For instance, on construction, design, materials, and labour.
- On the other hand, cancelling a project or parts of project after the preparatory work has started wastes this investment. As a result, this requires re-planning of services and infrastructure. This creates uncertainty about supply chain and stakeholders. A notable example was the cancellation of the Phase 2 (Birmingham to Manchester, and Birmingham to Leeds) of HS2 project. The DfT and HS2 Ltd had to reassess infrastructure needs for Phase 1, especially in relation to Euston station and the West Coast Main Line.

The adoption of bi-mode trains on Great Western reduced immediate cost needs as it avoided full electrification. However, this decision committed the network to continue using diesel traction. This will potentially delay long-term decarbonisation.

These risks highlight why it is crucial to define scope early, which should be based on a mature cost estimate. Moreover, it is equally important to have a realistic assessment of technical challenges and access constraints.

If the electrification scope is unclear, suppliers may price in contingency during the tendering phase of a project, or they may resist taking on performance risk. Conversely, a

well-defined scope enables collaborative procurement models such as design-build contracts or alliances. These forms of project delivery help align incentives and share risk more effectively. The RIA ECC report notes that collaborative contracts work best when there is a well-defined scope, with the client specifying the outputs rather than the inputs.
To conclude, the scope definition is a complex process. It will need to consider interactions between economic appraisal, technical feasibility, standards, access, and governance.

2.6 Literature Synthesis and Identification of Knowledge Gaps

The literature reviewed in this chapter provides:

a) A clear definition and appraisal of value-for-money.
b) An overview of the cost drivers and delivery challenges in the UK railway electrification.

There are several gaps that have been identified, despite the depth of the literature:

1. **Value-for-money Definition and Interpretation in Practice.** The literature demonstrates consensus on how value-for-money is defined at a policy and audit level. This is mainly through the DfT's Value for Money Framework and the NAO's '3 Es' (economy, efficiency, and effectiveness). Conclusively, the concept of value-for-money is clear at high level. However, value-for-money appraisals are typically performed on a scheme-by-scheme basis at business-case level. More importantly, the literature provides limited information on how the value-for-money appraisals translate into real-world decisions (decisions that affect scope definition, sequencing, and prioritisation of investment). This creates a gap between value-for-money appraisal and delivery. This supports the need to examine how value-for-money is manifested at the interface between appraisal and delivery by using the practitioners' perspectives.

2. **Structural Appraisal Gap for UK Railway Electrification.** The literature identifies CBA as the dominant method in UK transport appraisal. While MCDA and benchmarking provide additional support for option comparison and cost assessment. However, no single method fully captures the whole-life, whole-system and programme-level value of railway electrification. CBA can underweight non-monetised environmental, social, operational, and resilience benefits. MCDA can

include wider qualitative factors. However, MCDA is limited by its normative nature and its lower acceptance in formal value-for-money decisions. Benchmarking can support cost comparison, but it depends heavily on consistent scope boundaries and does not directly measure benefits. This creates a structural appraisal gap for electrification. The available methods may each assess part of the value case, but do not fully reflect the interaction between capital cost, delivery readiness, system benefits, programme continuity, and long-term railway outcomes. This gap is revisited in Chapter 5 and supported by the indicative appraisal considerations in Appendix B.

3. **Cost Drivers and Delivery Efficiency.** The literature identifies cost drivers that affect UK railway electrification. These include technical standards, railway access constraints, procurement strategies, governance arrangements, programme continuity etc. These cost drivers are well documented individually, and they are often presented in isolation. The literature provides limited synthesis of how these factors interact during delivery to influence cost variability, risk exposure, and efficiency outcomes. This dissertation addresses this gap by integrating information from literature with qualitative information from industry practitioners.

4. **Limited Practitioner Perspectives.** Most of the existing evidence on electrification is manly coming from official reviews and audits. These sources may be valuable but provide limited visibility of how practitioners experience and respond to delivery constraints and challenges. There is a clear absence of practitioner perspectives from the academic literature. In particular, there is a lack of information from those responsible for design, client-led assurance, and construction. This creates a gap in understanding the practical decision-making that affects value-for-money outcomes during delivery. The dissertation addresses this gap through semi-structured interviews with industry practitioners. These interviews will provide information that complements the published evidence.

5. **Current Context and Delivery Implications.** The strategic context for investment in UK railway electrification is evolving. This is because of:

    a) decarbonisation objectives,

b) changing railway traction approaches supported from different rolling-stock types (hydrogen, battery, bi-mode, tri-mode, etc), and

c) ongoing institutional reform (introduction of GBR).

These changes are well articulated in policy documents. However, the implications of these changes to electrification and value-for-money are not yet well captured in the literature. Furthermore, the literature remains dominated by analysis of earlier programmes. This dissertation will consider how current conditions are perceived by the practitioners and influence delivery decisions, risk management, and efficiency in practice. This provides important current context and supports the development of recommendations. Most important, these recommendations will be grounded in current delivery practices rather than limited to historical information.

In summary, the literature provides in depth information on value-for-money appraisal, cost drivers, and delivery challenges. However, it offers limited information into how value-for-money appraisals are manifested during delivery. Furthermore, there is limited information on the interaction between technical standards, access, scope change, and governance factors that shape outcomes in practice. This dissertation addresses these limitations by synthesising existing evidence and amplifying it with through the information derived the interviews.

3 METHODOLOGY

3.1 Research Approach

This dissertation adopts a qualitative approach because it doesn't focus on numerical data. It is an exploratory research as there is limited prior knowledge. This approach is appropriate for an applied MBA study that aims to resolve real-life problems. Furthermore, value-for-money is not a purely objective or technical concept.

As identified in section 2.6, existing literature provides limited information in how the value-for-money frameworks are manifested into delivery. Specifically, on how schemes move beyond appraisal into project implementation. This dissertation addresses this gap by analysing practitioners' perspectives at the interface between governance, standards and legislation, access, scope, and risk management.

The contributions of this dissertation are operational in nature as defined in management research. The research focuses on delivery-level decisions that influence cost and performance. Additionally, it considers strategy at policy level. Therefore, a qualitative approach has been considered suitable.

Value-for-money is defined formally through the DfT's Value for Money Framework and the NAO's '3 Es' (economy, efficiency, and effectiveness). However, its practical manifestation depends on how these frameworks are interpreted and applied by practitioners during delivery. Therefore, the research seeks to understand meanings, perceptions, and decision-making processes rather than to test hypotheses.

The research follows an explanatory approach, focusing on how value-for-money is understood and manifested in practice. The research does not attempt to quantify cost drivers, establish statistical relationships, or predict outcomes.

The research does not seek to evaluate a single project or to compare quantified performance metrics across schemes. Although, it aims to explore patterns and interfaces presented by practitioners across multiple themes.

The research does not use surveys or statistical analysis. The chosen approach allows depth of understanding while remaining proportionate and feasible within the available timeframe.

3.2 Data Collection and Sampling Strategy

3.2.1 Data collection method

Primary data is collected through semi-structured interviews with practitioners involved in UK railway electrification. Semi-structured interviews provide a balance between consistency and flexibility. To ensure that all research questions are addressed, an interview guide should be used. Additionally, open-ended questions tailored to the background and experience of each interviewee allow to elaborate on issues, they consider significant.

This method facilitates discussion on topics such as governance, standards application, cost drivers, procurement, and scope decisions. Semi-structured interviews are widely used in infrastructure and policy research because the expert judgement is central.

3.2.2 Sampling strategy

Participants are selected based on their involvement in the delivery of UK railway electrification. The participants are from all the phases of project delivery (Design, Client-led Assurance, and Construction) including individuals from functions that support delivery such as Maintenance, Operation, and Electrification Asset Managers.

The focus on practitioners with experience on delivery is deliberate. This is because the literature synthesis identified a gap in practitioner perspectives. Especially, from individuals responsible for delivering projects within the constraints of standards, access, budgets, and governance processes. By targeting these individuals, the research aims to gather information into how value-for-money affect real delivery decisions.

The study does not include policymakers or senior sponsors responsible for setting national strategy. This is a conscious choice as the research aim is to understand how existing frameworks are manifested during delivery, rather than how they are formulated. The implications of this choice are recorded as a limitation in Section 3.4.

The interview sample was not intended to be statistically representative of the wider railway industry. Instead, it was selected to represent delivery-side practitioner perspectives. Participants covered a range of functions involved in railway electrification delivery (including design, construction, contractor delivery, client-side assurance, standards, procurement, commissioning, traction power, and asset-related roles). This breadth supported the study's aim of examining value-for-money through the practical decisions and constraints that shape electrification programme outcomes.

3.3 Data Analysis Approach

Interview data is analysed using a thematic analysis approach. Thematic analysis allows systematic examination of the interview transcripts. This will involve a qualitative method suitable for identifying and interpreting patterns within the interview data.

The empirical material was processed through a structured qualitative review. Interview transcripts were reviewed to identify statements relevant to the research questions. These statements were then coded against recurring issues (e.g. as access constraints, governance, scope maturity, standards application, procurement, capability, programme continuity, etc). The analysis focused on recurring patterns and relevant differences between practitioner perspectives, rather than quantifying the frequency of responses.

The analysis follows the below process:

1. Familiarisation with the data through repeated reading of the transcripts.
2. Initial coding to identify relevant concepts related to value-for-money. This should involve cost drivers, governance, access, standards, scope decisions etc.
3. Development of wider themes by grouping related codes.
4. Review and refinement of themes in line with the research questions.

Themes are developed inductively from the data but interpreted in relation to the concepts established in the literature review. This ensures analytical linkage between empirical perspectives and existing knowledge without introducing new theoretical frameworks.

Thematic analysis is appropriate for an exploratory MBA study, because it supports explanation and allows findings to be structured clearly against the research questions. It is a widely accepted method in qualitative research across management and infrastructure studies.

The data from the face-to-face interviews will be coded manually by the researcher. For the data from the online interviews digital tools were used to support the initial coding. In all cases, the interpretation is research led.

3.4 Research Limitations

Several limitations are acknowledged, as part of the methodology:

- The selection of the individuals is mainly from the delivery-side of projects. This means that findings would be delivery-side perspectives and subsequently may not capture the full rationale behind policy or funding decisions.
- The qualitative nature of the research means that the data is explanatory.
- The absence of policymaker interviews limits perspectives into strategy. However, this is partially mitigated through the literature review and analysis.

3.5 Ethical Considerations

The ethical considerations are in line with principles for qualitative research.

The interviewees are informed of the purpose of the research at the beginning of the meeting as well as their right to withdraw at any stage.

The input will be anonymous in order to maintain the confidentiality unless the interviewees explicitly state their name to be stated as a source. Practitioners IDs will be used to identify practitioners (e.g. P01). Any data will be stored securely and used purely for academic purposes.

3.6 Summary

This chapter has outlined and justified the research methodology adopted for the dissertation. The dissertation will follow a qualitative and exploratory approach, aiming to address the research questions.

The semi-structured interviews provide the primary data source. This will be followed by thematic analysis to generate explanatory information into value-for-money in UK railway electrification.

The methodology is aligned with the research aim and acknowledges its limitations. The next chapter presents the findings arising from the application of this research design.

4 FINDINGS

4.1 Introduction to the Findings

This chapter presents the empirical findings stemmed from the semi-structured interviews with the practitioners involved in UK railway electrification project delivery. In accordance with the research, the interview data has been analysed thematically in order to identify recurring patterns in how the practitioners described value-for-money, cost drivers, and delivery methodologies. As a result, the findings have been organised by the main themes emerging from the data, instead of independent cost drivers, project history, or practitioner type. This structure is intended to show where views converged and where they differed. Therefore, the following sections of this chapter report the interview findings in an empirical form and focus on the perspectives provided by participants. The interpretation of these findings, and their wider implications, is undertaken in Chapter 5 - Discussion.

4.2 Practitioners' Definition of Value-for-Money in UK Railway Electrification

4.2.1 Value-for-money beyond initial capital cost

In the interviews, value-for-money was rarely defined as synonymous with the lowest initial capital of a scheme. Instead, participants described it as a broader judgement about whether electrification decisions avoided unnecessary cost while still delivering a robust railway. P06 and P12 were explicit that capital expenditure alone is an insufficient metric to judge value-for-money, because cheaper choices could transfer burden to maintenance and operations post project delivery. A similar position appeared in P10, P21 and P22, all of whom warned that narrow capital framing could misrepresent the true cost of electrification where wider project costs, indirect costs, or longer-term impacts were not sufficiently captured. Similarly, P01 aligned value-for-money to simplicity, maintainability and potential for future extension in contract to minimum initial capital cost. Lastly, P17, involved in delivery integration, treated value-for-money as more than low unit cost; connecting it with buildability, coordination and the avoidance of redesign and wasted effort.

This wider framing did not mean that cost discipline was not present. Instead, the practitioners suggested that cost should be judged against whether it contributed to a more effective holistic outcome. On this basis, the dominant pattern in the data was that value-for-money was treated as a judgement-based concept and not simply having a low initial cost. A nuance came from P17 and P21, that suggested that activities which appear cost-adding at project stage may still represent value-for-money where they prevent more expensive consequences later. This did not contradict the main pattern. However, it did make it clearer by showing that several practitioners differentiate between immediate cost reduction and genuine value.

4.2.2 Whole life, operational, and system value

A clear pattern in the interviews was that practitioners associated value-for-money with whole-life and operational performance. Value-for-money was not linked to initial capital cost alone. P06 was explicit that decisions appearing more expensive at the outset of a scheme could still represent better value-for-money where they reduce maintenance demand, failure risk, or operational disruption. P12 adopted a similar position by linking value-for-money to maintenance burden and track-access implications over the life of the asset. At the same time, P17 associated value-for-money with reliability, maintainability, and the avoidance of downstream (or operational) failure. Furthermore, similar points were raised by P14, who suggested that short-term avoidance of post-construction testing or close-out cost could create maintenance burden and reduce whole-life efficiency. P01 and P02 added a practical delivery perspective. This is because both P01 and P02 treated maintainability, extensibility of the network, access, depot implications, training, as part of the value-for-money narrative rather than subjects outside it.

Additionally, several practitioners framed value-for-money in holistic railway system terms. In particular, P10 connected operational flexibility, traction power resilience, passenger experience, and rolling stock flexibility. At the same time, P22 referred to connectivity, resilience, and public-service improvement. Across these perspectives, electrification was rarely treated as an isolated engineering intervention. However, the practitioners tended to judge value-for-money in terms of resilience, usefulness, and operational effectiveness of the resulting railway system. A more limited nuance within this pattern came from P01. P01 doubted that battery traction (BEMU) has good long-term benefits in comparison to electrification beyond niche applications.

4.2.3 Perceived limitations of current appraisal methods and business-case framework

A recurring pattern that emerged from several interviews was that practitioners considered current appraisal methods and business-case framework to be too narrow to reflect the full value of electrification. Particularly, P10 suggested that even where scheme cost had been reduced, the business case could remain weak because wider benefits were not fully captured or articulated. In that instance, the definition of electrification value was seen as narrower than the operational and railway system benefits that the P10 experience with electrification in practice. P22 made a similar point, but at a more strategic level, arguing that appraisal and decision-making remained too focused on immediate capital expenditure. Additionally, practitioners stated that the current appraisal methods did not capture the broader public, operational, environmental, and network benefits. Lastly, P17, involved in delivery integration, suggested that the business case for electrification could be weakened where infrastructure and rolling stock decisions were framed separately rather than as part of one system.

A related concern was raised about the use of simplified cost metrics. In particular, P21 warned about the usefulness of STK-style comparison where the boundary between core electrification cost and wider route investment is unclear. At the same time, P03 noted that simple STK comparison was of limited value where route conditions differed significantly. P22 made a similar point. P22 argued that STK comparison could be misleading unless scope boundaries were explicitly defined. These perspectives did not reject appraisal or benchmarking. However, it was indicated that non-clearly defined metrics could understate the broader value that electrification could provide.

4.3 Governance, Client Capability, and Funding

4.3.1 Technical client capability and quality of decisions

Interviewees frequently linked the quality of project decisions to the technical capability on the client-side and particularly in the sponsor role. The dominant trend was that insufficient technical understanding led to poor judgement regarding scope, requirements, interfaces and general risk. On the other hand, strong technical understanding is related to higher quality decisions.

Particularly, P01 highlighted that limited technical capability on the client side leads to increased delivery risk. Similarly, P05 stated that project managers and sponsors did not always have the understanding needed to challenge requirements or grasp system integration issues. This leads to arising inefficiency that could be avoided. P13 added that sponsor roles on the client side were normally held by people with project management backgrounds instead of technical background.

P12 made similar statements. P12 argued that poor quality decisions were related to situations in which contracts were abandoned before the client fully understood what the project required. From that perspective, the presence of a capable technical client was perceived as key element for value-for-money. This is because they will define the outputs clearly from early stage and avoid premature commitment. P03 reinforced this theme. P03 argued that people in senior client roles without sufficient relevant experience could slow down delivery and cause rework.

A more specific concern was added by P19. P19 stated that some project engineers (aka client facing role) and general assurance staff were expected to challenge standards or design proposals. However, the assurance staff did not often possess adequate knowledge of design and by default rely on written rules rather than informed judgement. P15 introduced an important nuance by suggesting that some problems attributed to standards were in fact failures of understanding and standards application. These perspectives put emphasis on the competence of those making technical decisions.

4.3.2 Fragmented governance, unstructured interfaces, and client-led assurance burden

Apart from the capability of individual decision makers, the interviews highlighted as an inefficiency driver the fragmented governance, unstructured interfaces, and client-led assurance burden. Specifically, P02 described fragmented delivery where multiple construction contractors and design organisations in a scheme increases the interfaces burden. Additionally, P02 and P03 highlighted that when different delivery teams are involved in different changes it creates inefficiencies because of discontinuity. P08 raised a similar point. P08 noted that delays and re-design are consequences of having multiple independent contracts without having proper integration between electrification, signaling, civils, and wider route interventions. Similarly, P13 and P21 emphasised that poor coordination between sponsors and engineering teams lead to important decisions not to be aligned at early stage, as a result, this could lead to rework that could be avoided.

Moreover, P17 highlighted excessive client-led assurance, repeated checking, and paper-heavy deliverables as a delivery risk. Similarly, P19 noted that client-led assurance activities are multilayered, tend to be insufficient, and can become a delivery risk. P03 reinforced this point, but from a design perspective. P03 resented that projects have a newer assurance regime which can be heavily staged if it follows the progressive client-led assurance process. Also, P03 articulated that client-led assurance processes can be administratively burdensome, with repeated meetings and review points without adding equivalent value to project delivery. P18 added that complex delivery environments or complex contracting arrangements could lead in having multiple planning and management layers across clients, alliances, and contractors. This could increase overhead and reduce efficiency. P10 noted a consistent version of this concern. P10 suggested that standard assurance processes could be workable on conventional schemes, but major-programme processes had become overly onerous and less efficient. P23 reinforced this pattern by describing ORR authorisation and associated legal and assurance activity on Wigan to Bolton as a major burden on time and effort. Additionally, P23 suggested that a culture of demonstrating compliance to everything could become disproportionate in practice.

However, there were important exceptions within this pattern. The participants did not reject process or assurance. In particular, P10 noted that the standard Network Rail assurance as broadly robust on conventional work, despite the fact criticising more bespoke programme arrangements. P15 added a nuance to this. P15 stated that bureaucracy was not the central problem by itself. P15 argued that many difficulties raised from poor understanding, late decisions, and failure to use available derogation or exemption routes at the right time. P17 provided a similar perspective. P17 suggested that some assurance could add value where it prevented failure and avoided later redesign. While P17 noted that problem lies in poor timing, weak submissions, and weak alignment between what was being developed and what the railway actually needs. To conclude, these views suggest that participants were not so much concerned with the presence of governance and assurance processes but with fragmentation, duplication, and the way such processes were applied in practice.

4.3.3 Discontinuity of funding, annual budget constraints, and sponsor decisions

Apart from capability and governance, participants associated inefficiency with the discontinuity of funding (stop-start funding), annual budget constraints, and short-term sponsor decisions. P02 highlighted that discontinuity in funding as highly damaging. This is because trained electrification resources could be lost between schemes. Afterwards, this capability would have to be rebuilt at a later stage at additional cost. A similar point was raised by P06, where it was argued that from the construction contractor side uncertainty about future workload forces organisations to carry resources and maintain their capability at risk. Also, P06 added that this practice leads to higher pricing when the work proceeds. Moreover, P01 connected workload continuity with inefficient delivery. P10 noted that annual funding constraints could lead to inefficient spending behaviour. This could include pressure to use the remaining budget instead of optimising expenditure. P13 reinforced this point. P13 noted that the funding assurance process can be cumbersome, as expenditure requires extensive justification. Additionally, P11 stated that often money had to be spent in the financial period or returned. Subsequently, P11 argued that this practice usually creates a misalignment between delivery and fund timing.

The practitioners associate funding with sponsor decisions. P10 noted that the progression of scheme progression could depend on sponsor appetite even where costs had been reduced. This indicated that affordability and priority were shaped by sponsors rather than the value of the scheme. P21 added a similar concern about priority and pressure for early visible progress, particularly to the introduction of foundations. P21 suggested that early acceleration of the schedule without the proper design maturity could lead to inefficiency. P17 offered an additional perspective and innovation funding, where it was tied to live projects rather than being made available earlier.

In conclusion, these perspectives suggest that participants experienced:

- discontinuity of funding
- annual spending constraints
- and short-term sponsor decisions.

These conditions could lead to delivery inefficiency and increase costs.

4.4 Main drivers of unit-cost variation and delivery inefficiency

4.4.1 Scope maturity and late changes

A strong and recurring pattern that emerged from the interviews was that the participants associated inefficient delivery with following factors:

- immature scope,
- hidden scope, and
- changes introduced at a late delivery stage.

P12 described uncertain scope as the biggest delivery risk. Particularly, P12 highlighted that contracts were awarded before the design is mature and before the client fully understands what the project requires. P07 presented a similar point. P07 argued that under-investment in survey and scope definition at early stages could lead to later redesign or disruption. Also, P07 highlighted that this approach could lead to adopting and more conservative solutions that result in inefficiencies. P02 noted that early feasibility estimates are often too high-level. This is because construction, access, and deliverability are not understood properly at early stages. P04 highlighted that scope inefficiency can arise at mature design stages or even at construction stage when requirements and timetable assumptions change. This results in wasted effort and repeated rework.

Several participants said that poor information at early stages (e.g. health and safety files, source records, pre-construction information) could lead to hidden scope. This has been seen as an important cost driver. Particularly, P11 associated scope changes with missing asset information (e.g. source records). P11 highlighted that gaps in information create rework and delays. P02 raised a similar point, highlighting that electrification costs can grow beyond core electrification work if the predecessor dependencies (e.g. route clearance works, enabling works, signaling, etc.) are late as this will create standing time as people, machines and possessions may have been already committed. P19 described that from a design governance perspective unresolved unknowns pushed to later stages do not disappear. These unknowns could result in additional costs and delays. Similarly, P04 connected hidden scope at early stages with an undefined timetable. P04 noted that this could affect other traction power requirements, platform requirements, and cause wider re-design works.

Participants described late change as a significant cost driver. P06 noted that requirements may be over-applied or introduced late in the project development. This could happen because asset owners are not engaged early and particularly in the tender documentation. Likewise, P08 noted late change as an important cost driver, especially where there are multiple contracts and poor integration. This could allow rework to appear at later stage. P09 highlighted that material changes during construction are a significant risk. This is because they can create incompatibilities and lead to urgent procurement. Similarly, P21 cautioned against premature visible progress where the design has not matured enough. This reinforced the wider pattern that early construction progress can create inefficiency rather than genuine progress.

In conclusion, the two key factors that participants described as central to efficient delivery are:

- robust scope definition, and
- disciplined change control.

At the same time, the key factors that the participants described that lead to avoidable cost are:

- requirements emerging at a late stage,
- incomplete early definition, and
- unresolved unknowns.

4.4.2 Route complexity, route clearance interventions, foundations, and power supply

One of the main dominant patterns was that cost differences were not only due to the electrification installation. A key factor was the required intervention on a route in order to make electrification workable. P03 stated that route characteristics differ significantly. P03 noted that areas with curved track, bridges, tunnels, and viaducts require more OCS structures in comparison to a simpler straight route. P02 described stations, bridges, level crossings, and complex junctions as disproportionately expensive because they require bespoke interventions and heavier disruption. Similarly, P10 highlighted that electrifying legacy infrastructure is costly. This is because numerous clearance interventions are required. P01 argued that particular system decisions (including ATF and higher-speed design assumptions) can significantly increase cost. This happens due to larger substations, extra conductors, and wider intervention.

P07 described foundations and ground conditions as a principal source of cost variation. P07 highlighted that in some cases the cost was more significant than the core equipment itself. P04 stated that feeder station configuration along with the associated land acquisition can substantially increase cost. This can happen even when core equipment costs appear relatively small. Similarly, P02 identified feeder stations and National Grid connections as major cost items that are often underestimated.

In conclusion, participants treated route complexity, route clearance interventions, foundations and traction power, as significant factors of cost variation. It was also noted that this cost is intrinsic to the specifics of a scheme and not fully avoidable.

4.4.3 Track access, possessions, logistics, and workforce productivity

One of the strongest themes that have been identified is access and possession constraints. Particularly, P01 described track access as the biggest cost driver. P02 argued that the current rules force too much construction work into full possessions and night working. Similarly, P02 identified track access as one of the main cost and delay drivers. P02 stated that short possessions reduce productive time and can undermine the benefit of having modern plant and equipment. This is because a shift still contains travel time, set-up, and execution. P09 reinforced this point from a construction perspective. P09 identified blockades as a more efficient form of construction work than repeated weekend or midweek possessions. This is because they reduced repeated possession losses. In conclusion, restriction on track access has a significant negative impact on productivity and subsequently increases costs.

Additionally, participants identified that limitations to access can impede logistics and workforce deployment. P02 highlighted the spacing of road-rail access points as a practical productivity blocker, which normally are positioned on 5 km intervals. This is because longer travel distances reduce working time and increase labor costs. Also, P02 noted that disruption payments can become a significant part of total cost. Notably, P14 described high-output delivery as heavily dependent on tightly sequenced work, where masts, cantilever frames, and wiring need to be correctly sequenced. Poor sequencing could lead to wasted time on site as teams attend site before prerequisite tasks are complete (e.g the dropper installation team attends site before the installation of the contact and catenary wires). Additionally, P18 added that shorter access windows increase overhead. P18 identified that the site productivity in the UK is affected by the number of people that are required on site.

However, there was conflict between the information provided by the practitioners. P01 and P18 saw scope for more productive access arrangements, but P08 was more cautious, stating that access cannot always be significantly improved on busy routes.

In conclusion, the interviews suggested that access is a central driver of efficiency. Limitations on access can negatively impact site output and increase overall cost.

4.4.4 Standards, over-specification, and proportionality of requirements

A clear pattern that emerged during the interviews was that standards and over-specification were a significant cost driver. P01 viewed some UK safety and clearance requirements as overly onerous and not always proportionate to the value they add. P01 cited parapets and the associated interventions as examples of standards-bearing cost. Similarly, P05 and P13 highlighted that additional requirements from asset managers beyond standards are significant cost drivers. Also, P10 indicated that standards had previously pushed costs up due to platform, parapet, and route clearance interventions. P10 noted that risk-assessed requirements, as somewhat more proportionate. P18 added that some UK standards are over-prescriptive and lead to an increase in labor in comparison with other countries. It should be noted that through these perspectives participants treated that the problem was not compliance itself but that the requirements were applied in ways that were stricter or more burdensome than what was needed. P23 added that parapets and electrical clearance requirements remained notable cost drivers where the requirement was perceived as more onerous than the risk being managed. Additionally, P23 suggested that some design and assurance assumptions were pursued to a level of precision that was difficult to justify in live railway conditions.

The main disagreement between these views was that some participants highlighted that the problem was not in standards themselves, but in poor understanding. P15 was the clearest expression of this position. P15 argued that many problems blamed on standards in fact arise because organisations do not understand the standards properly. In addition, P15 noted that organisations fail to use derogations or exemptions early enough. Thus, they make late decisions that reduce choice and increase costs. P19 presented a related concern. P19 identified that inexperienced assurance staff may default to the written rule rather than apply informed engineering judgement. P10 offered a further caveat. P10 described Network Rail processes as broadly workable on conventional schemes. However, P10 reserved some criticism for more bespoke and onerous schemes. This position did not remove the wider concern about over-specification, but it did sharpen it. In conclusion, the practical cost driver was often the interaction between onerous requirements and the way they were interpreted, challenged, and applied in live delivery.

4.5 Rolling programmes, standardisation, and capability retention

4.5.1 Programme continuity and retention of competence

A strong theme in the interviews was that rolling programme was associated with:

- retaining skilled people,
- avoiding repeated remobilisation, and
- improving delivery efficiency over time.

P02 described skills retention as a major value-for-money issue. P02 argued that stop-start funding risks losing trained personnel. Subsequently, this recreates training and mobilisation costs later. P05, P11, and P13 made similar points from the client and sponsor side. They suggested that continuity is cheaper than allowing competence to decay and then building it again. Similarly, P06 noted that stop-start delivery erodes capability and learning. P10 and P22 treated continuity as a route to lower cost because skills, resources, and experience are retained.

Furthermore, participants associate workload continuity with the accumulation and subsequently the transfer of lessons learned. P03 suggested that continuity helps skills and experience build progressively. P07 associated stop-start delivery with disruption to learning-curve gains in addition to productivity. Similarly, P08 noted that a rolling programme is a route to lower cost due to broader skills availability. P01 implied that a long-term programme would allow plant, methods, and working practices to improve progressively rather than being reset repeatedly.

An important caveat is that continuity was not presented as sufficient on its own. P02 observed that the industry does not consistently capture post-project learning. P08 and P18 pointed towards the same direction. Therefore, the interviews suggest that continuity was valued not only because work continues, but because it allows competence and experience to be retained and carried forward.

4.5.2 Repeatability, standardisation, and learning effects

Participants connected rolling programme with a greater willingness to invest in delivery capability. Particularly, P18 noted that longer workbank visibility allows increased investment in training and workforce development. Also, P18 argued that stop-start workbanks push organisations towards underusing staff or towards contingent labor that affects learning curves. Similarly, P05 treated continuity as commercially valuable. This is because it allows savings at procurement through bulk ordering due to stronger negotiating power. P22 presented discontinuous delivery as weakening the supply chain instead of strengthening it. P07 added that continuity positively affects the commercial conditions under which suppliers commit people and plant to electrification work.

The main caveat for this theme is the marked dynamics following implementation of a rolling programme. P18 argued that a rolling programme will still preserve enough marker competition. Moreover, P07 described the use of competitive rates from earlier work packages to inform later target costs. This could preserve commercial discipline without encouraging distorted pricing. Also, P22 explicitly rejected the view that continuity will limit supplier diversity. P22 argued that stop-start delivery is more likely to contract the market. In that light, the interviews suggest that continuity was usually associated with stronger supply chain confidence and subsequently investment. Concerns about reduced competition appeared mainly as a caveat to be managed rather than as a dominant objection. P23 provided a similar point. P23 supported a rolling programme while noting that continuity should not reduce supplier competition too far. This reinforced the view that programme continuity was valued by participants, but that market structure remained a consideration within repeatable delivery models.

4.5.3 Limits and trade-offs of standardisation

An additional recurring theme was that participants associated rolling programme with lower unit cost due to repetition of similar work. Particularly, P01 preferred a simple, repeatable system and suggested that standardisation provides a base from which later improvement can be applied more efficiently. Similarly, P17 favored proven standard systems and accepted standard products. P17 noted that agreed construction preferences at early design stages could remove construction restrictions. Likewise, P07 described repeatable design and construction methods as important factors to lower costs. P05 made a similar point from an assurance perspective. P05 stated that simple repetitive designs can be reviewed more efficiently through a batch approach.

Participants viewed repeatability and standardisation as factors that allowed incremental improvement. P03 supported innovation but stressed that it needed to be introduced in a controlled manner. P18 offered a similar point. P18 argued that incremental improvement and shared lessons were more reliable than significant innovations introduced during live projects. P08 added an important nuance. P08 presented standardisation as a trade-off; stating that standardisation can improve repeatability, fabrication efficiency, and coordination, but it can also embed over-design and excess material if it is not periodically examined.

In conclusion, the interview evidence suggests that repeatability was seen as valuable because it reduces avoidable novelty and supports learning. At the same time, it still leaves room for innovation and improvement in a rolling programme.

4.5.4 Whole-system planning and long-term value-for-money

The evidence suggested that the benefits of continuity were dependent on wider whole-system planning rather than continuity in isolation. Particularly, P17 articulated that value-for-money is weakened where electrification is treated separately from rolling-stock strategy. P17 pointed to the need for closer integration of infrastructure and rolling-stock in terms of delivery strategy. P22 made a related point. P22 treated the separation of rolling-stock and infrastructure as a weakness in current decision-making process. P02 connected rolling-stock availability and compatibility as part of programme scope. Furthermore, P02 argued that testing, commissioning, and entry into service need to be planned from the outset. P01 made a similar point. P01 contrasted fragmented UK planning with a more coherent long-term planning on other countries.

Participants associated long-term value-for-money to project sequencing. P11 argued that major decisions and interfaces need to be coordinated early. This is because misaligned sequencing can accelerate costs or create standing costs. P08 suggested that strategic continuity alone is not enough. Integration between contracts and work packages needs to be in place. P05 added a focused point by highlighting to the costs created when whole-system testing and commissioning planning is missing.

These views suggest that participants did not see continuity as self-sufficient. Rather, its value depended on:

- stable planning assumptions,
- disciplined sequencing, and
- integration across the wider railway system.

Therefore, continuity could be translated into practical efficiency.

4.6 Practical design, procurement, and delivery choices on complex corridors

Section 4.4 identified the main drivers of cost and delivery inefficiency as reported by participants. This section turns from those broader drivers to practical design, procurement, and delivery choices.

4.6.1 Early contractor involvement, constructability, and integrated design

A clear idea that emerged from the interviews was that early installation contractor involvement related to stronger delivery outcomes. P02 argued that feasibility and early estimating are weakened when construction input is not present. This is because practical constraints are not tested early enough. P06 noted that asset managers are often engaged too late. This allows generic or unnecessary requirements to enter the scheme before delivery is understood. P18 made a comparable point. P18 argued that installation contractors should be involved earlier in optioneering and outline design. This will enable the development of technical solutions first-time-right rather than being revisited later.

Additionally, participants associate constructability with the quality of integration between disciplines. P17 described earlier involvement of key delivery disciplines as important in reducing later redesign as this allows identifying clashes before site work begins. Moreover, P17 described plant limitations, access points, installation preferences, and site constraints as necessary input to design rather than as input that could be added after the design had significantly matured. Likewise, P08 connected better outcomes with closer relationship between designer and installation contractor. In conclusion, early involvement was not presented simply as a process. It was described as timed input that improves buildability and coordination.

4.6.2 Procurement, risk allocation, and commercial incentives

Often participants connected value-for-money to procurement, risk allocation, and commercial incentives. The strongest pattern was that incorrect risk allocation was seen as capable of increasing cost rather than reducing it. P12 and P23 were explicit that risk should sit with the party best able to control it. They stated that indiscriminate transfer to installation contractors ultimately increases cost through claims behaviour and pressure on construction delivery. From this perspective, P12 regarded lump-sum contracts as suitable only where scope is well defined and uncertainty is low. On the other hand, target-cost and pain-share/gain-share arrangements were seen as more suitable under greater uncertainty. P12 distinguished time-and-expense arrangements. These contracts were seen as better for quality but riskier for budget. P12 noted that time-and-expense arrangements could be constrained by activity-based payments, which were described as improving cash flow without some of the disadvantages of pure lump-sum or pure time-and-expense. P02 reinforced this point. P02 noted that lump-sum estimates are weak where scope and assumptions are not mature.

Additionally, participants associate value-for-money with the commercial incentive structures included in contracts. P07 described arrangements that could support credible pricing and reduce re-pricing at later stages. P07 noted that shared commercial incentives between different parties in the same project could lead to cost reduction. Similarly, P07 noted that ring-fenced budget, pain-share/gain-share, and KPI-based management, could lead to collaborative behaviours. P18 added a related point. P18 supported output-based specification on the basis that the client should define the required outcome. This will allow the market to determine the most efficient technical solution. Also, the interview with P08 suggested that tendering can be distorted where too much emphasis is placed on lowest price rather than realistic cost. P09 provided a narrower but relevant point. P09 criticised the use of multiple steelwork suppliers on one project where a simpler supply arrangement was seen as likely to reduce technical interfaces.

In conclusion, not a single commercial model was presented as universally best. However, participants associate value-for-money with contracts aligned with incentives and the degree of uncertainty.

4.6.3 Design maturity, sequencing, and change control

Another strong pattern was that participants associated better performance with:

- stronger design maturity before construction,
- more disciplined sequencing, and
- tighter control of later change.

P12 treated uncertain scope as a major delivery risk. This is because contracts could be awarded before design is mature and before the client fully understands the job. Similarly, trial holes, utility diversions, or other unresolved site conditions were described as items that can consume possessions. Likewise, P09 connected poor value to design immaturity, missing surveys or inaccurate source records. P09 noted that information gaps lead to additional investigation and delivery disruption.

Additionally, participants described sequencing decisions as a main driver of inefficiency. P08 and P17 outlined a more disciplined approach. This is presented below:

- Layouts are progressed to a sufficient level.
- Foundation positions are checked on site with the presence of the designer.
- If limited engineering adjustment is needed, it is done on site. Otherwise, it is resolved efficiently in the design office.
- The layouts are then frozen before the commencement of detailed follow-up design.

P08 and P17 suggested that accepting some early delay can be more efficient than pushing visible progress too early.

P21, as previously stated, added a similar concern about false progress where early activities proceed before key design decisions are established. P14 provided a parallel example from high-output perspective. P14 described in detail how poor sequencing between activities can lead to teams attending site before prerequisite work is complete. This leads to creating waste rather than progress. P02 added that predecessor dependencies outside the core electrification package can produce standing time and subsequently cost. P17 contributed an important nuance. P17 noted that fixing key inputs early and managing changes on later stages in a structured manner is an effective way of managing large and complex projects.

In conclusion, these views suggest that participants did not see early progress on site linked with readiness in itself. They associated better outcomes with schemes in which surveys, site verification, sequencing, and controlled change were treated as potential risks to delivery.

4.6.4 Testing, commissioning, entry into service, and handover

The late stages of delivery were described as an area where project choices could significantly increase cost and cause inefficiency. P14 was the clearest source on this theme. P14 described the late agreement of testing requirements as a major contributor to delays. Additionally, P14 noted that prolonged waiting periods between physical completion on site and entry into service as a significant cost driver. This is because large numbers of staff could remain in place after construction completion while testing and commissioning issues were still unresolved. This creates a sunk cost that is not always visible in headline construction cost. P02 provided a related point but for earlier stage. P02 argued that rolling-stock availability, testing, commissioning, and entry into service should be considered from the outset. P23 added that standards and current-collection testing were problematic in some locations. Additionally, P23 warned that certain metrics were not fully consistent or repeatable. This supports the wider finding that testing-related requirements can become a source of uncertainty late in delivery.

Other participants reinforced the importance of a holistic project close-out management. P05 pointed to the cost created where system-level testing and commissioning leadership was missing. P05 added an example in which the absence of a dedicated manager overseeing the whole railway system created unnecessary delay. Also, P11 described post-commissioning modification arising where a utility interface had not been considered properly at early stages. In conclusion, participants associate better outcomes with testing, commissioning, entry into service, and handover being treated as integral parts of project delivery.

4.7 Cross-theme findings for complex railway corridors

4.7.1 Interactions between access, scope, standards, and interfaces

A cross-theme pattern was that high cost and delivery inefficiency were rarely described as coming from a single isolated cause. Usually, participants portrayed them as the product of interacting constraints within the same scheme.

Particularly, P02 linked access difficulties to immature scope and predecessor dependencies. P02 argued that where access is secured early but design, enabling works, or multidisciplinary inputs remain unresolved, possessions can be used inefficiently. As a result, standing time can increase. P12 described a similar interaction. This was between uncertain scope, possessions, utilities diversions, consents, and unresolved site conditions. This resulted in construction access being consumed in discovering problems rather than delivering productive work. Likewise, P04 linked unsettled timetable assumptions, service requirements, feeder-station decisions, utility coordination, and multidisciplinary interfaces. P04 noted that all these items can combine and lead to redesigning and reduce efficiency.

Moreover, this interactional pattern appeared in participants' views of standards, clearances, route constraints, and wider interfaces. P08 described fragmented contracts across electrification, route clearance, signalling, and associated works as a source of redesign and conflict. Similarly, P01 suggested that technical and standards-related choices (such as clearance interventions and system configuration) could worsen access and become a delivery burden. P21 and P22 added a related point from a systems perspective. They indicated that premature progress, weak interface coordination, poor cost boundary definition, and fragmented track-train decisions can amplify one another in practice.

In conclusion, the main point was that access, scope, standards, and interfaces were often experienced together. Therefore, cost escalation and inefficiency were not usually presented as the effect of one factor. They were presented as outcomes of multiple interactions within the same scheme.

4.7.2 Conditions associated with better or worse delivery efficiency

Participants saw better delivery efficiency achieved through a set of project conditions rather than with any single intervention. More efficient delivery was linked to mature scope, earlier surveys, constructability input, integrated working across design and construction, repeatable methods, workable access, continuity of people, and proportionate assurance. P02, P07, and P12 each connected better outcomes with stronger early definition and a more realistic understanding of what the job required before major commitments were made. Similarly, P08 and P17 associate stronger performance with closer integration, disciplined handling of change, and repeatable delivery methods. P03 and P18 connected efficiency to continuity of teams, retained experience, and learning processes. P23 added that better efficiency was associated with more proportionate standards application, clearer risk ownership, and more integrated planning across signalling, electrification, and rolling-stock. This reinforced the wider pattern that coordinated system decisions matter more than isolated optimisation within one discipline.

In contrast, poor delivery efficiency was linked to the opposite conditions. Participants described premature construction, fragmented contracts, weak interfaces, stop-start funding, late-emerging requirements, immature design, as factors that tended to compound one another. P08 described fragmented contracts and poor integration as a cause of inefficiency. P12 and P02 connected inefficiency outcomes to uncertain scope and commitments made before access, risks, and site conditions were properly understood. P07 associated stop-start delivery, and poorly bounded scope with overhead growth. P03 linked inefficiency to discontinuity between stages and excessive client-led assurance burden.

A useful caveat within this pattern was that some participants, particularly P08, did not treat all inefficiency as avoidable. It was noted that route complexity and access constraints can impose difficulties even when delivery is well organised. Even so, the dominant pattern was that participants associated stronger efficiency with coordinated, mature, and repeatable delivery conditions. They also connected weaker efficiency with fragmentation, instability, and late correction.

4.8 Summary

This chapter has presented the main empirical findings from the practitioner interviews on value-for-money in UK railway electrification. Value-for-money was rarely understood as lowest initial capital cost alone. Usually, participants described it in broader terms. This included whole-life performance, operationality, maintainability, resilience, and the avoidance of unnecessary cost and rework. Furthermore, the findings showed that governance and funding conditions were seen as important. Particularly technical client capability, fragmented interfaces, layered assurance, stop-start funding, and annual budget pressures.

The strongest recurring drivers of higher cost and weaker efficiency were immature scope, late change, route and power-supply complexity, restricted access, productivity loss in possessions, and the disproportionate/inconsistent application of requirements. Furthermore, participants connected better outcomes to rolling programme continuity, retention of skilled people, stronger supply-chain confidence, repeatability, and the aggravated transfer of lessons learnt. On complex corridors, efficient delivery was associated with earlier contractor involvement, better commercial models, tighter control of design maturity, projects sequencing, and earlier planning of testing, commissioning, entry into service, and handover. These findings provide the empirical basis for the discussion chapter that follows.

5 DISCUSSION

5.1 Introduction to Discussion

This chapter interprets the findings in Chapter 4 in relation to the research questions and the literature review in Chapter 2. Its purpose is to explain what the findings mean in order to understand value-for-money in UK railway electrification programmes. Therefore, the discussion moves from description of cost drivers and delivery conditions to interpretation on how these factors influence efficiency, affordability, and strategic decision-making.

The discussion is based on the view that value-for-money in electrification cannot be explained by headline capital cost alone. As established in the literature review, electrification cost and delivery performance are shaped by several interacting factors such as: governance, scope definition, standards application, access constraints, procurement arrangements, delivery capability, and programme continuity. In this light, value-for-money is not determined only by the direct engineering cost of the electrification system. Value-for-money is also determined by the wider conditions under which schemes are planned, governed, and delivered.

An additional issue is that the perception of electrification cost can become extremely focused on the actual system itself. This mainly means Traction Power and OCS assets. However, the evidence suggests that the wider cost problem is more complex. The RIA ECC report was commissioned in response to a loss of confidence in electrification affordability following GWEP. But the recommendations of the report extend well beyond core engineering assets, and it included risk apportionment, design maturity, standards, power supply, route clearance, plant, and delivery methodology. This is quite important because it presents that value-for-money should be approached as a whole-project and whole-delivery issue, rather than as a narrow question of assets alone.

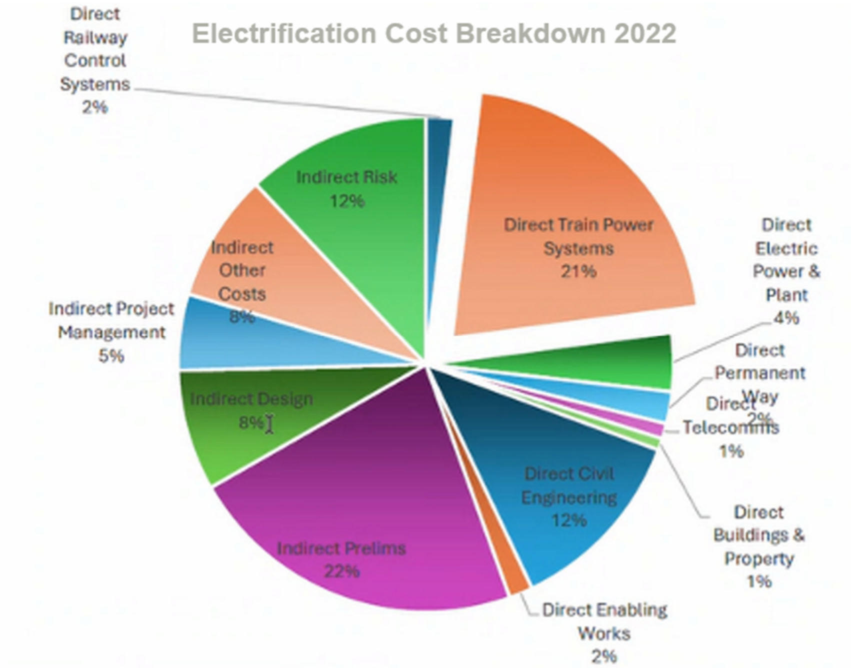

Figure 5-1: Indicative electrification cost breakdown
Source: Adapted from RIA PowerPoint slides

Figure 5-1 is included as a prominent figure for the discussion chapter. Its purpose is to illustrate that the electrification system does not necessarily represent the dominant share of total project cost. Furthermore, it presents that substantial costs may sit in preliminaries, civils, design, project management, risk, enabling works, and other indirect elements. This supports the central argument of the chapter, which is that value-for-money cannot be assessed credibly by focusing only on the direct electrification system. Subsequently, the wider delivery environment must be considered. This interpretation is also consistent with interview evidence in the study. Practitioners repeatedly pointed to access, scope maturity, foundations, interfaces, governance fragmentation, and programme continuity as major drivers of cost and efficiency.

The chapter is as follows. Section 5.2 interprets the key findings from Chapter 4, considering the research questions and the literature review from Chapter 2. Section 5.3 considers the governance and delivery implications of those findings. Section 5.4 addresses the STK cost interpretation issue. Section 5.5 considers the implications for value-for-money assessment. Finally, section 5.6 sets out evidence-based recommendations for industry and delivery practice. The chapter closes with a brief synthesis that prepares the transition to Chapter 6.

5.2 Interpretation of the Key Findings

The findings indicate that practitioners understood value-for-money is a broader element than just lower initial capital cost. The significance of this is not that practitioners departed from established public-sector definitions of value-for-money. However, they interpreted those definitions from a more delivery-aware perspective. Reviewing Chapter 2, the perspective of the practitioners agrees more closely with the 3 E's (economy, efficiency, and effectiveness) framework. They did not see value-for-money as a narrow cost-minimising interpretation. In practice, this means that value-for-money was judged on whether expenditure produced a robust, maintainable and operationally effective railway. It was not seen as merely reducing visible capital cost at project level.

This is significant because it helps explain why headline project cost or unit-cost comparison was not treated by interviewees as a sufficient indicator of scheme performance. The literature review showed that cost-benefit analysis, multi-criteria decision analysis and benchmarking all offer useful ways to support infrastructure appraisal. However, each method becomes weaker when complex project conditions are reduced to simplified comparisons. Chapter 4 findings support this perspective. Practitioners appeared to consider low cost with caution. This is because it could reflect omitted scope, deferred intervention, or a transfer of burden into operations and maintenance. Equally, practitioners did not automatically interpret higher cost as waste. Particularly, in complex route conditions, traction power requirements, interfaces or access constraints were unavoidable. The main consideration is that value-for-money is perceived by practitioners as a question of whether total expenditure is proportionate to the capability and performance of the railway produced. It is not perceived as a low visible capital figure in isolation.

A second important interpretation is that practitioners connect value-for-money with whole-life and railway performance. This reinforces the literature review in Chapter 2, which identified electrification as potentially offering lower operating cost, lower maintenance burden, better performance, decarbonisation benefits, and wider network advantages over time. However, the findings add practical sharpness to the literature. This is because practitioners connected value-for-money to concrete issues such as maintainability, isolation strategy, access burden, commissioning readiness, interfaces, and whether the resulting system could be extended or operated efficiently. In analytical terms, this means that the study's findings strengthen the argument that value-for-money in electrification is not different from the quality of the system produced. A scheme that is cheaper to install but at the same time is harder to be maintained, more disruptive to be operated, or more difficult to be extended, was not generally perceived as better value.

Additionally, it has been observed that there is a tension between how value-for-money is formally framed and how it is understood in delivery. Particularly, chapter 4 indicated that practitioners were concerned not only that some benefits are weakly captured. They were also concerned that some costs are poorly framed when business cases are developed too narrowly or too early. This does not represent a rejection of appraisal discipline. However, it suggests that appraisal can become less credible when it is detached from delivery. This interpretation is consistent with the literature review in Chapter 2, and particularly with the limitations of appraisal. Therefore, the findings refine the dissertation's argument by showing that practitioners see value-for-money as dependent on the realism of what is being appraised, not merely on the method used to appraise it.

Taken together, the findings primarily answer the first research question. They show that practitioners understood value-for-money as a disciplined but multi-dimensional judgement, which was centered on various factors such as:

- proportionality between expenditure,
- delivery practicality, and
- the long-term usefulness of the railway system created.

The literature established that value-for-money should extend beyond capital cost. The findings show more clearly why these matters in electrification. This is because the apparent cost of the visible system can obscure the importance of wider project conditions, indirect scope, and post-handover consequences. For that reason, practitioners' understanding of value-for-money is best interpreted not as opposition to formal appraisal, but as a challenge to overly narrow interpretations of it.

5.3 Governance and Delivery Implications

The findings suggest that governance is not simply an administrative background to electrification delivery. Governance is part of the mechanism through which value-for-money is either protected or weakened. Chapter 4 showed that practitioners repeatedly associated poor outcomes with weak client-side technical understanding, fragmented decision-making, misaligned interfaces, layered assurance and unstable funding conditions.

This broadly supports the literature review in Chapter 2. The literature presented governance and procurement structure as central to value-for-money. This is because they shape accountability, estimate realism, risk allocation and the maturity of projects at the point of commitment. The OVfM reinforces that connection by arguing that mega-projects are often undermined when decision-making becomes convoluted, estimates are fixed too early, and governance structures prioritise process without sufficient delivery readiness. In this respect, the findings answer the second research question. The findings indicate that governance affects value-for-money not only through formal approval structures. The findings also affect value-for-money through the quality and timing of the decisions those structures produce.

A central implication is related to client capability. The findings suggest that governance becomes less effective where sponsors, project engineers or assurance lack sufficient technical depth. This matters because electrification depends on early judgement about what is genuinely required, what can be standardised, and where uncertainty still remains. Therefore, the governance issue is not simply whether roles exist. It is whether the people on roles are capable of producing technically credible decisions at the point where value-for-money judgements are formed.

The evidence on client-led assurance burden requires a more careful interpretation. Chapter 4 did not show that practitioners opposed assurance in principle. On the contrary, some participants regarded standard assurance as workable on conventional schemes. Also, they accepted that checking and reviewing can protect whole-life value when proportionate and technically informed. The concern was more specific. Assurance appeared to reduce value when it was repeated, layered or disconnected from material project risk. This distinction is important because it separates legitimate governance from governance friction. The OVfM makes a similar point. The OVfM argues that assurance structures can blur accountability and shift attention from substance to process. In conclusion, assurance affects delivery efficiency not by its mere existence, but by whether it helps resolve uncertainty early. Instead, assurance results in adding delay and administrative overhead without equivalent value.

Additionally, the findings indicate that governance should be distinguished from technical delivery. Technical delivery relates to the demands of the route and system being delivered, such as clearances, power supply, legacy infrastructure, junction complexity or access constraints. However, governance is about how those demands are interpreted. This distinction matters because it prevents poor outcomes from being attributed to either to "difficult infrastructure" or to "bad governance" alone. A complex route will remain complex under any governance model. However, weak governance increases the likelihood that complexity is discovered too late, divided across multiple organisations, or translated into inefficiency. Therefore, governance matters because it conditions whether technical complexity remains an unavoidable cost driver or becomes an avoidable source of inefficiency.

Funding discontinuity, such as stop-start funding, annual budget pressure and short-term sponsor behaviour, further strengthens this argument. The findings suggest that funding discontinuity is not just an external constraint, but governance conditions that shape efficiency directly. Chapter 4 associated discontinuity with loss of skilled labour, supplier caution, remobilisation cost and inefficient spending behaviour driven by financial-year boundaries rather than delivery logic. This interpretation is closely aligned with the literature review in Chapter 2. The literature argues that annual budget constraint and unstable workbanks undermine learning, weaken productivity and increase cost over time. The Transport Committee's recent report makes the same broader point by describing boom-and-bust investment as damaging to skills retention, innovation and overall efficiency. The implication here is not that every funding change produces inefficiency, but that unstable funding continuity weakens the conditions under which electrification delivery can improve.

In conclusion, the findings suggest that governance affects value-for-money mainly by shaping the conditions within which technical delivery takes place. Strong governance does not remove the physical constraints of electrifying a complex legacy railway. However, it can improve how those constraints are understood, sequenced and integrated. By contrast, weak governance tends to magnify uncertainty through poor early decisions, fragmented interfaces, disproportionate assurance and unstable funding conditions.

5.4 Single-Track Kilometre Interpretation and Cost Boundary Definition

A central issue observed in the literature review is that electrification costs are usually presented as STK rates with limited clarity on what defines the STK cost boundary. Therefore, reported STK values across projects may include different scopes of work. This reduces the reliability of the STK metric and, by extension, the appraisal/value-for-money assessment.

The RIA ECC report notes that STK is widely used as an electrification cost metric. Nevertheless, it clarifies that not all projects include the same elements in their reported STK values. Specifically, it highlights that some projects require significant electrical clearance works, signalling immunisation, and traction power works. While other projects do not require these elements. Consequently, RIA warns that unit costs are not by themselves an estimating tool. RIA recommends the use of the Rail Method of Measurement to improve consistency among projects for cost comparison purposes.

This dissertation does not seek to redefine the term for STK. However, it proposes clear STK cost boundaries to support the benchmark appraisal method. The purpose is to differentiate the core electrification scope from wider route-specific electrifications and route improvement works non-driven by electrification. This will allow consistency between reported STK costs which will enable schemes to be compared and analysed.

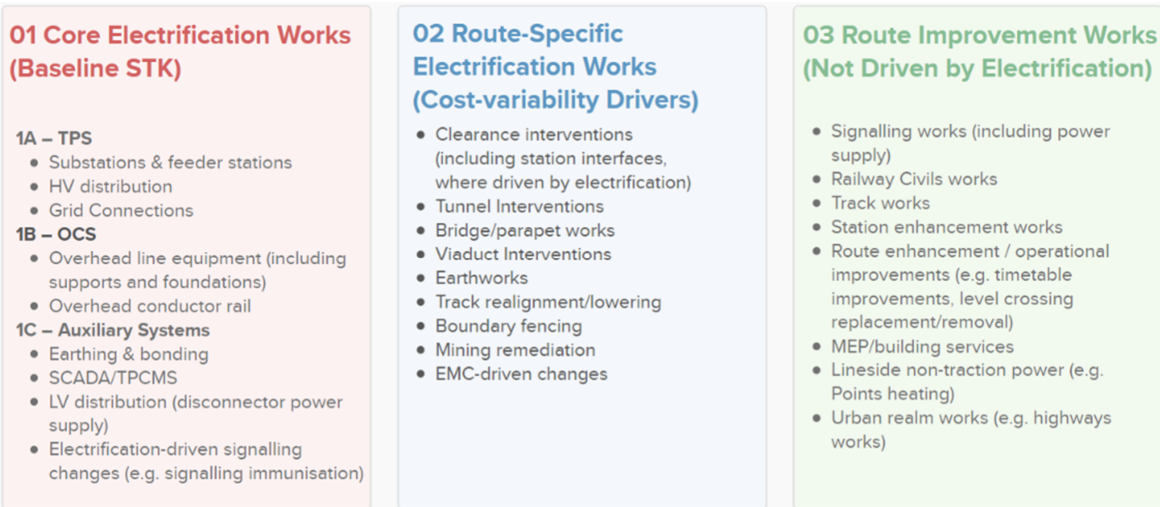

Figure 5-2: Proposed STK cost boundaries
Source: Author

The above Figure 5-2 illustrates the author's proposal for the STK cost boundaries in UK electrification programmes, which is a three-layer framework. These are described below:

a) The first layer includes 'Core Electrification Works' required for each electrification project, separated into engineering disciplines as traditionally interpreted by Network Rail, the main UK infrastructure owner. These are the traction power system, overhead contact system, and auxiliary systems.

b) The second layer is about 'Route-Specific Electrification Works', which are a major cost-variability driver. These types of interventions may be highly significant on certain routes but absent on others. This layer mainly includes route-clearance interventions, bridge and parapet works, and track realignment/lowering.

c) The third layer, 'Route Improvement Works', includes wider project elements that should not be driven by electrification. These may include route enhancement, or operational improvement works, building services works, and civils works not driven by electrification. The works under this layer may be important for the business case for a route enhancement, but their inclusion in the unit rates dilutes the cost of electrification.

Such categorisation of the STK unit rate is significant, because a high STK value may indicate poor delivery efficiency, but it may also present an inconsistent categorisation of costs. Alternatively, a low STK value may indicate high delivery efficiency, but it may exclude substantial integration necessary to accommodate the core electrification systems. Therefore, the issue is not only the unit rate itself, but the scope boundary that underlines it.

STK has direct implications for appraisal methods. If projects are compared without clear disclosure of cost boundaries, there is a risk that the comparison is not on a like-for-like basis. In this sense, cost boundary clarity is not only a costing issue, but also an appraisal issue, as STK affects how schemes are compared to each other. Published STK unit rates are frequently used in industry to indicate what electrification should cost. The RIA ECC report suggests cost ranges for simpler and more complex schemes. However, those ranges are only meaningful where the basis of comparison is consistent. Therefore, there is a need to use STK with greater precision and transparency. The three-layer interpretation helps differentiate between the baseline cost of electrification, the additional cost of route-specific works, and the wider project costs that should sit outside the STK comparison.

The contribution of this section may be limited, but it is important. It does not propose a new costing standard, nor does it claim to resolve all issues of electrification benchmarking. However, it provides a clearer interpretive framework to enable value-for-money assessment to be based on more transparent data.

5.5 Implications for value-for-money Assessment

The findings indicate that value-for-money assessment should remain appraisal-led, but should not be interpreted through narrow capital-cost comparison alone. Chapter 2 showed that cost-benefit analysis remains the dominant formal method in UK transport appraisal. This is because it converts diverse impacts into a single economic measure and supports comparison between options. However, the same literature identified clear limitations:

- CBA can underweight non-monetised effects,
- it is sensitive to assumptions, and
- it can encourage overconfidence in apparently precise outputs where the underlying evidence base is unstable.

The completed findings reinforce those concerns in a more delivery-specific way. They suggest that electrification options may appear stronger or weaker than they really are. This can happen if the assessment boundary is too narrow or if the scheme enters appraisal with immature scope, unresolved interfaces, or unrealistic delivery assumptions.

The first implication is that value-for-money assessment should distinguish more clearly between economy and value. A lower upfront capital figure may satisfy a short-term economic test. However, the findings suggest that it may still represent weak value-for-money where it transfers burden into later maintenance, access, testing, operations or future modification. This is consistent with the literature review in Chapter 2, which defined value-for-money through the interaction of economy, efficiency and effectiveness rather than expenditure minimisation alone.

The second implication is that the quality of value-for-money assessment depends heavily on the maturity and credibility of what is being assessed. The findings indicated that practitioners were concerned that some benefits are weakly captured. Furthermore, they expressed doubts that some costs are poorly framed where assumptions are still moving, enabling works remain unresolved, or wider interfaces sit outside the visible scheme boundary. In that sense, the weakness does not lie purely in the appraisal method itself. It lies in the institutional and technical quality of the information supplied to that method.

The third implication is that access, sequencing and delivery productivity should be treated as part of appraisal rather than as pure construction detail. The findings suggest that options that appear similar at a high level may generate significant different value outcomes. This is because realistic possession, disruption and logistics conditions are not always considered. For value-for-money assessment, this means that comparative judgement should reflect the practical delivery environment of each option, not simply its nominal capital scope.

Additionally, the findings imply that delivery continuity is significant from an assessment perspective. If electrification is appraised only as a set of isolated schemes, the analysis may understate the value that is brought from retained capability, repeatability and lower remobilisation cost. At the same time, the appraisal analysis suggests that delivering schemes in small, interrupted phases may look careful, but this sense of caution may be misleading. This does not suggest that programme consideration replace project appraisal. However, project appraisal in electrification should be interpreted with clearer awareness of the programme conditions within which schemes are expected to be delivered.

Concluding, the findings imply that value-for-money assessment in UK railway electrification should remain disciplined and evidence-based. However, they should be interpreted through a whole-project and whole-system lens. Narrow capital-cost comparison is inadequate. This is because it can obscure the significance of governance quality, access constraints, scope maturity, delivery continuity and cost-boundary clarity. This section supports the research questions by showing that value-for-money depends on delivery conditions, not just appraisal methods.

5.6 Recommendations for industry and delivery practice

The discussion suggests that better value-for-money in UK railway electrification is most likely to come from improving the conditions under which schemes are planned, integrated and delivered. The recommendations below are therefore grouped at two levels:

a) strategic programme conditions
b) project-delivery.

Strategic programme conditions

The first recommendation is that electrification should be supported through a more stable rolling programme with clearer medium-term workbank visibility. As a minimum, if the control period framework is retained, the five-year settlement should be supported with an additional two to three years of likely electrification work. This follows directly from the repeated link in the findings between continuity, skills retention, stronger supplier confidence, repeatability and lower remobilisation cost. The wider project sources reinforce the same point by showing that unstable pipelines weaken efficiency and raise cost over time.

The second strategic recommendation is to strengthen the technical capability of infrastructure clients and sponsors at the points where decision about scope, standards challenge, delivery strategy and integration decisions are made. This arises from the evidence that weak client-side technical understanding can allow immature assumptions, excessive specification and fragmented judgement to move forward into later stages. This has consequences to both delivery efficiency and value-for-money.

The third strategic recommendation is that electrification should be planned more consistently as a whole-system programme rather than as a series of isolated infrastructure packages. The findings suggest that value-for-money is weakened where infrastructure, rolling-stock, access planning, testing and entry into service are treated as separate decisions. They should be treated as parts of the same delivery logic. More integrated programme planning would not remove route complexity. However, it would reduce the likelihood that projects proceed on partial assumptions that later require redesign or create standing costs.

Project-delivery level

At the project-delivery level, the first recommendation is that earlier contractor, asset manager and delivery-discipline input should be built into optioneering and outline design. The findings strongly suggest that estimating, constructability assessment, and access planning are weaker where delivery knowledge enters too late, and that this increases the risk of later redesign and scope correction.

The second recommendation is that projects should not move into construction without a more disciplined threshold of scope maturity and design readiness. This follows from the recurring evidence on hidden scope, late change, moving service assumptions and avoidable redesign. This is consistent with the wider industry evidence that design maturity is critical before live installation begins.

The third project-delivery recommendation is that procurement and risk allocation should be aligned more closely to actual uncertainty. The findings suggest that poorly bounded risk transfer tends to increase cost through defensive pricing, claims behaviour and weak integration. At the same time, more collaborative structures are better suited where uncertainty remains significant. The dissertation evidence does not support a single universal contract model. However, it does support the principle that commercial structure should reflect the maturity of the work being procured.

The fourth project-delivery recommendation is that access strategy and logistics should be treated as core design and delivery parameters from the outset. The findings consistently showed that short possessions, constrained logistics, poorly sequenced prerequisite work and distorted access choices erode productivity and increase cost. This implies that access should inform delivery method early. Instead of access being treated as a secondary constraint once design has already matured.

The fifth project-delivery recommendation is that delivery integration should be strengthened across design, construction, and testing and commissioning interfaces. The evidence suggests that fragmentation is not merely an administrative inconvenience. Fragmentation is a cost driver where no actor has enough authority or visibility to coordinate the whole delivery sequence and resolve conflicts early.

The sixth project-delivery recommendation is that standardisation and assurance should be applied in a more disciplined and proportionate way. The findings support standardisation where it reduces unnecessary novelty and supports repeatability. However, they do not support rigid standardisation that prevents challenge or improvement. Similarly, the evidence does not suggest that assurance should be reduced indiscriminately, but rather that it should remain closely tied to project risk and technically informed decision-making.

Concluding, these recommendations remain closely grounded in the dissertation evidence. They suggest that better value-for-money is most likely to come from improving the conditions under which schemes are planned, integrated and delivered, rather than from focusing only on direct engineering cost.

5.7 Summary

This chapter has interpreted the findings from Chapter 4 in relation to the research questions and the literature review in Chapter 2. The discussion has shown that value-for-money in UK railway electrification is not adequately understood through narrow capital-cost comparison. This is because delivery efficiency and overall project value are shaped by governance quality, client capability, assurance proportionality, access constraints, scope maturity, delivery continuity, procurement structure, and the clarity of system and cost boundaries. Furthermore, it has been shown that appraisal remains useful, but only when they are applied with transparency about what is being compared and with proper attention to the delivery conditions that influence cost and performance. These interpretations remain bound by the qualitative and practitioner-based nature of the study. Nevertheless, they provide a coherent basis for the final chapter, which draws together the dissertation's overall conclusions and wider implications.

6 CONCLUSION

6.1 Overall Conclusion

This dissertation has shown that value-for-money in UK railway electrification cannot be judged through headline capital cost alone. Instead, it is a broader judgement about whether electrification is planned and delivered in a way that achieves strategic, operational, and long-term system value. In that sense, value-for-money is shaped not only by what is built, but by the conditions under which schemes are governed, specified, accessed, procured, and delivered.

The findings and discussion indicate that the strongest influences on value-for-money are governance quality, scope maturity, access conditions, standards application, delivery continuity, and the clarity of cost and system boundaries. Practitioners did not treat low initial cost as sufficient evidence of good value. Instead, they associated better value with electrification that is maintainable, extensible, proportionate in specification, and delivered through a stable and coordinated model. This directly answers the first research question. Value-for-money is best understood as the interaction of economy, efficiency, and effectiveness across the whole system. It is not a narrow measure of upfront expenditure.

Additionally, the dissertation finds that project governance and budgeting conditions significantly affect delivery efficiency and cost. Weak technical client capability, fragmented interfaces, excessive assurance burden, stop-start funding, and annual budget pressures were repeatedly associated with delay, redesign, and inefficient delivery. However, stronger technical leadership, clearer accountability, earlier coordination, and more stable programme conditions were associated with better outcomes. Therefore, the second research question is answered by showing that governance and funding are not secondary influences. They are central factors of whether electrification can achieve value-for-money.

In relation to the third research question, the study shows that unit-cost variation is driven by a combination of physical and institutional factors. These include route complexity, power supply requirements, route clearance interventions, access restrictions, scope immaturity, late change, and inconsistent or disproportionate application of standards. Therefore, cost variation cannot be interpreted credibly through single-track kilometre rates alone. Unless the cost boundary and delivery context are clearly defined. The study further concludes that rolling programmes, standardisation, and capability retention can improve value-for-money. However, this is only achieved where they are combined with realistic scope definition, repeatable delivery methods, and effective lesson transfer.

Finally, the fourth research question is answered by the strong emphasis practitioners placed on practical delivery decisions. Early contractor involvement, integrated design and construction thinking, disciplined change control, realistic access planning, and earlier preparation for testing, commissioning, and handover were all linked to better efficiency. Therefore, the dissertation concludes that better value-for-money in UK railway electrification is unlikely to come from one isolated intervention. It is more likely to come from improving the overall delivery environment within which schemes are developed and executed.

6.2 Recommendations

For policymakers and funders

- Support a stable rolling programme of electrification rather than stop-start investment cycles. As a minimum, if the five-year Control Period framework is retained, it should be supported by a further two-to-three-year visibility of the electrification workbank.
- Apply value-for-money judgement on a whole-life and whole-system basis. This should not apply to initial capital cost alone. It should be cognisant of maintainability, reliability, operational benefits, decarbonisation, and other wider benefits.
- Develop programme-level business cases for electrification, instead of relying only on isolated appraisal at project-level. This would allow for whole-life benefits, capability retention benefits, lesson learnt effects, mobilisation costs and wider benefits to be assessed more accurately.
- Improve funding continuity and reduce annual budget behaviours that defer work and increase whole-life costs. Where appropriate, funding structures should provide a clear programme envelope and, where possible, create incentives that allow savings to be re-used within a programme.
- Require clearer and more transparent cost boundaries when benchmarking or comparing schemes is adopted.

For industry and delivery organisations

- Strengthen technical client capability.
- Maintain clearer engineering leadership in key decisions.
- Improve scope maturity before commitment to delivery and tighten control of late change.
- Use more integrated delivery models where these reduce fragmentation and interface burden.
- Engage early with the electricity supply industry. This will allow grid connections, feeder locations and traction power requirements to be treated as programme-level items rather than late project-level interfaces.
- Apply standards and assurance more proportionately, while preserving safety and technical robustness.
- Retain and transfer capability, lessons learnt, and repeatable practices across successive schemes.

For future research

- Develop an appraisal approach for railway electrification that better captures whole-life, whole-system and programme-level value (see Appendix B).
- Extend the evidence base beyond qualitative practitioner insight through comparative case analysis and project-level cost data.

6.3 Final closing paragraph

The central conclusion of this dissertation is that UK railway electrification can deliver stronger value-for-money. This can be achieved if electrification is treated as a long-term delivery system rather than a series of isolated projects. Better outcomes depend not simply on spending less. They depend on governing, specifying, and delivering schemes more intelligently, more consistently, and with greater continuity. On that basis, the challenge is not whether electrification can provide value-for-money in principle, but whether the UK can create the conditions in which that value can be implemented in practice.

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Appendix A: Semi-Structured Interview Questions

Could you please describe your role and experience?

How do you understand the term value-for-money in the context of UK railway electrification programmes?

In your view, should value-for-money be assessed mainly through capital cost, or should wider whole-life, operational, maintenance, environmental, and system benefits also be considered?

What are the main factors that drive the cost of railway electrification in the UK?

To what extent do route characteristics (e.g. bridges, tunnels, stations, junctions, track alignment) affect electrification cost?

How important are track access, possessions, blockades, isolations, and site logistics in determining delivery efficiency?

Do you think current UK access arrangements allow electrification work to be delivered efficiently? Why or why not?

How do standards and safety requirements affect cost and delivery efficiency?

Are standards themselves the main issue, or is the issue more about how standards are interpreted and applied during project delivery?

How important is early scope definition?

What problems arise when scope, requirements, surveys, or interface information are not mature early enough?

How do late changes in scope and requirements affect cost, and rework?

What role does client capability play in achieving value-for-money in electrification projects?

Do project sponsors, project managers, engineering managers, and client-led assurance roles usually have the technical capability needed to make good decisions? What improvements would help?

How do governance structures and decision-making processes influence delivery efficiency?

Do you think current project governance and assurance processes are proportionate?

What procurement or contracting models work best, and why?

How should risk be allocated between the client, designer, and contractor?

Do lump-sum, target-cost, alliance, design-and-build, pain-share/gain-share, or activity-based payment models affect value-for-money differently?

How important is early contractor involvement in improving constructability and delivery efficiency?

How do multidisciplinary interfaces, such as civils, signalling, track, telecoms, traction power, utilities, rolling stock, and operations, affect cost and delivery?

Are National Grid connections, land acquisition, and traction power requirements sufficiently considered during early development?

How important are design maturity, surveys, and asset information before construction starts?

What practical decisions help reduce rework, delay, and avoidable cost during construction?

How important are testing, commissioning, handover, and entry into service?

What lessons should be learned from recent UK electrification schemes (e.g. Great Western, Midland Main Line, TransPennine Route Upgrade, Wigan to Bolton, or Scottish electrification schemes)?

How should the industry distinguish between core electrification cost and wider enabling or other project costs?

Would a rolling programme of electrification improve value-for-money? If so, how?

How would programme continuity affect skills retention, supply-chain confidence, procurement, plant utilisation, standardisation, and learning?

What are the advantages and disadvantages of standardisation and repeatable design?

Can innovation reduce cost, or does it increase complexity when introduced during live project delivery?

How well does the current appraisal or business-case process capture the wider benefits of electrification?

What changes would most improve value-for-money in future UK railway electrification programmes?

Is there anything else you think is important for understanding cost drivers, delivery efficiency, or value-for-money in UK railway electrification?

Appendix B: Indicative Appraisal Considerations for Railway Electrification

This appendix builds on Section 2.2.4, which refers to the strengths and limitations of established appraisal methods. These are cost-benefit analysis, multi-criteria decision analysis and benchmarking. The dissertation identifies an appraisal gap in the way railway electrification is assessed. This is particularly true when value is considered mainly through monetised benefits, benefit-cost ratios, or capital cost comparison.

Addressing this gap in full is outside the scope of this dissertation. A complete appraisal framework would require further policy, economic, technical and industry development. This will need to be followed by testing against live and historic schemes. However, the dissertation's recommendations can be supported by setting out the main appraisal considerations that such future work should address.

Therefore, the purpose of this appendix is to provide an indicative basis for an electrification-specific appraisal supplement. This supplement would support existing public-sector appraisal and business-case processes. Its role would be to make whole-life, whole-system and programme-level value more visible during early option selection and business-case development.

Appraisal dimension	**Indicative considerations**
Whole-life operating and maintenance cost	Appraisal should consider the long-term cost of operating and maintaining the electrified railway. This should include but not be limited to electrification infrastructure maintenance, rolling stock maintenance, inspections, isolation arrangements, asset access, maintainability and future renewal burden.
System benefits	The benefits case should consider reliability, resilience, capacity, improved acceleration, operational flexibility, diversionary capability, freight performance and the ability to operate a more efficient railway. These benefits may be significant even where

	they are difficult to isolate within a narrow project-level appraisal.
Programme-level value	Appraisal should consider whether a scheme forms part of a stable long-term programme rather than an isolated project. Relevant factors include continuity of workload, learning effects, standardisation, capability retention, reduced remobilisation, supplier confidence and productivity improvement across successive schemes.
Delivery readiness	Before commitment to delivery, appraisal should test whether the scheme has sufficient maturity. This includes scope definition, access strategy, constructability, consent readiness, possession planning, land requirements, environmental constraints, testing, commissioning and realistic delivery sequencing.
Wider system interfaces	Electrification should be appraised as part of a wider railway system. Interfaces with signalling, civils and structures, track, telecoms, rolling stock, depots, operations, maintenance, grid connections and service introduction should be considered early.
Strategic outcomes	Appraisal should recognise long-term strategic outcomes. These should include but not be limited to decarbonisation, energy resilience, modal shift, freight growth, long-term network development and alignment with future rolling stock and infrastructure strategy.
Electrification-specific value gap	Appraisal should challenge whether electrification value is being assessed too narrowly. Particular attention should be given to benefits that may sit across projects, organisations or funding periods, such as network flexibility, operational efficiency, resilience, supply-chain capability, whole-system integration and the cumulative value of a rolling programme.

This checklist could be used as an early-stage appraisal prompt to challenge whether an electrification option has been assessed comprehensively. It does not resolve the appraisal gap by itself, but it identifies the areas that a future electrification appraisal supplement should develop in more detail.

The checklist is indicative and should be developed further through policy, client and industry collaboration.

Statement:
I hereby expressly declare that, according to the article 8 of Law 1559/1986, this dissertation is solely the product of my personal work, does not infringe any intellectual property, personality and personal data rights of third parties, does not contain works/contributions from third parties for which the permission of the authors/beneficiaries is required, is not the product of partial or total plagiarism, and that the sources used are limited to the literature references alone and meet the rules of scientific citations.