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The RIA Electrification Cost Challenge

David Clarke

Technical Director, Railway Industry Association

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- UK electrification strategy since 2007
- The National Electrification Programme – what did we learn?
- What should electrification cost?

UK Electrification since 2007

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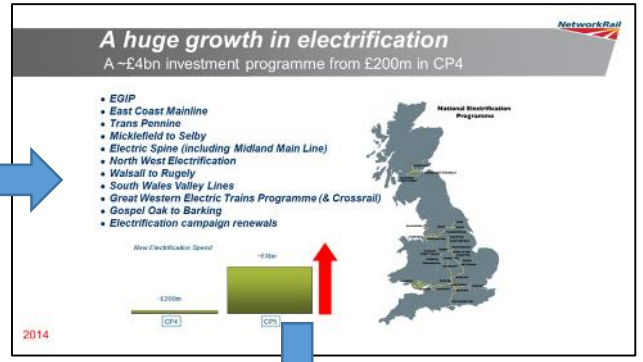
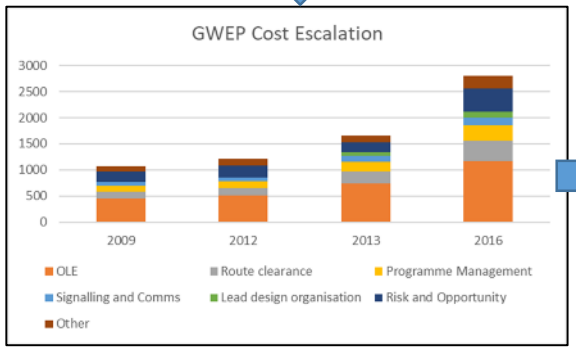
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019

Network Rail/ ATOC Letter to Dft





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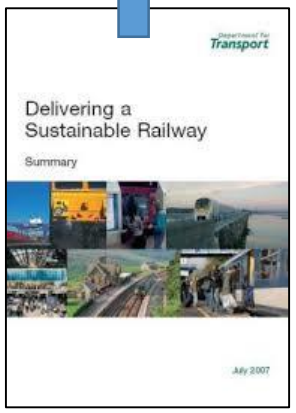

NAO National Audit Office

The purpose of the RIA Electrification Cost Challenge Report

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- Assist industry (client and supplier) and Government decision making on rail electrification.
- **Restore Government confidence** in the rail industry to deliver electrification schemes at an affordable cost on time and to budget.
- Highlight evidence that **electrification can be, and is being, delivered for between 33%-50% of GWEP costs** using examples from around the UK and internationally.
- **Identify good practice** in delivering electrification schemes and effect a significant change across the whole industry in the way that electrification projects are planned and delivered, from initial business case to energisation.
- Call for a minimum 10-Year **rolling programme** of electrification to enable the industry to deliver schemes at significantly lower cost and retain learning and skills and incentivise investment.

Health Warning

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- This is not a blame game
- The whole industry is culpable in the cost escalation in some recent projects
- Equally many projects have been successfully delivered

It all started well ……

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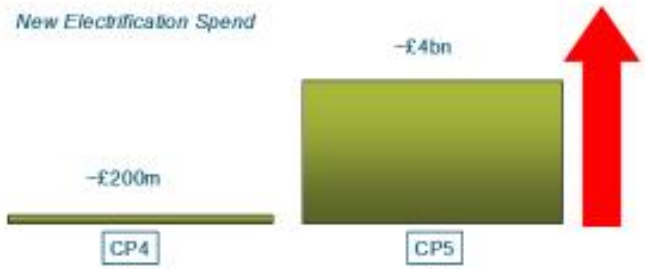
A huge growth in electrification

A ~£4bn investment programme from £200m in CP4

NetworkRail

- EGIP
- East Coast Mainline
- Trans Pennine
- Micklefield to Selby
- Electric Spine (including Midland Main Line)
- North West Electrification
- Walsall to Rugely
- South Wales Valley Lines
- Great Western Electric Trains Programme (& Crossrail)
- Gospel Oak to Barking
- Electrification campaign renewals



2014

Many of the challenges of a ‘huge growth in electrification’ were recognised…….

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- **Skills -** particularly in delivering Overheal Line Electrification (OLE)
- **Resources** – suppliers encouraged to ramp up and create delivery partnerships
- **Best practice** – Railway Electrification Delivery Group (REDG) set up
- **Productivity** – A new High Output System was developed to deliver more efficiently

But perhaps some challenges were not fully recognised…..

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- Compliance with current standards
- Development of a new high output (Plant and OLE) system during project delivery
- Accelerating from £200m over 5 years to £4000m over 5 years
- Lack of experienced resources in both client and supplier leading to ‘learning on the job’
- Immaturity of design and programme
- Need for clear leadership and accountability
- Mis-aligned incentives

So what happened and what have we learnt?

Feast and Famine/ Unrealistic Programme

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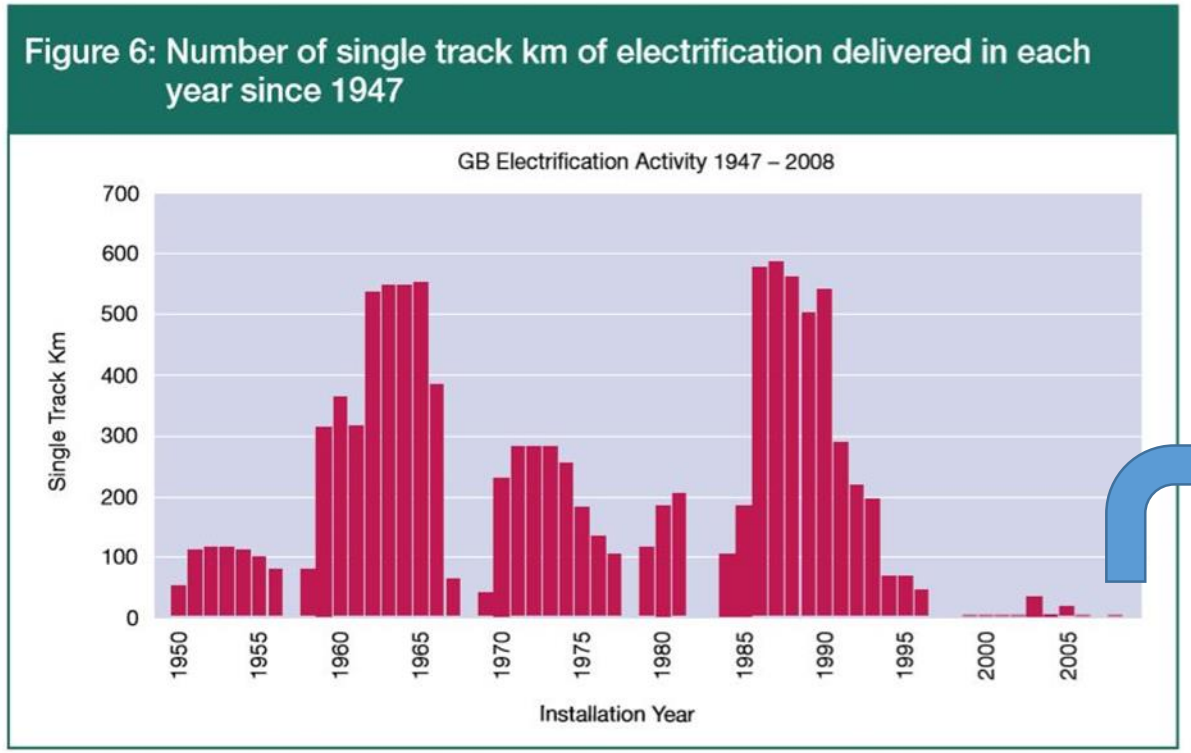

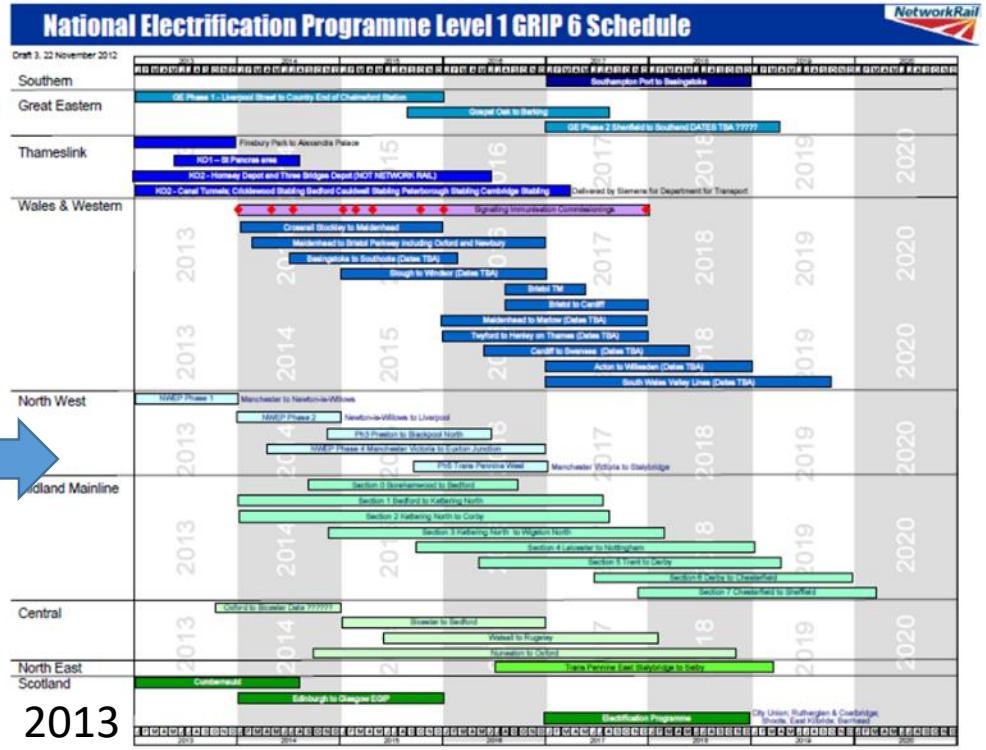

20 years since the last major electrification programme the industry started a 2000km programme across multiple routes

Lesson: Realistic Programme

Lesson: Experienced Resource

Novel Technology

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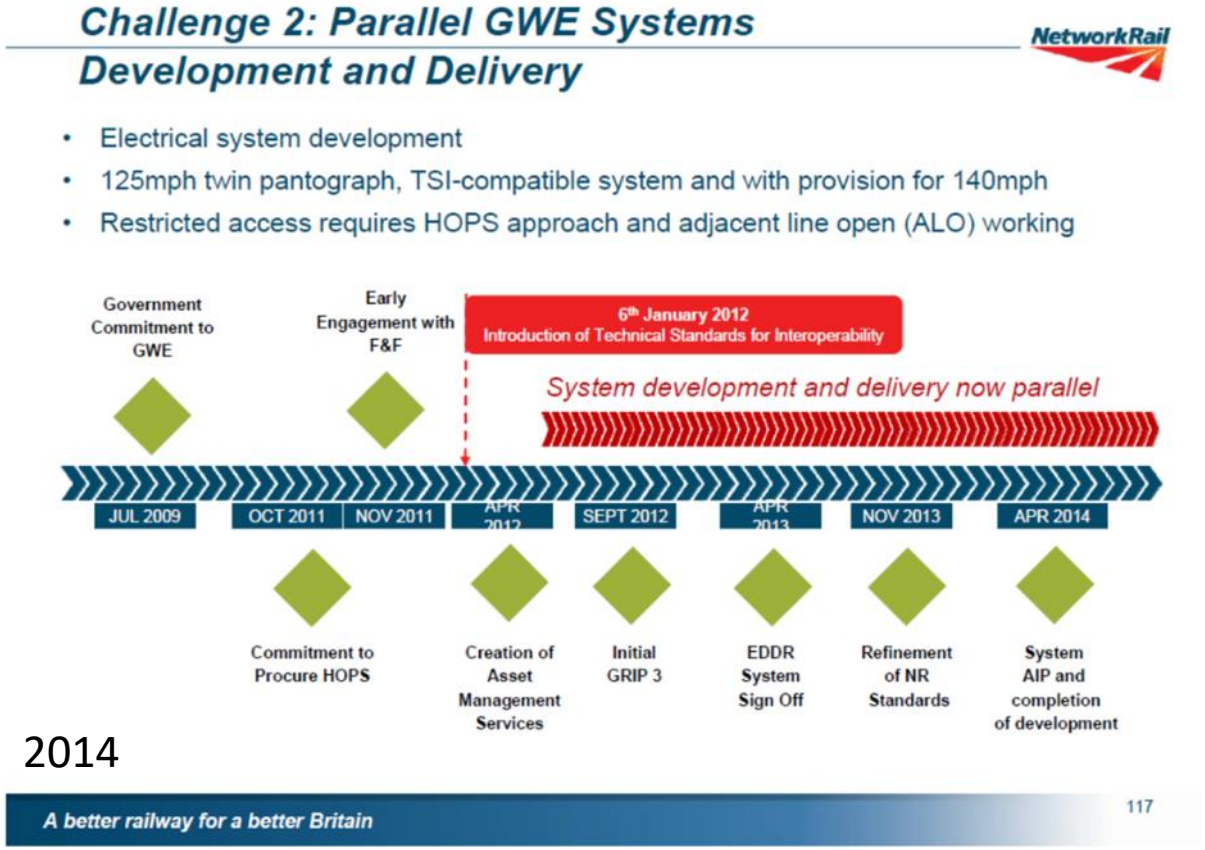
- To maximise productivity a ‘high output’ system comprising a new ‘factory train’ and a new overhead line system were commissioned.

Novel Technology

- To maximise productivity a ‘high output’ system comprising a new ‘factory train’ and a new overhead line system were commissioned.
- Development of this system overlapped with design and delivery.
- A 1000km main line project is not the place to work out ‘teething troubles’



Lesson: Proven Technology

Poor Productivity and Rework

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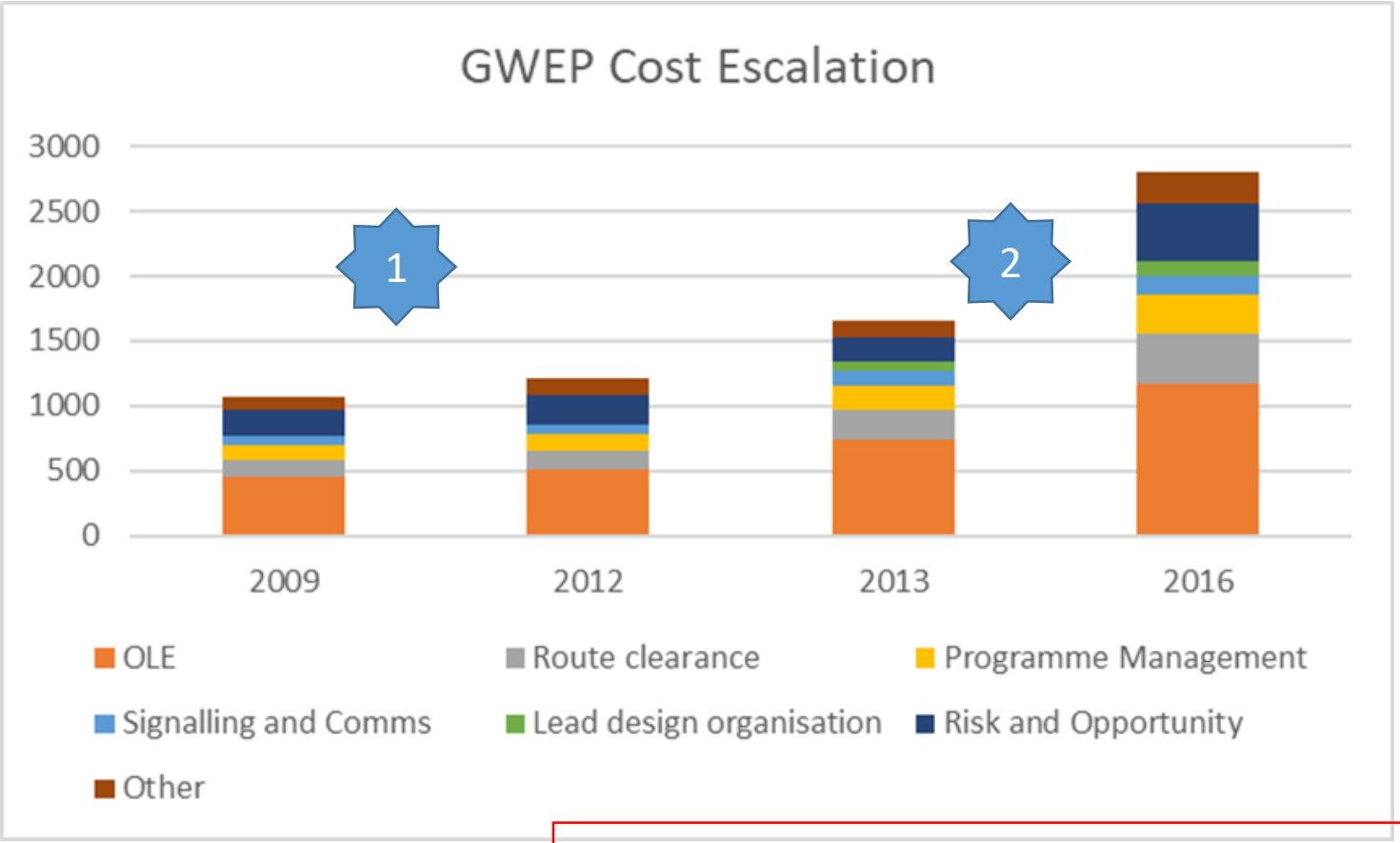
- Early foundation designs resulted in very long steel piles
- The ‘factory train’ could not drive these piles to the required depth at the expected rate
- NR undertook full scale tests and reverted to an old empirical design standards which resulted in shorter piles but ……..
- By then there was programme slippage which was not recovered

Lesson: Proven Methodology

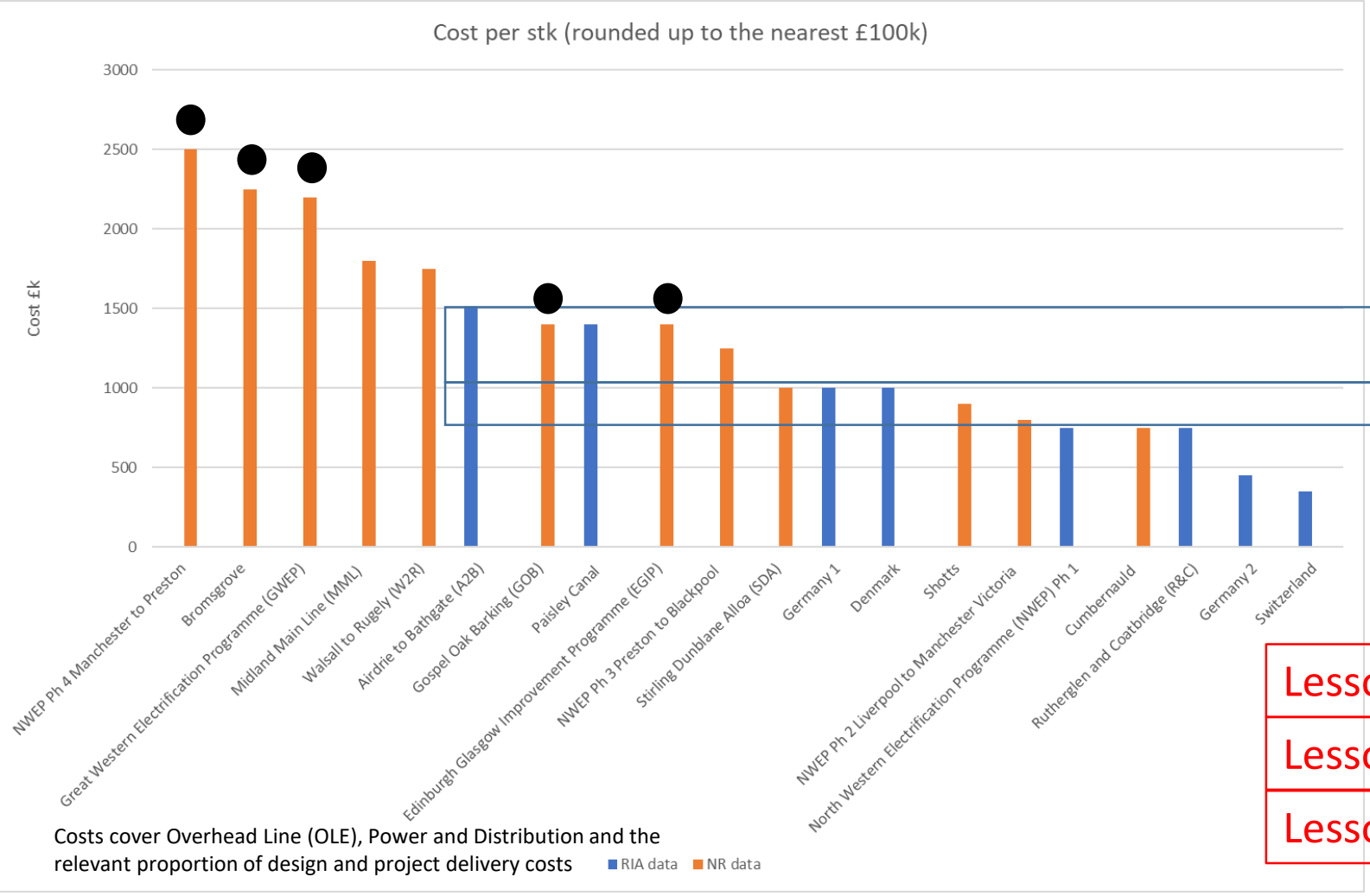
Consequential cost escalation



1. New Trains ordered for delivery in July 2017, Factory Train ordered, Series 1 OLE development starts
2. Construction starts but design is immature, risks are not held in the right place and assumed productivity is not achieved

Lesson: Early collaboration and design development mitigates risk

Not all projects had problems …



Costs cover Overhead Line (OLE), Power and Distribution and the relevant proportion of design and project delivery costs

● Projects which experienced delivery difficulties

Complex projects £1m to £1.5m/stk

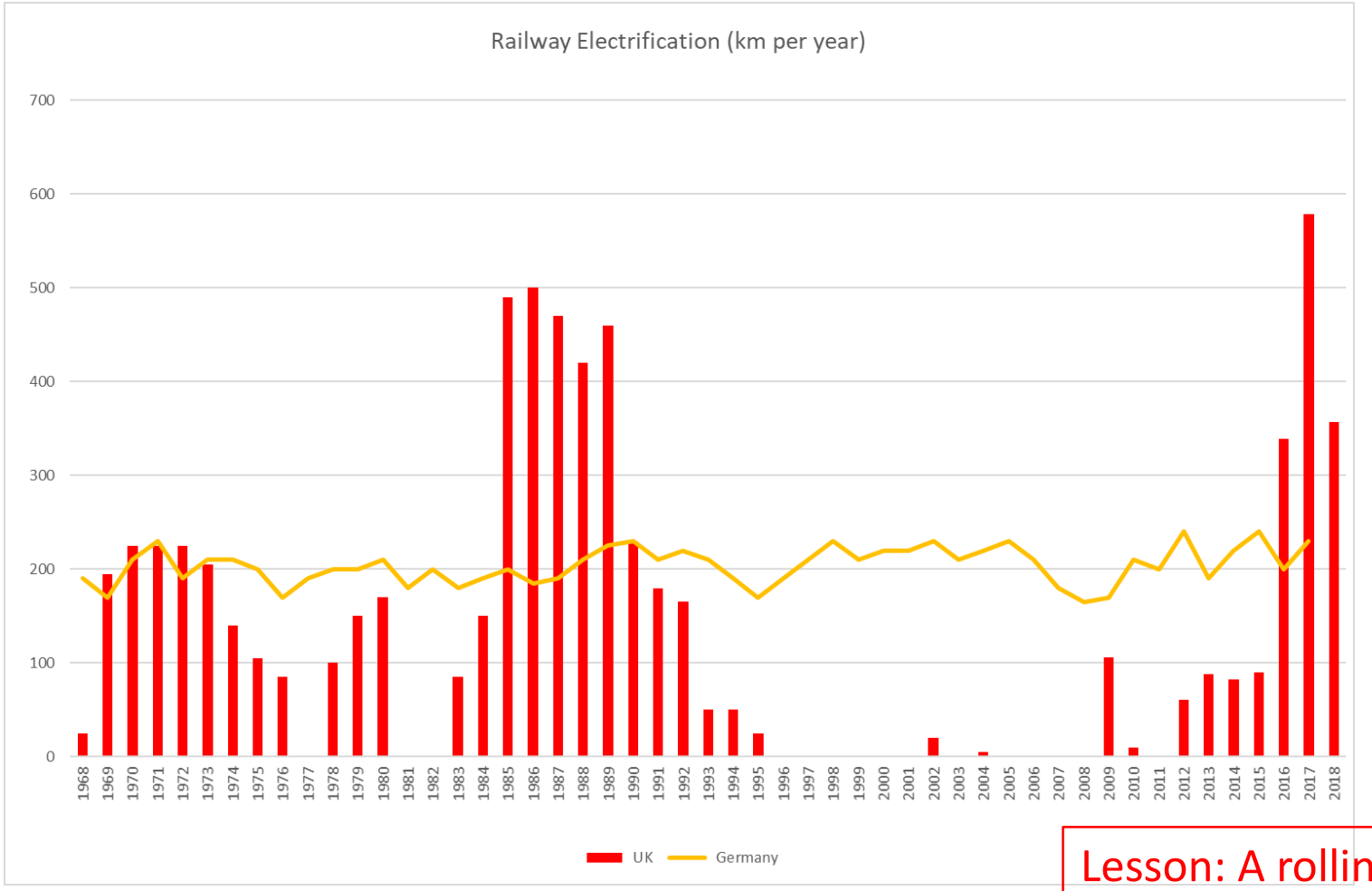
Simpler projects £0.75m to £1m/stk

Lesson: There is an efficient cost range

Lesson: Complexity is a cost driver

Lesson: Access is a cost driver

There is scope to do even better ….



Recommendation:

To establish a minimum 10 year rolling programme of electrification to progressively lower the long-term operating costs of the railway towards European norms and to support investment in people, process and plant.

Lesson: A rolling programme drives efficiency

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Benchmarking

An example of success (first part of EGIP)

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- **Cumbernauld to Springburn**
  - Start on site Feb 2013
  - Passenger Service May 2014
  - Actual Cost £61.5m (£3.4m saving)
  - 57 stk new OLE (**c£1m/stk**)
  - 960 x 6 m piles
  - 800 Series 2 OLE Structures
  - 5 bridges, 2 track lowers
  - Possession strategy increased nightly access by 30%
  - Co-location of team

Lesson	
Realistic Programme	Yes
Proven Technology	Yes
Proven Methodology	Yes
Collaboration	Yes
Efficient Cost	Yes
Low Complexity	Yes
Good Access	Yes
Rolling Programme	Yes

International Benchmark - Banedenmark

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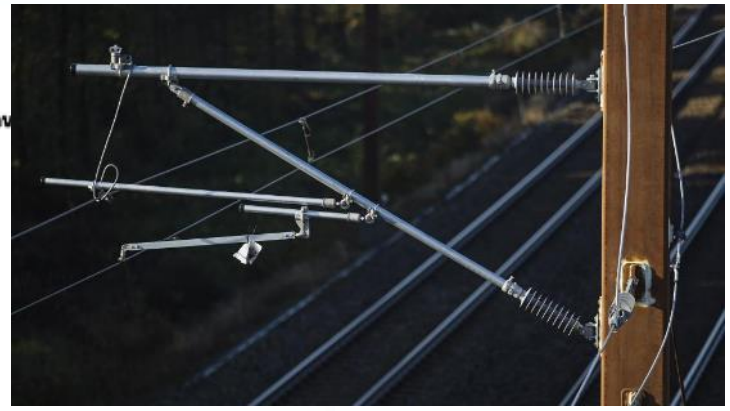
- Programme 2014 – 2026
- Electrify 1362 stk 12Bn DKK c**£1m/ stk**
  - 13 Traction power substations
  - 42 Auto transformer stations
  - Enabling works
  - Non-electrified lines are options
- Rolled out as a joint programme
  - Functional requirements spec
  - Supplier to have TSI approved system
  - Suppliers to be responsible for innovation
  - Continuous work for 10 years
  - One approval process



Lesson	
Realistic Programme	Yes
Proven Technology	Yes
Proven Methodology	Yes
Collaboration	Yes
Efficient Cost	Yes
Low Complexity	No
Good Access	Varies
Rolling Programme	Yes

International Benchmark 2017

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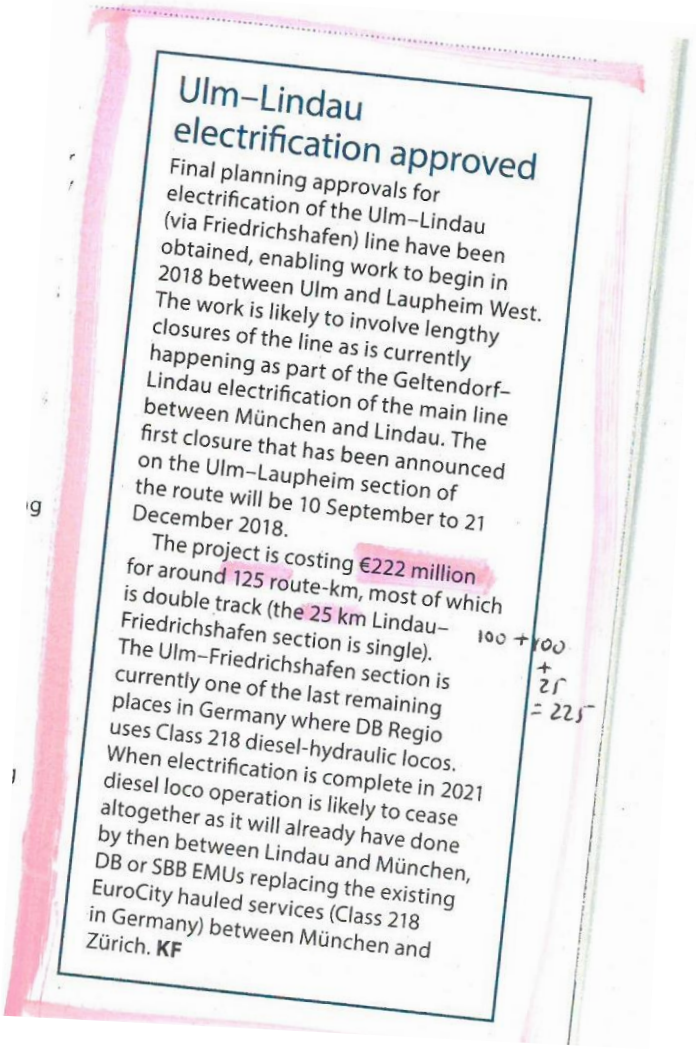
- **c€1m per stk**

- What's the secret?
- Few structures?
- Blockades?
- Proven OLE system?
- Greater efficiency?
- Rolling Programme? (See Later)



Ulm–Lindau electrification approved

Final planning approvals for electrification of the Ulm–Lindau (via Friedrichshafen) line have been obtained, enabling work to begin in 2018 between Ulm and Laupheim West. The work is likely to involve lengthy closures of the line as is currently happening as part of the Geltendorf–Lindau electrification of the main line between München and Lindau. The first closure that has been announced on the Ulm–Laupheim section of the route will be 10 September to 21 December 2018.

The project is costing €222 million for around 125 route-km, most of which is double track (the 25 km Lindau–Friedrichshafen section is single). The Ulm–Friedrichshafen section is currently one of the last remaining places in Germany where DB Regio uses Class 218 diesel-hydraulic locos. When electrification is complete in 2021 diesel loco operation is likely to cease altogether as it will already have done by then between Lindau and München, DB or SBB EMUs replacing the existing EuroCity hauled services (Class 218 in Germany) between München and Zürich. **KF**

100 + 100 + 25 = 225

Lesson	
Realistic Programme	Yes
Proven Technology	Yes
Proven Methodology	Yes
Collaboration	?
Efficient Cost	Yes
Low Complexity	Yes
Good Access	Yes
Rolling Programme	Yes

International Benchmark 2017 – SBB

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- Re-electrification of Frauenfeld-Weinfelden Line
- Three years in planning
- Normal Traffic 155 trains per day
- 6km double track including demolition of existing OLE system
- 9 days line closure in the summer holidays instead of 600 nights saving an estimated 20%
- Replacing portals with single track cantilevers
- Foundations in advance, demolition of existing structures, erection of new catenary

- 13m CHF = £9.75m for 32stkm (including demolition of existing OLE) = **£305k per stk** albeit OLE only – no bridge structures or power
- Video https://vimeo.com/236053661

Lesson	
Realistic Programme	Yes
Proven Technology	Yes
Proven Methodology	Yes
Collaboration	Yes
Efficient Cost	Yes
Low Complexity	Yes
Good Access	Yes
Rolling Programme	Yes

International Benchmark 2017 - Germany

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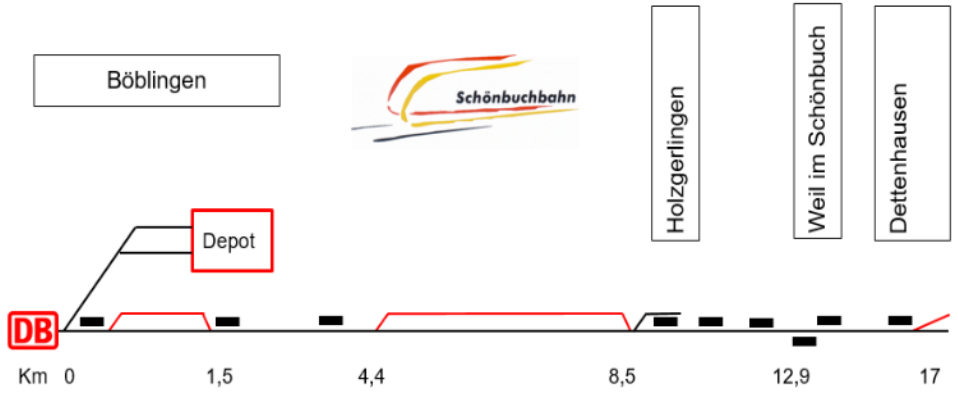
- Electrification of the Schönbuchbahn branch line near Stuttgart
- The €103m route upgrade project includes removing level-crossings, upgrading the route to 100kmph, double tracking on parts of the route, installing new depots, electrifying the route and providing new electric trains
- Electrification of 29.6 stk cost €9.3m (£8.11m) = €314k/ stk and includes for foundations, structures, small parts steelwork and conductors.
- Allowing 25% for client project management and design costs = €392k/ stk or c£345k/ stk
- The following should be taken into consideration:
  - No Grid or additional feeding connections were needed
  - There was no substantial route clearance required – such as bridge reconstruction, track lowering, parapet raising etc.
  - There was no Schedule 4 costs (possession access charges to train operating companies).
  - The overhead line system used is 15kV, which is standard in Germany. There would be a slight cost increase (<10%) for a UK 25kV system say **£375k/stk.**

Lesson	
Realistic Programme	Yes
Proven Technology	Yes
Proven Methodology	Yes
Collaboration	Yes
Efficient Cost	Yes
Low Complexity	Yes
Good Access	Yes
Rolling Programme	Yes



Stirling Dunblane Alloa – 2018

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- **Stirling Dunblane Alloa**
  - July 2017 ORR deliverability review
  - Start on site Nov 2016
  - Electric passenger Service December 2018
  - Four week closure May 2018
  - Actual Cost **c£1.0m/stk**
  - 100 stk new OLE

Lesson	
Realistic Programme	Yes
Proven Technology	Yes
Proven Methodology	Yes
Collaboration	Yes
Efficient Cost	Yes
Low Complexity	Yes
Good Access	Yes
Rolling Programme	Yes

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Lessons Learnt

Lessons Learnt

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Standards

- Future projects should use proven systems that comply with the relevant standards.
- Avoid developing and obtaining approval for new systems as part of a project.
- Review the NR standards suite to support output specification.
- Implement a ‘standards freeze’ for the duration of a project.

Foundations

- Have an appropriate level of GI/SI to support design prior to commencing foundation installation.
- Use empirical design methods where justified by PAN 101/ CIV074

Masts

- Future procurement should allow for alternative designs and site specific modelling that deliver outcome requirements, including life cycle reliability and maintainability against the benchmark of NR Master Series.

Lessons Learnt

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Overhead Line Equipment (OLE)

- To maximise value for money, the procurement process should allow for proven compliant proprietary designs to deliver outcome requirements, including life cycle reliability and maintainability against the benchmark of NR Master Series, rather than mandating the use of NR Master Series in major electrification schemes.

Power Supply

- At the optioneering stage, future projects should ensure that all options for traction power supplies are considered, including distribution and traction power storage options.
- Cost comparison should be on the basis of lowest overall electrification scheme cost. Operating and maintenance costs and the resilience of the alternatives should be included in this assessment.

Lessons Learnt

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Clearances to Bridges and Structures

- Wherever possible, future projects should secure all necessary consents, such as via a Transport Works Order, and undertake route clearance in advance of OLE works, even if this means extending the programme.
- Work required should be based on developed design options, which include detailed evaluation of the benefits and trade-offs of adopting innovative methods of reducing the need for bridge reconstruction and other route clearance works.
- To provide certainty for a project, the contract should include a ‘standards freeze’.
- Network Rail should develop generic risk assessments for solutions to support site specific risk assessments.
- RSSB should support the industry in examining the case for adopting insulated Pantograph Horns.
- Sufficient detailed design should be undertaken at GRIP 3 (Option Selection)

Lessons Learnt

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Plant

- The recommendation to establish a ‘rolling programme’ of electrification would both reduce the competition for scarce plant by allowing forward planning and create the incentive to, over time, invest in more productive plant, process and skills to further optimise delivery.

Delivery Methodology

- Retain and exchange knowledge and experience from recent projects. Establishing a rolling programme of electrification would help this retention and exchange of knowledge and experience and create a platform for continuous improvement.
- Network Rail retains its role as Technical Authority as it devolves further to regions and routes.
- Review NR GRIP process to bring forward detailed design on a risk assessed basis

Route Clearance

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- The unit cost analysis does not included route clearance – altering bridges and structures to provide electrical clearances
- This is because the volume of work varies significantly from project to project from zero to 30-40% of total project costs in some cases.
- There is however significant opportunity to reduce these costs as recent projects have not always taken advantage of the following innovations……

Bridge and Structure Clearance Innovations

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Underbridge Arms	Building on experience from the 1970's in 2011 NR commissioned tests which demonstrated that underbridge arms which locate the OLE accurately below a bridge can allow the OLE to be 174mm from the bridge structure without flashover
Surge Arrestors	As part of their delivery alliance (See Section 6.5) The Danish Railways have successfully introduced surge arrestors – which allows the air gap clearance to be reduced from 270mm to 150mm. These are now approved for use in the UK.
F&F Insulating Contact Wire Cover	This allows the air gap clearance to the contact wire to be reduced to 125mm or 70mm
GLS Insulating Coating	This coating which has a 40-year life applied to the underside of bridges allows the air gap to be reduced to 100 mm or less when in combination as below. It has been successfully used on a number of UK bridges.
Combination of surge arrestor, insulated coating and contact wire cover	In tests conducted by Southampton University for Network Rail it was demonstrated that even in wet conditions the air gap could be reduced to 20mm before flashover. This effectively means the tipping point for bridge reconstruction is mechanical rather than electrical clearances. (See Cardiff Intersection Bridge Case Study)

Bridge and Structure Clearance Innovations

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Case Study - Cardiff Intersection Bridge

- A very low and highly skewed bridge carrying a local railway over the Great Western Mail Line which itself crosses a substantial culvert.
- Reconstruction was costed at £40m-£50m, track lowering and culvert diversion was estimated to cost £10m-£15m and either option would cause very significant train disruption.
- A collaboration between Network Rail Route (Client), Andromeda Engineering (Design), Siemens (Surge Arrestors), GLS Coatings (Insulated Coating on the underside of the bridge) and the University of Southampton (HV lab tests to prove concept) helped develop from the concept to a proven viable design solution.
- Implemented in 2018 for a combined design and installation cost of below £1 million. The project won a Railway Industry Innovation Award in 2018.

No track intervention with the use of insulated coatings and surge arrestors

Bridge and Structure Clearance Innovations

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Probabilistic Gauging	A statistical simulation method to 'squeeze more' out of a structure compared to the traditional and conservative gauging methods.
Bar Conductor	Bar or beam conductors have been successfully used in tunnels worldwide to achieve the necessary clearances. Recent UK installations have experienced maintenance issues.
ElevArch – Jacking up a masonry arch bridge **See Case Study**	In a world first, Freyssinet have successfully demonstrated that it is feasible to safely jack up an entire masonry arch bridge to achieve electrification clearances at approximately 33% less cost and programme duration than demolishing and reconstructing the bridge. This approach which can be applied to multi-span bridges also has the benefit of retaining the visual appearance of the existing bridge and requiring less track access.
Standard Bridge Designs	Where it is necessary to re-construct a bridge this should be done as efficiently as possible. Earlier (pre 1993) electrification schemes used standard designs which could deal with the relatively minor variances between many overbridges crossing a (say) two track railway.

Bridge and Structure Clearances

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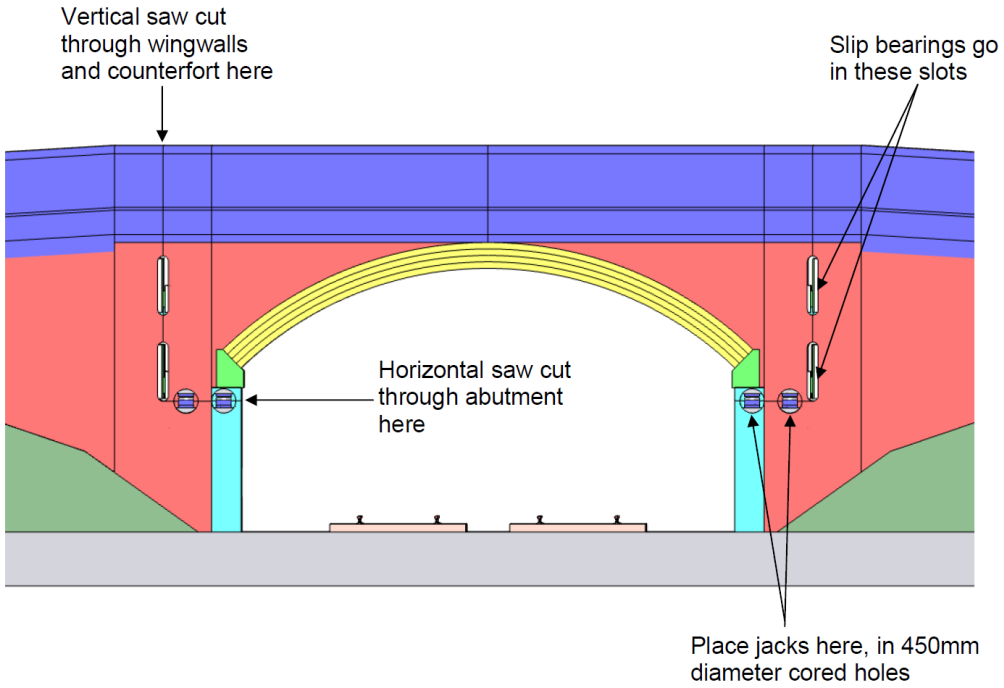
- **Case Study** – ElevArch – jacking up rather than rebuilding masonry arch bridges
- Approx 33% less cost and programme duration than demolishing and reconstructing the bridge



- http://freyssinet.co.uk/worlds-first-elevarch-bridge-lift/
- https://youtu.be/KhumV315nFk

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RIA Technical & Innovation