# Feasibility of smart traction energy management on the Western Route

RSSB Research

T1270

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# Why the RSSB research programme exists, and what it does

RAIL SAFETY AND STANDARDS BOARD
Research and Innovation

## Enable a safe and efficient railway by providing knowledge and solutions to best utilise existing assets and unlock future change.

Originally established as a safety research programme in 2001, the programme has evolved to underpin RSSB's critical role in enabling a safer and more efficient railway.

By providing the right safety tools, standards and guidance to improve current practices and facilitate the introduction of new technology, the programme addresses new and unknown risks and helps overcome barriers to change.

> "RSSB will continue to be funded to perform research related to its core role in ensuring a safe and efficient rail network"

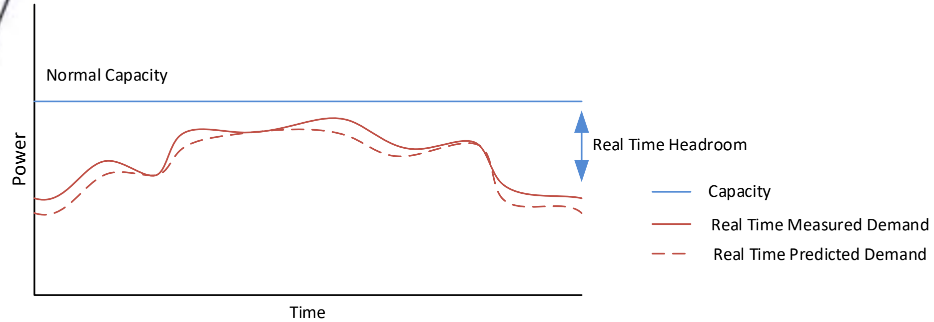
Great British Railways: The Williams-Shapps Plan for Rail (2021)

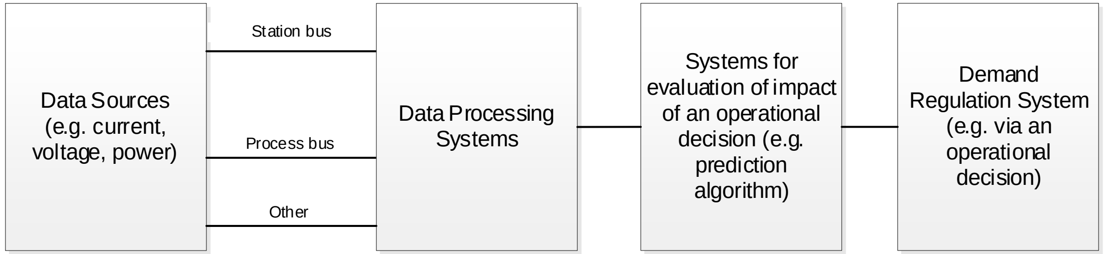
| | | | |
|---|---|---|---|
| *The **driver** for change* | **Make the most of today's railway**<br>How can we optimise operation of current assets without compromising safety or requiring capital expenditure? | **Enable system improvements**<br>How can we improve whole system performance and value for money when replacing physical and digital assets? | **Unlock fundamental change**<br>How can we safely and efficiently drive step-change in the railway value proposition? |
| *Type of **innovation*** | **Optimisation** | **Incremental** | **Radical** |
| ***RSSB Research** programme* | Provide sound **evidence to inform changes that require whole system considerations** beyond individual organisations' knowledge and incentives. | Develop and test incremental **improvements to existing solutions that cut across organisational boundaries** and which the market would not pursue. | Support **pre-commercial development of solutions novel to rail** and inform the **standardisation and safety analysis needed to de-risk their deployment.** |

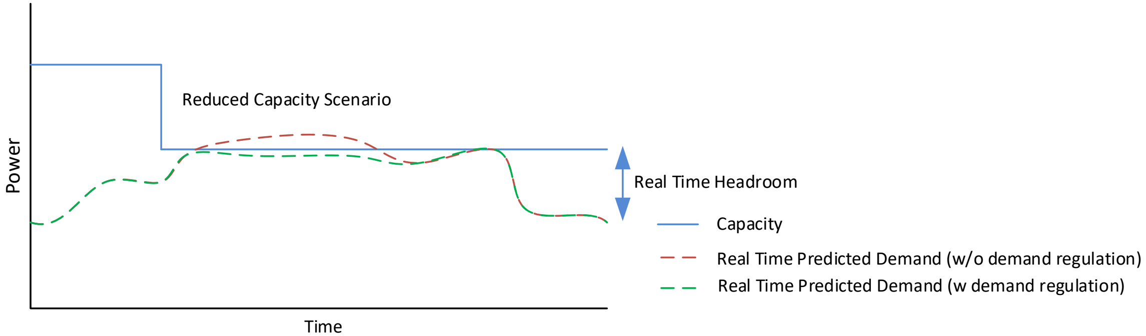
# Background to the project

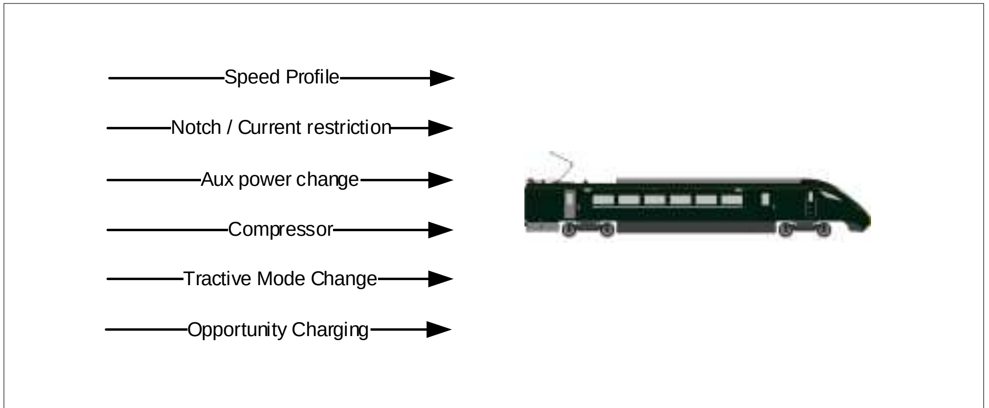
- Parts of the existing traction power network already estimated to be at full capacity during times of peak demand
- Longer trains, additional paths and battery trains will increase traction demand
- Demand must be managed efficiently to ensure optimal use of the system
- The project assesses the feasibility of technological solutions to real time traction power demand management
- Explores the means of execution
    - Connected Driver Advisory System (C-DAS)
    - IEC 61850 (standardised communication protocol for equipment in substations)
- C-DAS and 61850 technology is already adopted on the Western route

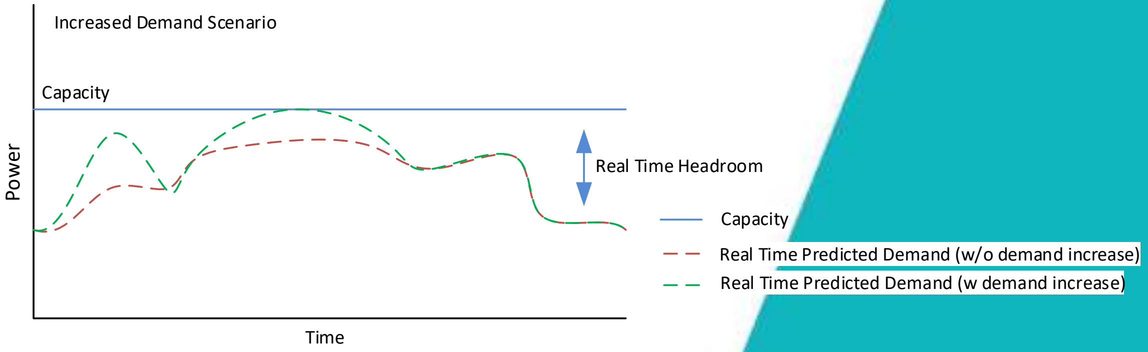
# System concept



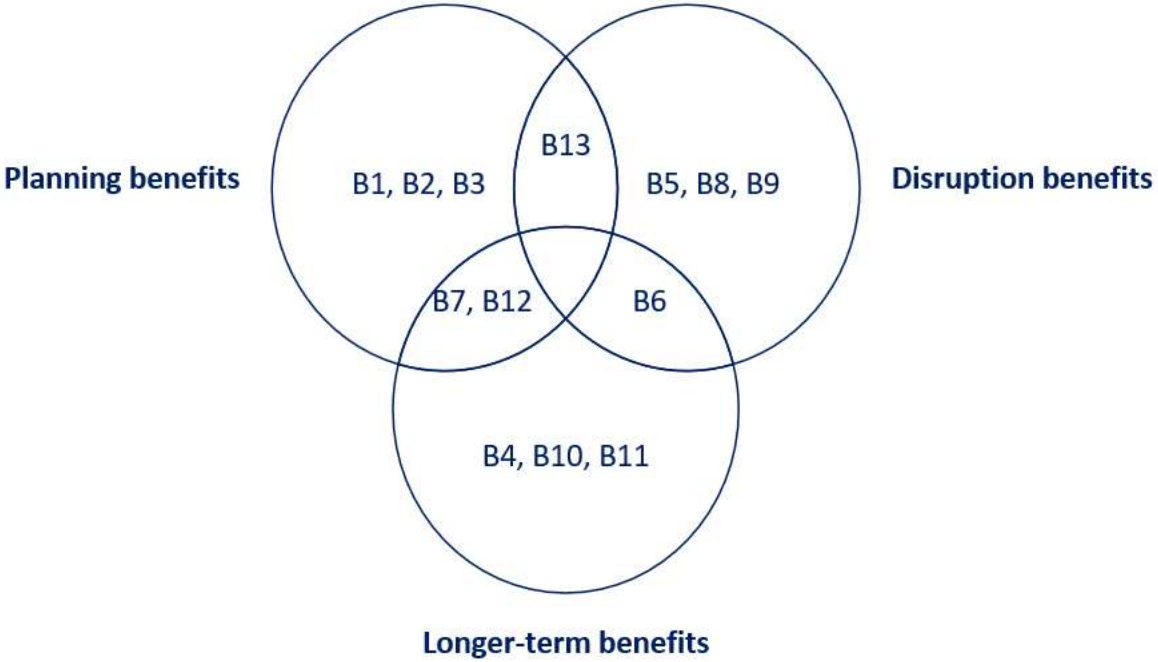



# Potential benefits

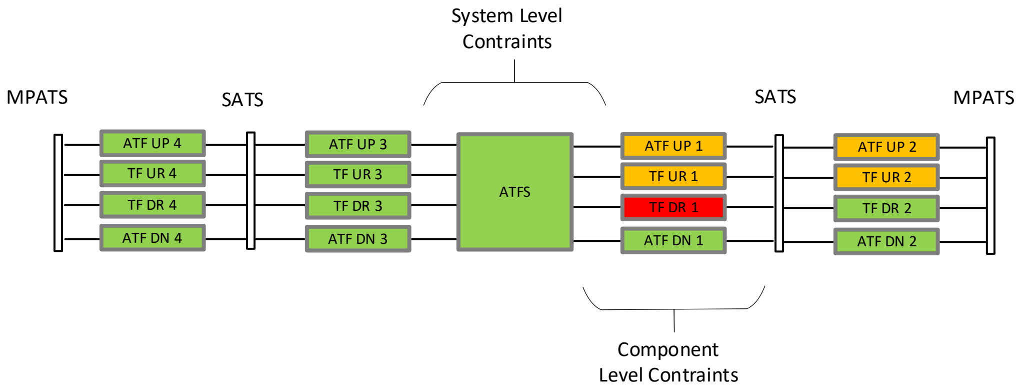
| |
|---|
| B1 – Remove modelling pessimism with real time measurements |
| B2 – Longer trains |
| B3 – Additional paths |
| B4 – Conditional Service Agreements (instead of permanent restrictions) |
| B5 – Avoid permanent restrictions driven by temporary or conditional power supply conditions |
| B6 – Reduction in maximum demand |
| B7 – Calculation of system losses |
| B8 – Maximising utilisation under perturbed conditions |
| B9 – Increased level of services in hot weather conditions |
| B10 – Optimised battery charging |
| B11 – Prioritisation of services by energy efficiency |
| B12 – Increased speed of assessment of timetable or service changes |
| B13 – Increased levels of service in N-2 feeding arrangements |



# Capacity measurement

Capacity not a single metric or measurement:

- System level constraints (such as unbalance limits at a supply point).
- Component level constraints (such as OCS thermal rating).




The key system level constraints were identified as:

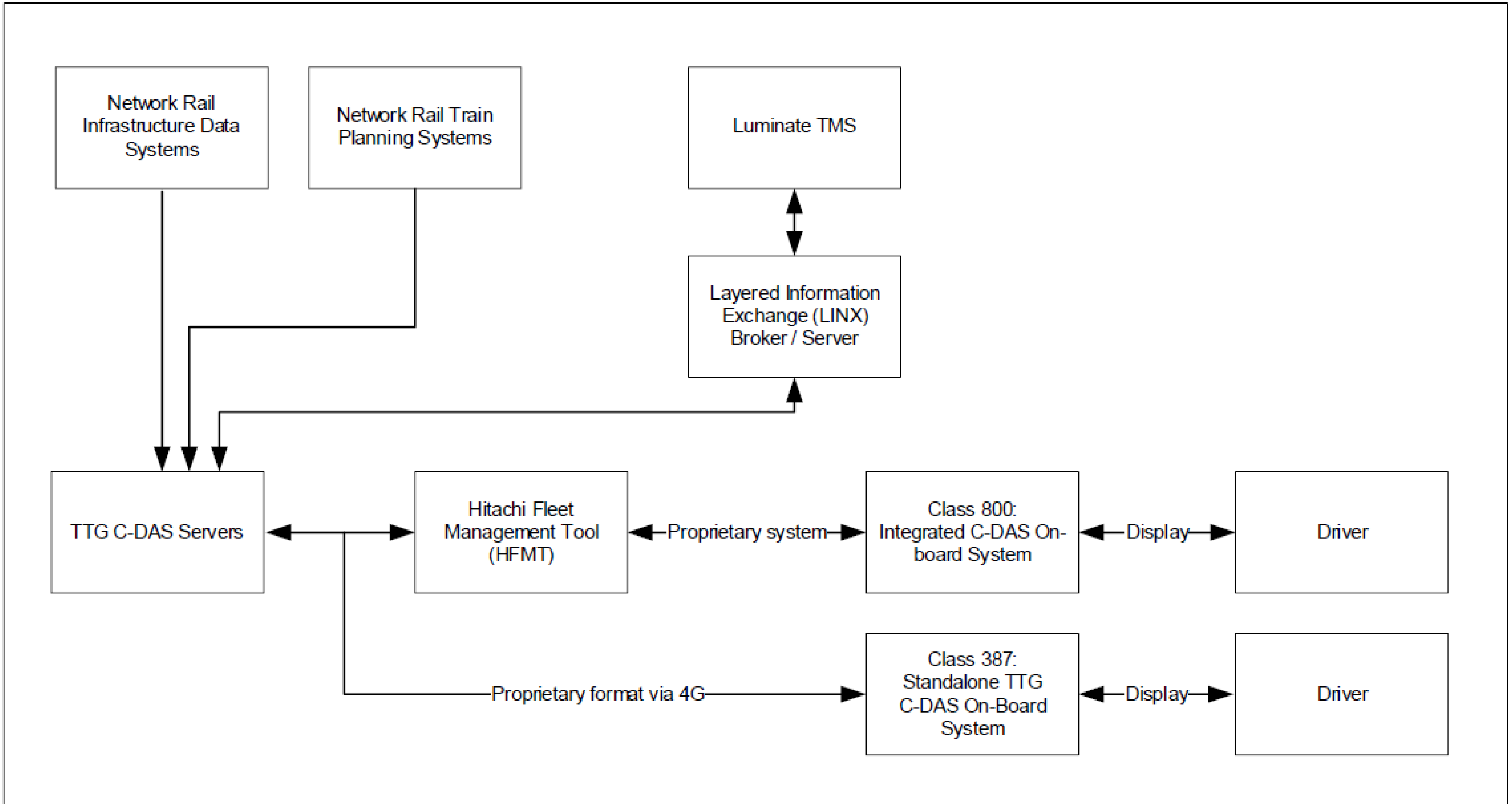
- Voltage harmonic limits.
- Voltage unbalance limits.
- Grid transformer thermal limit.
- Firm Service Capacity limits (where applicable).
- System voltage limits / pantograph voltage limits.

The key component level constraints were identified as:

- Conductor & Cable currents (adjusted for ambient temperature).

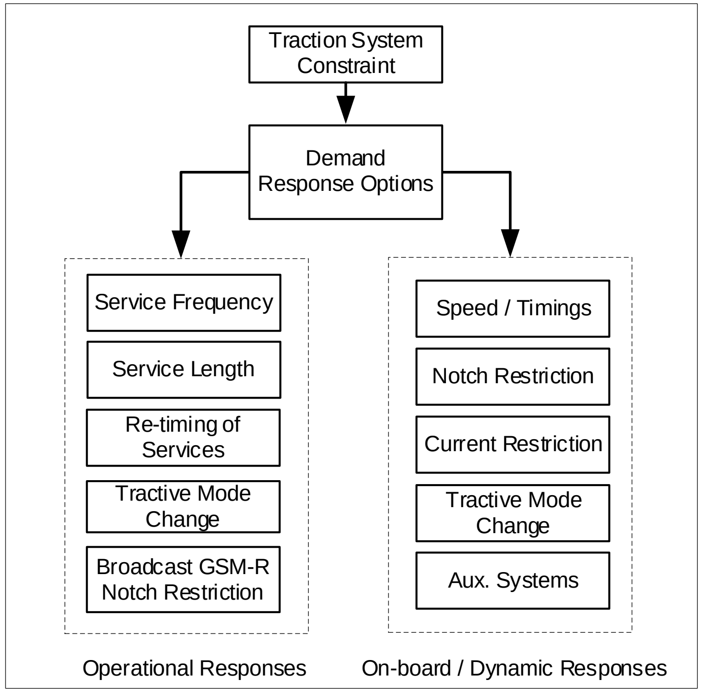
# Relationship between C-DAS and TMS

## System architecture for the Western route

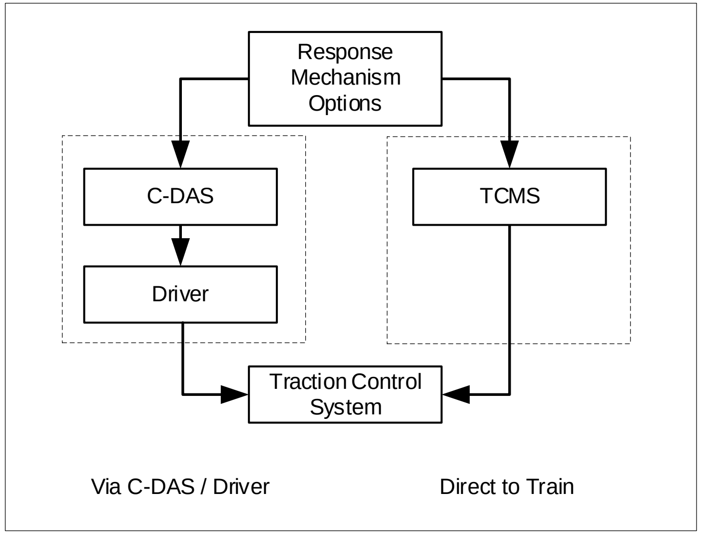


# Demand response system

## Demand response:



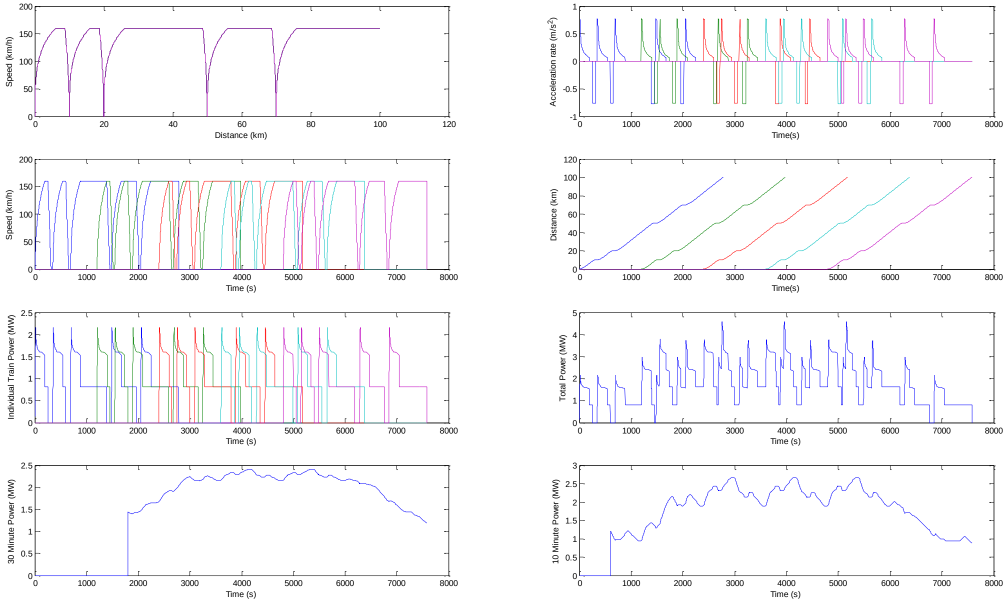

## Response mechanism:

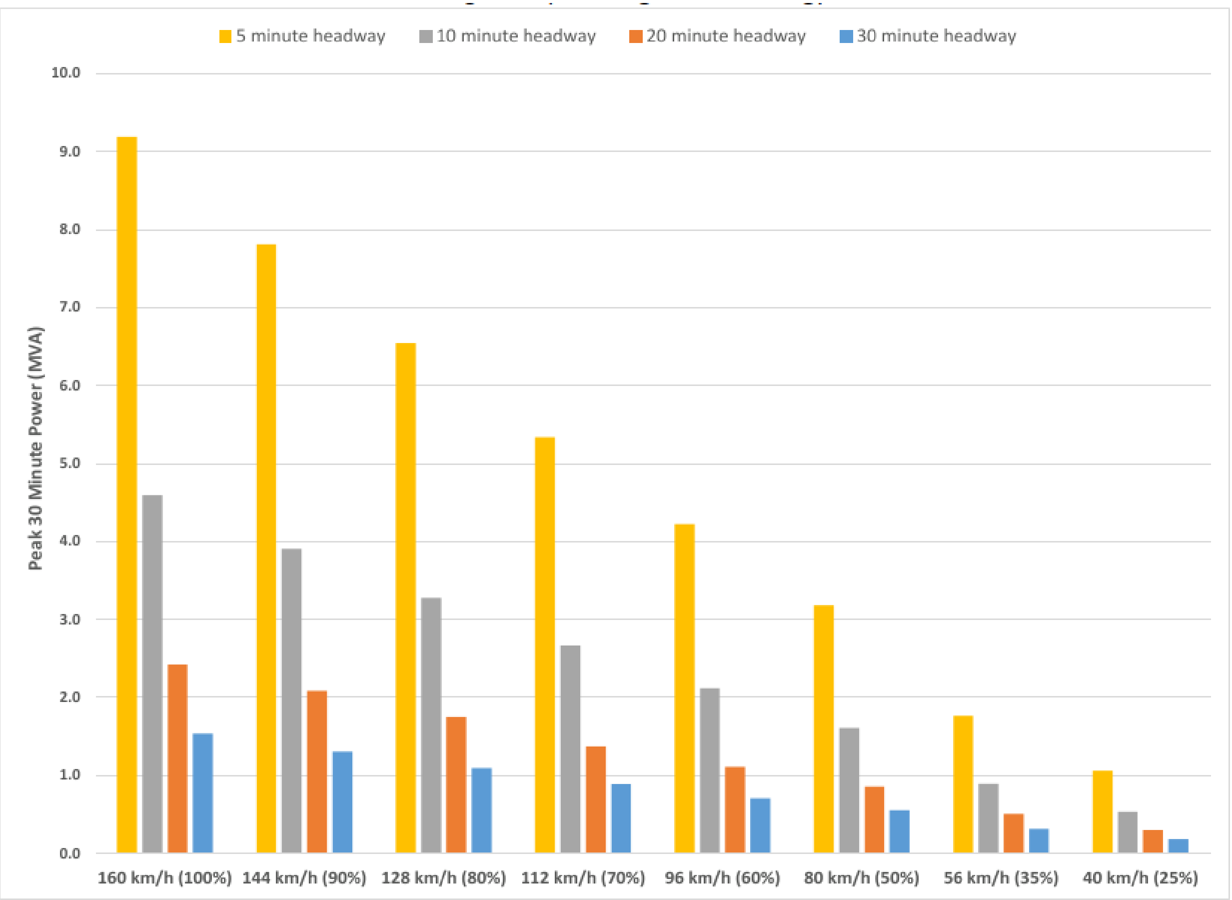


# Regulation strategy

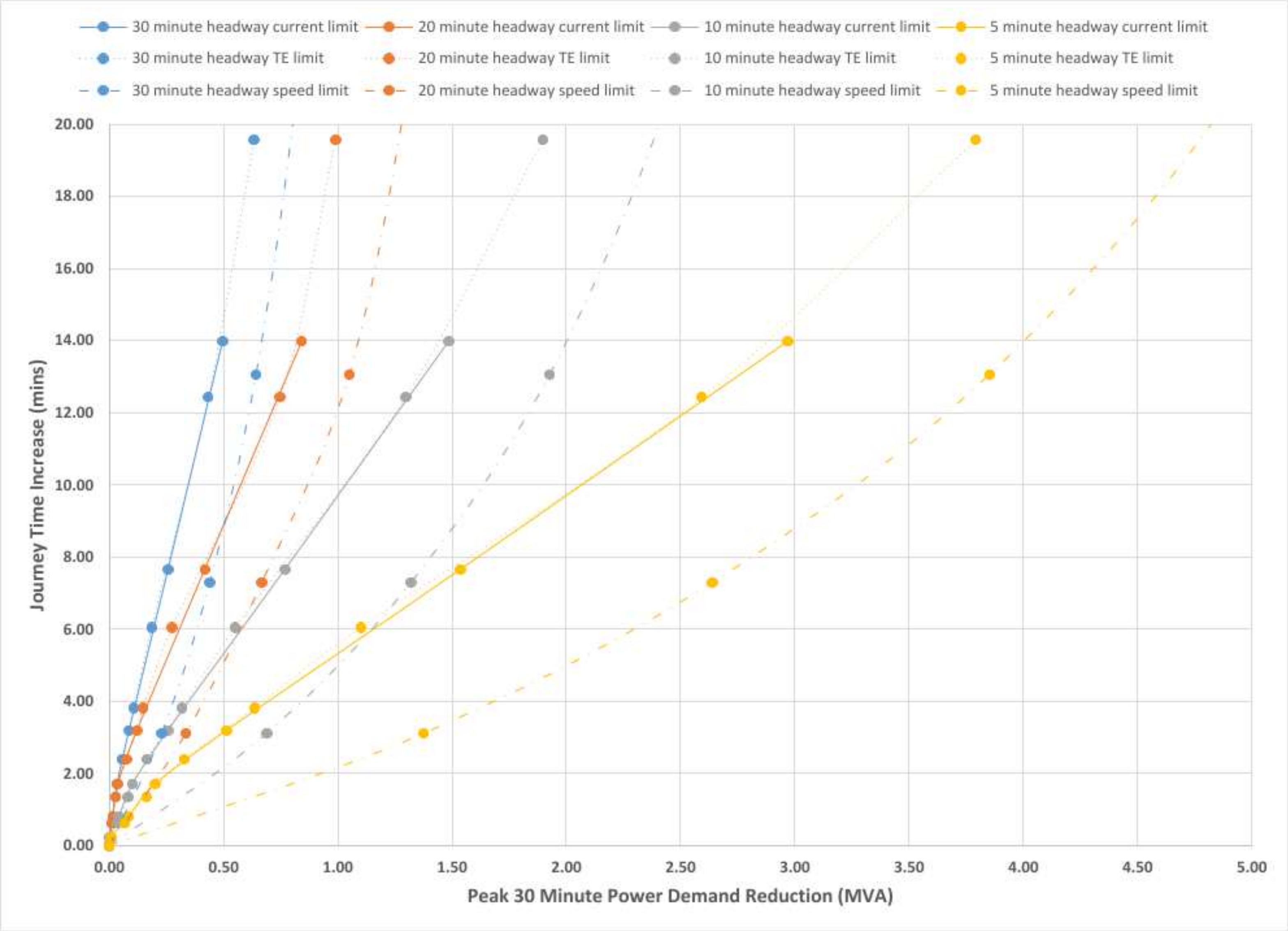
Typical 4 Car EMU

Assumed to be 100 km, level, stations at 10 km, 20 km, 50 km and 70 km, linespeed of 160 km/h.

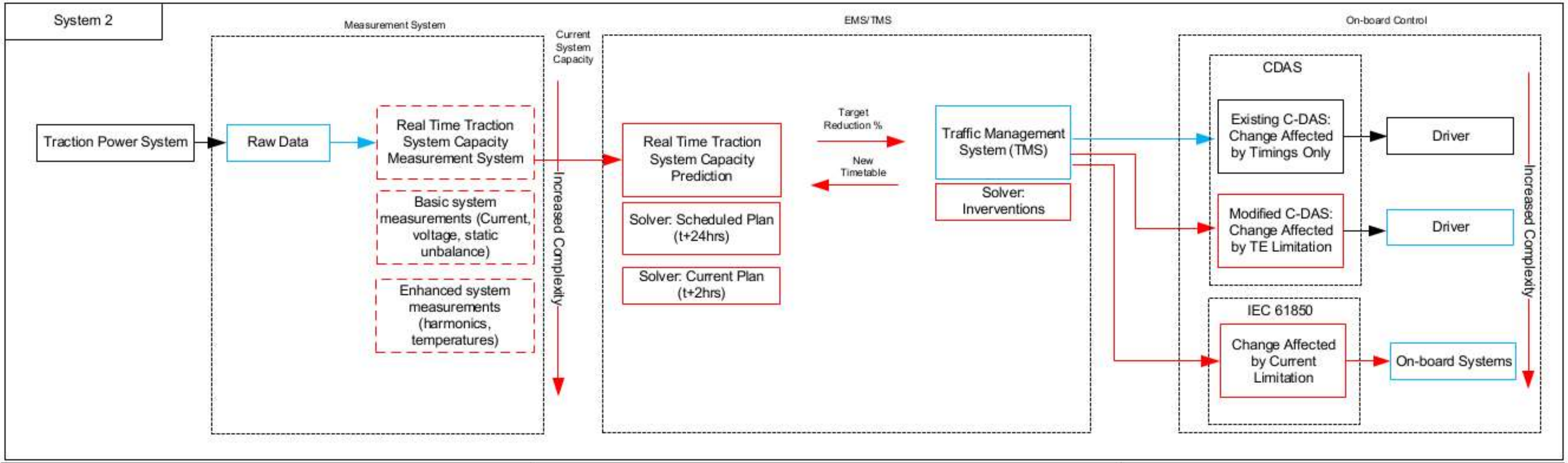


# Regulation strategy



# Regulator concept




| Measurement System | TMS/EMS | On-board Control |
|---|---|---|
| None* | Forecast functionality developed to trigger intervention**** | Existing C-DAS (Speed/Timings)* |
| Basic Measurement System** | | Modified C-DAS (Notch)** |
| Enhanced Measurement System**** | | IEC 61850 Current Limit**** |

*low complexity, **** high complexity; The top row in the above table represents the minimum viable solution.

# System options matrix

- Range of benefits depending on the system option (A, B, C, D)

| M – Measurement system | E – EMS / TMS | O – On-board | B - Benefits |
|---|---|---|---|
| M1 - Basic Measurement, current & voltages 1Hz, incoming and outgoing feeder at ATFS & Midpoint. Static unbalance limit. | E0 - Energy Dashboard | O1 - Existing CDAS speed Control | B1 - Remove modelling pessimism (planning stage only) |
| M2 - Remote Data - harmonic and unbalance processed data | E1 - Demand Prediction Module at system level + TMS timing integration + Evaluation against measured demand + Means to execute into via TMS/CDAS + Receipt of measurement metrics | O2 - Enhanced CDAS Notch Advice | B2 - Longer Trains |
| M3 - Remote Data - harmonic and unbalance raw high speed data | E2 - Demand prediction for harmonics & unbalance | O3 - 61850 On-Board DC Limit | B3 - Additional Paths |
| M4 - Remote Data - Grid Transformer Temperature | E3 - Demand prediction for grid transformer temperature | | B4 - Conditional Service Agreements (instead of permanent restrictions) |
| M5 - Track Feeder Current Thermal Model | E4 - Demand prediction model at track feeder / cable level | | B5 - Avoid permanent restrictions driven by temporary or conditional power supply conditions |
| M6 - Train Voltage Current & Location | E5 - 61850 integration | | B6 - Reduction in Maximum Demand |
| | | | B7 - Calculation of System losses |
| | | | B8 - Maximising utilisation under perturbed conditions |
| | | | B9 - Increased services in hot weather conditions |
| | | | B10 - Optimised Battery Charging Limits |
| | | | B11 - Prioritisation of services by Energy Efficiency |
| | | | B12 - Increased speed of assessment of changes |

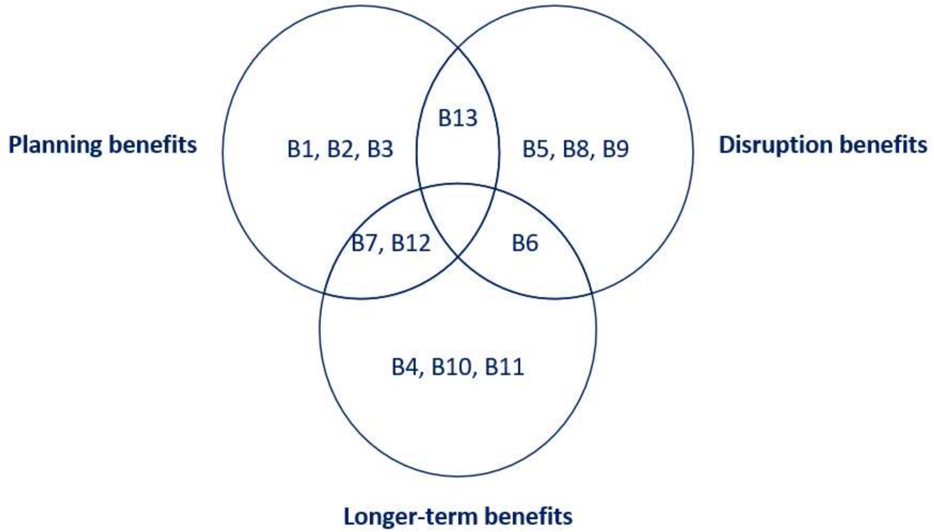
# System options – four selected options

- Simplification of system options matrix into four options.

| Option | Subsystem Options | Benefits | Description |
|---|---|---|---|
| A | M1, E0 | B1, B2, B3 | Basic System |
| B | Option 1 + M2, M3, M4, M5, E1, E2, E3, E4, O1, O2 | Option 1 + B4, B5, B6, B7, B8, B9 | Enhanced Measurement System + Execution Via C-DAS |
| C | Option 2 + M6 | Option 2 | Enhanced Measurement System + Execution via C-DAS including on-board voltage and current data |
| D | Option 3 + E5, O3 | Option 3 + B10 | IEC 61850 Integration |

# Benefits framework – summary

- Benefits divided into three categories:
  - Planning benefits
  - Disruption benefits
  - Longer-term benefits

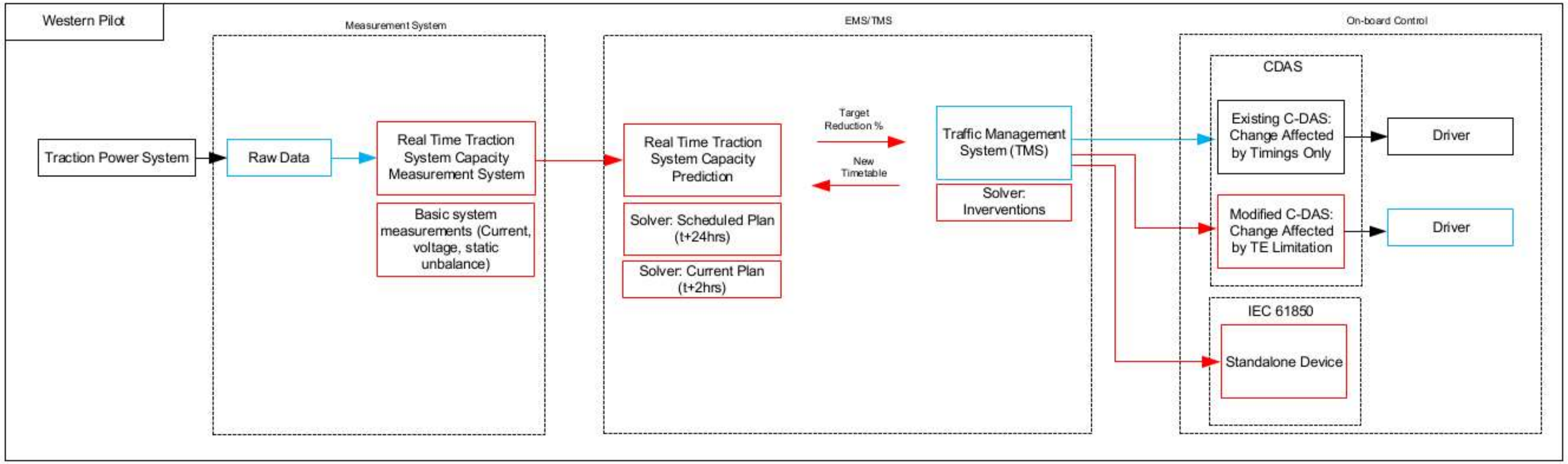



- Development and operating costs ‘order of magnitude’ at this stage
- £1.8 of benefits for every £1 invested (conservative assumptions)
- Costs and benefits narrative in the Part 3 report “*Cost benefit analysis framework*”

# Next steps

- Measurement system
- Execution system (demand regulator)
- Overall Energy Management System

- End-to-end pilot scheme



# Summary

- Maximising use of existing electrification
- Potentially avoid unnecessary system upgrades
- Improve performance under perturbed operation
- Support the roll out of battery trains and phasing out of diesel-only trains

- **T1270 project reports available on the RSSB Research Catalogue:** **https://www.rssb.co.uk/research-catalogue/CatalogueItem/T1270**