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Developing an Operational Philosophy for Britain's railways

John Armstrong*[a], John Preston[a], Ian Hood[b]

[a]Transportation Research Group, University of Southampton, Southampton SO16 7QF, UK
Arup, 13 Fitzroy St., London W1T 4BQ, UK

Abstract

Following decades of decline and contraction, Britain's railways have seen significant passenger and freight traffic growth in recent decades, presenting the industry with a combination of opportunities and challenges. This growth has taken place against a backdrop of railway privatisation, industry fragmentation and organisational change, and rapid and widespread technological developments. In response to (and anticipation of) these changes and developments, the industry has developed a range of strategic plans and guidelines for its future development, including a series of Rail Technical Strategies, a National Operating Strategy and the Digital Railway programme. These documents have been primarily technical in their focus, and the industry therefore developed a complementary, overarching Operational Philosophy, to provide the context for and wider aims of specific technical developments. This paper explains the context and objectives of the Operational Philosophy and the development process used. It describes the contents of the final Operational Philosophy document, and the guidelines for its use and its subsequent application.

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Keywords: Railways; Operational Philosophy; Future Needs; Scenarios; Operational Requirements

1. Introduction

This paper describes the development of an Operational Philosophy for Britain's mainline railway system, explaining the context and objectives of the work, the development stages and the processes used, and the results obtained, including the 27 requirements comprising the final Operational Philosophy, and the recommended process for their application.

Following this introduction, the background to and context for the work is described. The specific objectives of the Operational Philosophy and the process used to develop it are then set out, followed by a description of the outcome and the Operational Philosophy itself, and its subsequent application. Finally, some conclusions are drawn, followed by a list of references.

2. Background/Context

Having dominated land-based passenger and freight transport in the second half of the 19th century and the first half of the 20th, railways declined in importance in the second half of the 20th century, in the face of competition from road transport and the growth of travel by air, and appeared set for a continuing state of managed decline. However, the development of high-speed passenger services in Japan in the 1960s, followed initially by France with Paris – Lyon services in 1981 and then by other countries, greatly reduced journey times, creating new markets and helping rail to compete with domestic (and, later, international) air travel. The development of containerisation created a new market for rail freight, which has significant advantages over road transport for the carriage of large numbers of containers over medium to long distances. In parallel with this, increased focus on unit train haulage of bulk commodities like coal, ore, steel and construction materials, rather than on individual wagonloads of freight, greatly increased the efficiency and competitiveness of rail freight in these sectors.

Alongside these developments, in Britain and elsewhere, the use of railways has seen an unanticipated resurgence in recent decades, despite the growth of budget airlines and increasing real-term costs of rail travel relative to other modes. Possible

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explanations for this include increasing road congestion, more onerous security requirements and restrictions for air travel, the role of information and communications technology (ICT) in enabling productive and/or enjoyable use of travel time on trains, and increasing environmental awareness coupled with rail's relatively small carbon footprint compared with road and air transport. The railway industry is thus faced with significant opportunities, but also considerable challenges in terms of providing the capacity and levels of services needed to meet demand and user expectations, and doing so in an affordable manner while also providing sufficient access to the network for the maintenance, renewal and enhancement of the infrastructure to ensure system reliability and safety.

The ICT developments enjoyed by railway users, as mentioned above, are also being applied by the railway industry to the planning, operation and management of the system. The industry's plans in this respect are encapsulated in the Digital Railway strategy (Network Rail, 2018a), and have also been reflected in Britain in a series of Rail Technical Strategy (RTS) documents. The first of these was coordinated by the Department for Transport (DfT), and published in 2007 alongside a government White Paper entitled *Delivering a Sustainable Railway*, identifying the needs of and setting out the plans for the growth and development of Britain's railways over the following 30 years. The two documents concluded (DfT, 2007) that, over the 30-year planning horizon,

> *the railway will have to expand its capacity to meet demand, reduce its environmental impact, meet increasing customer expectations for reliability, comfort, safety, security and information, whilst at the same time continuing to improve its cost efficiency.*

These objectives were subsequently summarised by the Technical Strategy Advisory Group (TSAG, 2009) as the '4Cs', i.e. Capacity, Customers, Cost and Carbon, as follows:

- *CAPACITY: increasing the capacity of the railway whilst further improving safety and performance*
- *CUSTOMERS: delivering a quality service to meet the rising expectations of passengers*
- *COST: improving the overall cost effectiveness of the railway*
- *CARBON: improving rail's overall environmental performance*

The 2007 RTS also identified eight "long-term themes for change", towards which the railway industry was expected to start working (DfT, 2007):

- ***Optimised track-train interface***, reducing energy demands, track maintenance costs and noise
- ***High reliability, high capacity***, providing reliable and intelligent infrastructure and rolling stock
- ***Simple, flexible, precise control system***, combining cab signalling with enhanced traffic management
- ***Optimised traction power and energy***, including bi-mode trains and regenerative braking on all trains
- ***An integrated view of safety, security and health***, including improved detection of and responses to hazards
- ***Improved passenger focus***, including use of data to provide improved information and optimised controller responses to perturbations
- ***Rationalisation and standardisation of assets***, including greater use of modular and 'off the shelf' equipment
- ***Differentiated technical principles and standards***, reflecting varying traffic types and levels on different routes

It was anticipated that some of these changes would be achieved "through 'natural' incremental change mechanisms", but that others would require more direct interventions. The RTS was "intended to be a living document, owned and updated by the industry in response to future technology development" and research outcomes, with TSAG taking a leading, coordinating role.

The 2012 update of the RTS, *The Future Railway*, was produced by the re-named Technology Strategy Leadership Group (TSLG, 2012), and set out a vision for Britain's railway in 2040, underpinned by a whole-system approach (particularly important in a fragmented industry), innovation, and "skilled, committed, adaptable people," and was based on the 4Cs and six consolidated themes:

- *Control, Command and Communication*
- *Energy*
- *Infrastructure*
- *Rolling Stock*
- *Information*
- *Customer Experience*

The Control, Command and Communication theme is focussed on a vision of the future where *real-time traffic management systems deliver a high-capacity, energy-efficient, on-time railway. In-cab signalling has largely displaced the need for lineside signalling infrastructure. Communication systems are optimised for operations and customer services.*

The focus on capacity, energy efficiency (and thus reduced carbon emissions), absence of lineside infrastructure (and thus reduced costs) and customer service addresses all of the 4Cs. The theme is closely linked to TSLG's Future Traffic Regulation Optimisation (FuTRO) project, whose aims were to develop

the frameworks for the concepts, requirements and architectures of next generation traffic management systems. These systems should be dynamic and able to optimise the use of the rail network, minimise delay, optimise traction energy use and maintain train connections for passengers.

The FuTRO project is now complete, and its deliverables are listed on the website of the Rail Safety and Standards Board (RSSB, 2018). Alongside the various timetable optimisation, driver guidance and data-related reports, the deliverables include an Operational Philosophy for Britain's mainline railways, which provides context and guidance for the development and implementation of the detailed, technical elements of FuTRO and the RTS. The objectives, development, contents and implementation of the Operational Philosophy, including its influence on the latest version of the RTS, are described in the following sections of this paper.

3. Objectives

In an industry briefing note, RSSB (2014a) notes the need for the railway industry to respond to the challenges and opportunities presented by traffic growth by adopting a "long-term strategy that is forward-looking, adaptive and technically ambitious." The same document describes the overall objective of the Operational Philosophy as being

to provide a suitable framework for the development of the techniques and technology required for FuTRO, and to provide a coherent roadmap for these activities [and] an outline descriptive philosophy of how the railway is projected to operate, unconstrained by limitations of existing and emerging technologies.

The aim of the Operational Philosophy was thus "to set clear outlines within which technological development can take place without hindrance", and it "therefore reflects railway operating principles" while also providing the scope and flexibility to look "beyond contemporary operating approaches towards 'blue-sky thinking' and significant innovation." It was also intended to provide a framework and set of requirements or criteria against which emerging technologies can be tested, "thus enabling the railway to continue to grow and adapt in a controlled way." Eurotunnel's operational philosophy document was cited as an example of and precedent for what RSSB was aiming to achieve, although its text was not made available, for reasons of commercial confidentiality.

The first formal report on the Operational Philosophy's development (RSSB, 2014b) established the objective of setting a course for the railway's future development and operation over the following 30+ years, sub-divided into 10-year intervals where appropriate, and taking account of (i) anticipated socio-economic changes, affecting demand for rail travel and transport, and the expectations of users, and (ii) likely and potential technological change, and the opportunities thus provided. It was anticipated that the Operational Philosophy would be "transformational and strategic", providing a "mechanism for managing technological development in the context of operational need" and challenging industry suppliers "to develop products and processes that meet this operational need."

4. Development Process/Methodology

Arup was appointed by RSSB to facilitate and lead the development of the Operational Philosophy, with support from the University of Southampton's Transportation Research Group (TRG), and with oversight and review provided by a cross-industry steering group and an expert review panel drawn from industry and academia. The Operational Philosophy was developed in three broad stages:

- Stage 1: development of initial overview, based on a literature review and an industry-wide stakeholder workshop
- Stage 2: definition of template, or contents list, for Operational Philosophy
- Stage 3: refinement and finalisation of Operational Philosophy, including a series of workshops to present and refine its contents

4.1. Stage 1: Initial Overview

An initial literature review identified a range of studies undertaken in Britain to investigate and ascertain likely ‘drivers of change’ and their consequences “for society, infrastructure in general and railways in particular” (RSSB, 2104b). The findings of these studies were collated and categorised using the STEEP (Social, Technological, Economic, Environmental, Political) classification system. The categorised drivers of change are summarised below:

- Social
  - *Ageing population* – this will affect system access requirements, including not only physical access to and from trains and stations, but also access to system information, as this increasingly moves online
  - *Growing demand for mobility* – this includes not only ‘traditional’ demand for peak period travel, but also moves towards demand for 24/7 passenger (as well as freight) access to the network, as acknowledged in 2018 by Network Rail’s outgoing chief executive (Rail Technology Magazine, 2018), with implications for engineering access to the network for maintenance and renewals activities
  - *Growing population and number of households* – this is likely to increase demand for passenger rail travel, especially in the context of station-centred residential developments, increasing road congestion, and apparently declining levels of driver licensing and car ownership among the younger, ‘millennial’ generations, as noted, for example by the UK’s Chartered Institution of Highways and Transportation (CIHT, 2018)
  - *Urbanisation* – as residential development is focussed in existing (or new) urban settlements, increasing densification improves the viability and attractiveness of rail for both intra- and inter-city travel, while also enhancing the potential viability of rail-served freight terminals at the edges of urban areas for the consolidation and onward distribution of freight (see also the ‘Urban Colonies’ scenario below)
  - *‘Digital natives’* – in contrast to the needs of currently ageing members of the population (see above), younger generations which have grown up with mobile ICT will have high expectations of the availability of high-quality, personally-tailored digital information and ticketing, together with network connectivity and power supply/charging facilities on trains and at stations
  - *Changing work patterns* – as indicated by recent declines in the sales of traditional season tickets (Modern Railways, 2018a), this presents the industry with a revenue challenge, but also potential opportunities in the form of reduced peak crowding and capacity requirements, and new types of demand outside the traditional peaks, if this can be satisfied and encouraged through the marketing and sales of new, flexible season tickets

- Technological
  - *Emergence of radical solutions to climate change* – as well as being relatively energy-efficient, rail has further advantages in terms of its contribution to climate change mitigation, due to its ability to operate using non-fossil fuel sources, primarily via electrification. However, its success in this regard depends upon the electricity generating mix, i.e. the extent to which nuclear power and/or renewables are used for generation
  - *Growing global energy deficit* – rail’s comparative energy efficiency is again beneficial in this regard, particularly when coupled with its abilities to use renewable energy sources in conjunction with its existing infrastructure and rolling stock fleet (on electrified routes), and to capture and recover kinetic energy during deceleration (where regenerative braking facilities are available in vehicles and infrastructure)
  - *(Semi-) autonomous [road] vehicles* – the gradual emergence of these vehicles presents a potential threat to rail, in that they may enable ‘hands-off’ travel and productive use of travel time combined with the flexibility and convenience of road transport, while also improving the environmental performance of road travel via the use of renewable energy sources
  - *High-speed rail travel* – the expansion of high-speed rail systems increases overall system capacity and, subject to service quality and ticket pricing, should increase patronage and user satisfaction
  - *Improved management systems* – improvements to human and technological management systems, including the application of Artificial Intelligence and Machine Learning, to increase capacity, efficiency and overall system performance, a recent example (Modern Railways, 2018b) being the application of the European Train Control System (ETCS) Level 2 and Automatic Train Operation (ATO) in the Thameslink central ‘core’ in London, supported by a Traffic Management System (TMS)
  - *‘Big data’ and data analytics* – the application of these technologies will play an important role in the improvement of management systems (see above)
  - *New materials* – the use of lighter, stronger materials and better-designed components and systems should reduce energy consumption and carbon emissions, improve component and system reliability and longevity, and, in the case of lighter, better-designed vehicles, also reduce wear on infrastructure (and themselves), in turn reducing maintenance and renewal needs and costs

- Economic
  - *The end of affluence and reduced disposable income* – this appears particularly to be the case for younger people, certainly in the UK, due to stagnant incomes, university tuition fees and rising housing costs, and is likely to be contributory factor, along with 'digital nativity', to reduced levels of car ownership and use, and increased use of public transport and of ride sharing
  - *Ageing infrastructure and obsolescence management* – railway infrastructure is typically quite old – often decades, and, in many cases, 150 or more years old – and more intensively used than before, requiring significant investment to maintain (and increase, in the face of climate change) its integrity and equip it with contemporary operating and maintenance technology, with significant cost implications
    The economics of the market – railway investment and net expenditure will reflect wider economic conditions

- Environmental
  - *Growing impact of climate change and weather events* – as indicated above, railway infrastructure and operations will need to be increasingly resilient to the effects of extreme weather, flooding and sea level rise
  - *Importance of security and resilience* – the personal, physical safety of staff, users and the wider public will continue to be important, as, increasingly, will be the security of industry and users' data to protect them against hacking attempts by individual and organised criminals, terrorists and hostile states

- Political
  - *Rising importance of local provision* – in the UK, some aspects of decision-making and transport funding have been devolved to the Scottish, Welsh and Northern Irish legislative assemblies, while Network Rail is devolving responsibilities from its central HQ to the eight individual Routes comprising the national railway network in Britain (Network Rail, 2017). It is important to reconcile this welcome focus on local demand and service provision with the wider needs and requirements for coordination of long-distance passenger and freight services using multiple Routes.
  - *Complex just-in-time models for manufacturing and food supply vulnerable to external shock* – movements of time-critical cargoes are vulnerable to the unpredictable effects of road congestion and delays (and, in the case of the UK, to the effects of Brexit, and the possible introduction of increased border controls and Customs checks). As a transport system scheduled to the minute (or less), railways are potentially well-placed to respond to these vulnerabilities, if they can demonstrate the necessary standards of punctuality, reliability and resilience to the effects of disruptive events
  - *Demand management of transport provision* – a combination of yield management techniques and improved data availability could generate additional demand for rail travel, particularly outside the traditional peak periods
  - *Integrated transport policy* – improved integration across and coordination between transport modes (as envisaged by 'Mobility as a Service', or MaaS) could increase rail's role as the core, long-distance element of multi-modal journeys. In the MaaS context, this integration might be achieved more via technology than by overarching, integrated service planning and coordination, with emerging travel and demand patterns feeding back into service planning and provision.

Because of the uncertainties inherent to these Drivers of Change and, especially, their potential effects on the railway industry, a scenario-based approach was used to explore their implications further and enable the initial development of the Operational Philosophy. The scenarios used were derived from the UK Government Office of Science and Technology's (OST's) Foresight project on Intelligent Infrastructure Systems (IISs), and its Scenarios report in particular (OST, 2006), and their implications for railways were derived from analysis by TRG of these and other scenario-based 'Futures' exercises (Armstrong and Preston, 2011). The IIS scenarios were based upon two 'axes of uncertainty' relating to the environmental impact of transport and the acceptance or otherwise of technology and data-sharing, and are illustrated in Figure 1 and summarised below (RSSB, 2014b):

In Perpetual Motion, the UK economy is prospering, new technologies have been adopted including those that make travel less environmentally damaging, and the demand for travel is high.

In Urban Colonies, good environmental practice is central to socio-economic policy, with people living closer to their place of work in expanded urban centres whilst rural areas have become more isolated. There has, though, been public resistance to data sharing due to privacy concerns.

In Tribal Trading, the UK has suffered an energy crisis and a long recession. Infrastructure has fallen into disrepair resulting in a more localised economy, and there is an increase in lawlessness and mistrust.

Finally, in Good Intentions, the focus is on reducing carbon emissions to limit climate change. This results in constraints imposed on personal mobility with people only travelling if they have sufficient carbon 'points'. Businesses use sophisticated technology to optimise logistics and distribution.

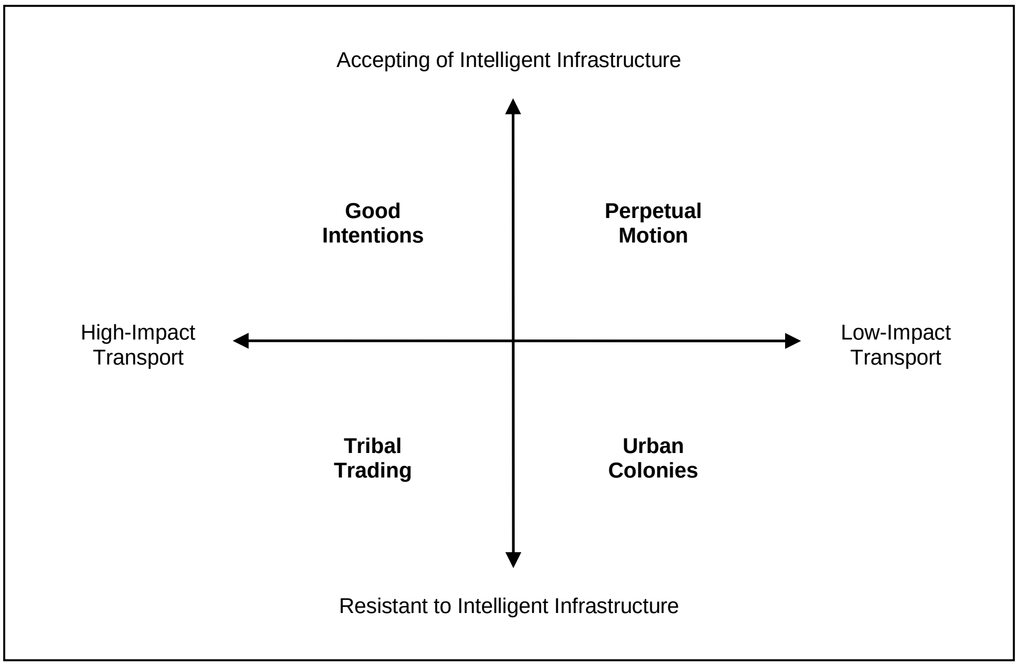


Fig. 1. Future Scenarios.

The literature review also identified a range of key railway operating principles, eight of which were considered to be fundamental to the main objectives of FuTRO (RSSB, 2014b):

- *Separation of trains*
- *Train regulation, to provide safe, robust and energy-efficient movement of trains*
- *Compatibility of rolling stock with infrastructure*
- *The railway must be safe and seen as safe*
- *A robust operating plan (one that is resistant to the effects of operational perturbations)*
- *Maximisation of line capacity*
- *Integration with other travel modes*
- *Flexibility to accommodate social, technological and organisational change*

On the basis of the review and its findings, it was concluded (RSSB, 2014b) that a "clear and unambiguous" Operational Philosophy was required,

> *setting out principles and objectives, rather than operational or technological specifics, and thus providing a framework for consistent, coherent and continuing improvement, in and through which the necessary details can be accommodated and communicated.*

It was also noted that the Operational Philosophy should cover "all relevant aspects of infrastructure, vehicles, operations, staff, customers, safety and information provision," while also reflecting the 4Cs, and should meet the needs of all railway industry stakeholders, while remaining as "uncomplicated and generic … as possible."

These findings and criteria provided the basis for a cross-industry stakeholder workshop, held in November 2013, with three broad objectives:

- *To raise awareness of the Future Traffic Regulation Optimisation (FuTRO) programme*
- *To engage delegates in a futures exercise to explore how operational needs might change over the coming decades*
- *To generate insights to feed into the drafting of an Operational Philosophy*

The 47 workshop participants were divided into four groups, one for each of the future scenarios shown in Figure 1, and were asked to consider the following questions in the context of their assigned scenario:

- *What should operations look like in order for GB heavy rail (passenger and freight) to thrive into this future?*
- *In other words, what actions should be taken to ensure that rail thrives over the coming decades as we head along this future path? How can GB heavy rail (passenger and freight) optimise operations into this future?*

Participants were initially asked to record ideas, actions or areas of activity on adhesive 'post-it' notes and assign them to one of the following eight categories for their scenario:

- *People*
- *Security and safety*
- *Infrastructure*
- *Asset Management*
- *Rolling Stock*
- *The Operating Plan*
- *Regulation and Control*
- *Other*

221 ideas were generated by the workshop in total.

4.2. Stage 2: Template Definition

The ideas generated by the workshop were subsequently reviewed and refined, 'unpacking' those that included multiple suggestions. Similar ideas were grouped and combined, reducing the total number to 179. For each of the eight categories listed above, ideas that were very similar or were generated for more than one of the four scenarios, were identified as common principles with high potential for inclusion in the Operational Philosophy. These ideas were combined, as were ideas that featured in more than one of the eight categories, and were supplemented with some distinctive and promising ideas appearing in single scenarios only, resulting in a final total of 32 'Common Operating Principles', as listed below (RSSB, 2014b).

1. *Personalised passenger information and journey planning*
2. *Flexible differential pricing*
3. *Integration with other transport modes*
4. *Interchangeability of technology*
5. *More open to spot bids/handle freight at short notice*
6. *Instant re-planning/real time flexibility/dynamic timetabling in real time/real time link to demand*
7. *ATO [Automatic Train Operation]*
8. *Operating in convoy*
9. *Trains manage self-separation*
10. *Flexible and dynamic timetabling*
11. *24/7 operation*
12. *Optimise timetable to demand/match capacity to demand*
13. *Understand customer requirements (who, what, where, when)*
14. *No timetable/on demand services*
15. *More accurate timetable planning tools/optimise train speeds to reduce conflicts/optimise margins and headways/precision and realism/increased measurement and analysis of train movements*
16. *Ensure passenger safety*
17. *Rationalise safety and control standards/adaptable to new technology*
18. *Customer facing staff*
19. *Differentiated railway/Freight priority*
20. *Network link to efficient urban distribution network*
21. *Remove lineside detection*
22. *Telecoms to handle data traffic*
23. *Simplified infrastructure and greater availability*
24. *Stations hub of activities/handle small amounts of freight/destinations in their own right*
25. *Focus on nodes to enable mass transit*
26. *Real time intelligent asset management/intelligent infrastructure*
27. *Automatic condition monitoring/self-assessing infrastructure/greater use of on-train equipment*
28. *Reduce station dwell times*
29. *Reduced train weight*
30. *Limit train speeds to reduce energy requirements*
31. *Re-generation/energy stored on train and re-charge points along the route/trains use various power supplies*
32. *Train configuration: high capacity/demand driven length (dynamic and adjustable)/adaptable modules/less 1st class/multi-deck*

These common principles, together with the findings of the literature review, were used to generate an initial set of 28 "operational requirements for the railway in 30+ years' time." Each requirement was assessed in terms of its likely impact on each of the 4Cs, ignoring any impacts beyond the railway (for example, carbon reductions arising from modal shift from road or air to rail). The assessment indicated that 21 of the 28 requirements would increase capacity; nine would reduce costs, while six would increase them; nine would reduce carbon; and 25 would contribute to increased customer satisfaction (RSSB, 2014b). Trade-offs between cost and the other 3Cs were identified as a significant potential issue for resolution and for the ordering of priorities. The requirements were also assessed in terms of their positions in the overall industry planning cycle, using the 'Plan-Deliver-Review' categorisation, and it was found that all three categories applied to many of the requirements, indicating that "the pressures of the 4Cs are requiring a much closer integration between the three activities."

Approximately two-thirds of these principles are reflected in the twelve "key capabilities" set out in the latest iteration of the Rail Technical Strategy, in the form of its Capability Delivery Plan (CDP; RSSB, 2017), whereas the CDP reflects all the finally-adopted operational requirements, as described and discussed below. This reflects the process of refinement used to develop the Operational Philosophy, and its influence in turn on the updated Rail Technical Strategy.

To assist with the development of a coherent set of operational requirements and their integration into a unified Operational Philosophy, nine distinct 'strands' or themes were identified for consideration and coverage, moving from demand through infrastructure and rolling stock provision to operations and revenue generation and protection (RSSB, 2014b):

- *Demand (customers)*
- *Operating standards and requirements (this category includes Safety)*
- *Infrastructure and asset management*
- *Rolling stock*
- *Staff*
- *Timetable/operating plan*
- *Command and control/traffic regulation*
- *Telecoms/information*
- *Revenue generation and protection/service provision ('two sides of the same coin', as experienced by operators and customers respectively)*

As part of the Operational Philosophy development process, each strand was considered in terms of the following, expanded 'Plan-Deliver-Review' cycle:

- *Input to planning process*
- *Output from planning process*
- *Deliver*
- *Review in real time/short term*
- *Review in medium to long term*

The contents and findings of the review processes are set out in detail in the Phase 1 high-level overview document (RSSB, 2014b).

4.3. Stage 3: Refinement and Finalisation of the Operational Philosophy

The operational requirements were tested and developed further in the context of three different types of case study route section:

- A high-frequency commuter route serving London and the south-east of England
- A regional route
- A long-distance main line, carrying freight as well as inter-city passenger services

Further workshops, technical focus groups and desktop analysis were used to refine and finalise the operational requirements and to combine them in a coherent Operational Philosophy document in a format agreed with the industry Working Group, and suitable for both describing and enabling the application and implementation of the Operational Philosophy.

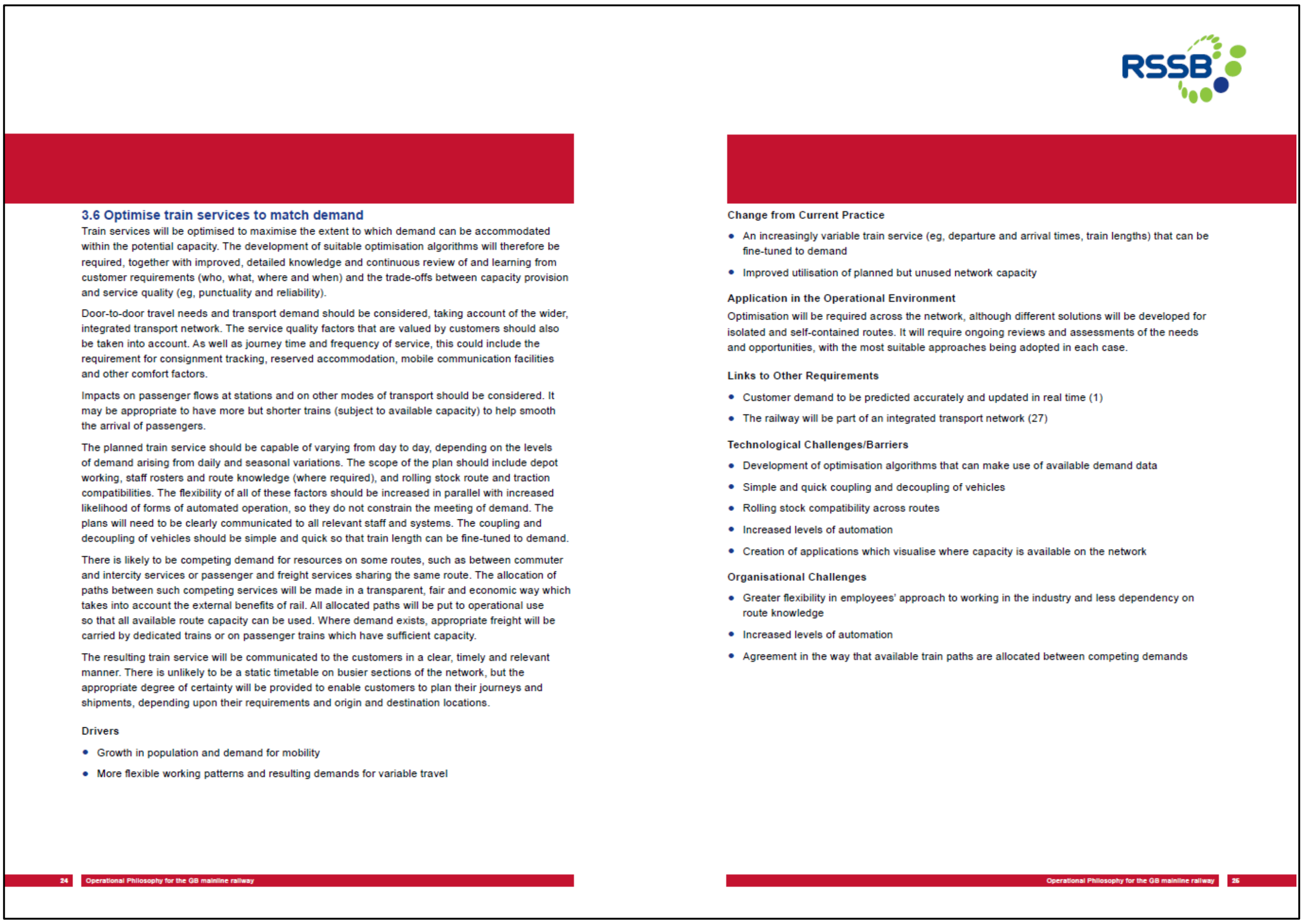
5. Outcome/Results

5.1. Publication, Format and Contents of the Operational Philosophy

The final Operational Philosophy (OP) document was agreed and published in 2014 (RSSB, 2014c). Following an industry foreword and an introduction, the document provides instructions for its use and a tickbox-based questionnaire for the assessment of proposals to check that they are consistent with the aims of the Operational Philosophy, based upon the final, agreed operational requirements (reduced in number from the 28 referred to above to 27). The requirements are then set out in detail, and are followed by a glossary. The operational requirements are set out in a standard format:

- Title
- Description of requirement
- Drivers and factors underlying the requirement
- Change from current practice involved
- Application of the requirement in the operational environment
- Links to other, related requirements
- Technological challenges and barriers associated with the requirement
- Organisational challenges and barriers associated with the requirement

An example is included in Figure 2, showing Requirement 6, to “Optimise train services to match demand” (RSSB, 2014c).



3.6 Optimise train services to match demand

Train services will be optimised to maximise the extent to which demand can be accommodated within the potential capacity. The development of suitable optimisation algorithms will therefore be required, together with improved, detailed knowledge and continuous review of and learning from customer requirements (who, what, where and when) and the trade-offs between capacity provision and service quality (eg, punctuality and reliability).

Door-to-door travel needs and transport demand should be considered, taking account of the wider, integrated transport network. The service quality factors that are valued by customers should also be taken into account. As well as journey time and frequency of service, this could include the requirement for consignment tracking, reserved accommodation, mobile communication facilities and other comfort factors.

Impacts on passenger flows at stations and on other modes of transport should be considered. It may be appropriate to have more but shorter trains (subject to available capacity) to help smooth the arrival of passengers.

The planned train service should be capable of varying from day to day, depending on the levels of demand arising from daily and seasonal variations. The scope of the plan should include depot working, staff rosters and route knowledge (where required), and rolling stock route and traction compatibilities. The flexibility of all of these factors should be increased in parallel with increased likelihood of forms of automated operation, so they do not constrain the meeting of demand. The plans will need to be clearly communicated to all relevant staff and systems. The coupling and decoupling of vehicles should be simple and quick so that train length can be fine-tuned to demand.

There is likely to be competing demand for resources on some routes, such as between commuter and intercity services or passenger and freight services sharing the same route. The allocation of paths between such competing services will be made in a transparent, fair and economic way which takes into account the external benefits of rail. All allocated paths will be put to operational use so that all available route capacity can be used. Where demand exists, appropriate freight will be carried by dedicated trains or on passenger trains which have sufficient capacity.

The resulting train service will be communicated to the customers in a clear, timely and relevant manner. There is unlikely to be a static timetable on busier sections of the network, but the appropriate degree of certainty will be provided to enable customers to plan their journeys and shipments, depending upon their requirements and origin and destination locations.

Drivers

- Growth in population and demand for mobility
- More flexible working patterns and resulting demands for variable travel

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Change from Current Practice

- An increasingly variable train service (eg, departure and arrival times, train lengths) that can be fine-tuned to demand
- Improved utilisation of planned but unused network capacity

Application in the Operational Environment

Optimisation will be required across the network, although different solutions will be developed for isolated and self-contained routes. It will require ongoing reviews and assessments of the needs and opportunities, with the most suitable approaches being adopted in each case.

Links to Other Requirements

- Customer demand to be predicted accurately and updated in real time (1)
- The railway will be part of an integrated transport network (27)

Technological Challenges/Barriers

- Development of optimisation algorithms that can make use of available demand data
- Simple and quick coupling and decoupling of vehicles
- Rolling stock compatibility across routes
- Increased levels of automation
- Creation of applications which visualise where capacity is available on the network

Organisational Challenges

- Greater flexibility in employees' approach to working in the industry and less dependency on route knowledge
- Increased levels of automation
- Agreement in the way that available train paths are allocated between competing demands

Operational Philosophy for the GB mainline railway 25

Fig. 2. Example of Operational Philosophy Requirement format.

The 27 operational requirements are as follows:

1. *Customer demand will be predicted accurately and updated in real time* – improved understanding and prediction of demand for rail services will inform operational decisions, including e.g. train stopping patterns and holding of late-running connections, and the provision of tailored user information
2. *Passenger demand will be managed* – mechanisms such as differential pricing will be used to better match demand to the available capacity, i.e. passengers will be encouraged to use less busy trains; individual user requirements will also be met
3. *The railway network will be operationally accessible by all* – passengers of all ages and mobilities will be able to use the network easily and conveniently , with luggage-handling and other assistance provided as necessary; the handling of freight movements will also be enhanced

4. *Optimise the use of existing capacity and provide the required additional passenger and freight capacity to facilitate growth* – the best possible use will be made of existing capacity, and, where necessary, additional passenger and/or freight capacity will be provided`
5. *Efficient management of underutilised capacity* – lightly-used sections of the network will be safeguarded for future use, reallocating capacity (e.g. rolling stock) between network sections as appropriate, and cost-effective means will be used to operate and maintain routes with low levels of demand
6. *Optimise train services to match demand* – train frequencies and formations will be varied to meet and respond to fluctuations in passenger and freight demand, and the wider transport 'offer' will be tailored to meet different customers' needs and keep them informed
7. *Trains will be accurately and reliably scheduled* – train services will be planned and operated to improved levels of precision, to enable improve punctuality throughout trains' journeys and across the network
8. *Train services can be rescheduled in near real time to match changes in demand* – the railway will respond dynamically to short-term changes in passenger and/or freight demand
9. *Provide on-demand services* – in addition to normal, timetabled train services, additional passenger and/or freight trains will be operated as necessary in response to short-term demand
10. *Flexible and tailored operations* – operating standards will vary, reflecting the infrastructure, demand and operating characteristics of different routes and locations, and an agreed vision of the railway's future; standards will be harmonized at international borders
11. *Operations will be more efficient* – better use will be made of industry assets, using remote condition monitoring (RCM) and predictive maintenance to improve asset reliability and increase network availability for passenger and freight train operations; increasing us may also be made of connecting rather than through train services
12. *Trans can operate 24/7* – improved asset maintenance planning and execution (including the use of RCM), together with network and operational flexibility, will enable passenger and freight services to operate around the clock and throughout the week
13. *Permit consistent and accurate operation* – improved precision in planning, operation (including the use of automatic train operation, or ATO) and management of services will enable increased punctuality and better use of available capacity
14. *Robust and adaptable contingency planning* – better understanding of user needs and the likely effects of disruptive events, together with better and more flexible contingency planning, will enable improved (quicker and tailored to users) responses to service disruptions
15. *Stations will manage passenger and goods flows effectively* – improved station design, management and information provision will smooth the flow of passengers and goods through stations and between trains and to/from other transport modes
16. *Freight terminals will load and unload trains effectively* – improved handling of freight services at terminals will facilitate inter-modal transfer of goods and improve the punctuality of freight trains on the shared national network, reducing potential delays and making better use of available capacity
17. *The operations will be resilient, reducing the likelihood of disruptions to customer journeys and shipments* – improved understanding of asset and system reliability, and the associated risks, will be used to improve reliability and to respond flexibly to residual system failures, whatever the cause
18. *Trains will be dynamically controlled to minimise delays* – as traffic management systems (TMSs) obtain improved information about trains' positions and performance characteristics, train movements will be controlled precisely to avoid conflicts and reduce delays
19. *Use instant operational feedback and look-ahead to address and anticipate problems, to improve the operational management of the railway* – TMSs will combine with wider industry management systems, data and tools to monitor operations and anticipate and respond to problems in a timely manner, minimising their impact on train services and users
20. *Improved operational system reviews and learning of lessons to improve the delivery of future operations* – industry data and user feedback will be used to learn lessons from operational problems and issues, their impacts on railway users and users' preferred responses, as part of a process of continuous improvement
21. *The railway will be adaptable to new technology* – railway assets (infrastructure and rolling stock) typically have long service lives, and must therefore be able to incorporate and apply ICT and other developments with much shorter life cycles, to improve industry performance and users' experiences
22. *An operational system that can make use of intelligent information* – industry data will be recorded and processed to generate information to assist decision-making and to maintain and improve system performance
23. *Customers need personalised, up-to-date information interactively provided* – railway users will be provided with whole-journey travel and (freight) consignment information reflecting their needs and preferences, including access to, egress from and interchange with the railway system; the process will be interactive and two-way, so that users can amend their plans and provide feedback and receive updated guidance (and potentially services) in response
24. *The operational railway will be safe and secure* – the railway will be designed, operated and maintained to ensure the safety and personal security of staff, users and non-users (for example at level crossings and other 'interfaces' between the railway and the public)

25. *Assure Cybersecurity* – the industry's data and that of its users will be stored and used securely, minimising the risks of sabotage and/or fraud, while also providing scope and opportunities for the development and deployment of innovative and useful tools and services for the mutual benefit of both parties
26. *The railway will be energy-efficient and reduce its environmental impact* – rail will maintain and improve upon its current advantages in terms of energy efficiency and environmental impact, reducing its energy consumption while also increasing its use of renewable energy sources and its ability to regenerate energy when trains are braking
27. *The railway will be part of an integrated transport network* – since railways do not typically provide 'door to door' transport services, they will instead provide this in conjunction with other transport modes, with through planning, ticketing and updated real-time information providing passengers with seamless 'Mobility as a Service' (MaaS) and freight users with reliable, trackable services between suppliers and customers

It can be seen that the requirements are consistent with and supportive of the OP's stated overall objective, to "effectively and efficiently move passengers and freight on the rail network, as part of their end-to-end journey" (RSSB, 2014c). As set out in its instructions, to apply the OP in practice, a user (typically, a proposer of a project, product or technical development) should review the proposal against the questionnaire set out in the OP (see Figure 3) and reflecting the list of requirements. If the answer to one or more questions is 'Yes' or 'Neutral', the proposal is likely to be consistent with the OP and its long-term vision for the industry; if, however, the answer to one or more questions is 'No', then the proposal may need further review and reconsideration.

RSSB

Rail Customers and Demand

Does your proposal...

1.	Contribute to the accurate prediction and real-time updating of customer demand?	Yes ☐	Neutral ☐	No ☐
2.	Improve the management of passenger demand?	Yes ☐	Neutral ☐	No ☐
3.	Enhance the operational accessibility of the railway network for any or all potential users?	Yes ☐	Neutral ☐	No ☐

Planning and Capacity

Does your proposal...

4.	Provide more productive use of existing capacity or additional capacity where required?	Yes ☐	Neutral ☐	No ☐
5.	Contribute to efficient management of underutilised capacity?	Yes ☐	Neutral ☐	No ☐
6.	Facilitate the optimisation of train services to match demand?	Yes ☐	Neutral ☐	No ☐
7.	Contribute to the accurate and reliable scheduling of trains?	Yes ☐	Neutral ☐	No ☐
8.	Facilitate near-real-time rescheduling of train services to match changes in demand?	Yes ☐	Neutral ☐	No ☐
9.	Assist with the provision of on-demand passenger and freight train services?	Yes ☐	Neutral ☐	No ☐

Operations

Does your proposal...

10.	Contribute to the flexible tailoring of operations to the varying characteristics and requirements of different routes and services?	Yes ☐	Neutral ☐	No ☐
11.	Improve operational efficiency?	Yes ☐	Neutral ☐	No ☐
12.	Facilitate 24 hours per day and 7 days per week operation?	Yes ☐	Neutral ☐	No ☐
13.	Contribute to the consistent and accurate operation of train services?	Yes ☐	Neutral ☐	No ☐
14.	Contribute to robust and adaptable contingency planning of train services?	Yes ☐	Neutral ☐	No ☐
15.	Contribute to the effective management of passenger and goods flows at stations and terminals?	Yes ☐	Neutral ☐	No ☐
16.	Assist with the automation and/or efficiency of train loading and unloading processes at freight terminals?	Yes ☐	Neutral ☐	No ☐
17.	Improve the resilience of operations, reducing the likelihood of disruptions to passenger journeys and freight shipments?	Yes ☐	Neutral ☐	No ☐
18.	Facilitate the dynamic control of trains to minimise delays?	Yes ☐	Neutral ☐	No ☐
19.	Facilitate instant operational feedback and look-ahead to address and anticipate problems, improving the operational management of the railway?	Yes ☐	Neutral ☐	No ☐
20.	Facilitate improved operational system reviews to learn lessons and improve the delivery of future operations?	Yes ☐	Neutral ☐	No ☐
21.	Maintain or enhance the railway's adaptability to new technology?	Yes ☐	Neutral ☐	No ☐

Information

Does your proposal...

22.	Facilitate the generation and/or use of intelligent information for operational systems from big data?	Yes ☐	Neutral ☐	No ☐
23.	Assist with the provision of personalised, up-to-date and interactive information to passenger and freight customers?	Yes ☐	Neutral ☐	No ☐

Safety and Security

Does your proposal...

24.	Improve the safety and security of the railway system?	Yes ☐	Neutral ☐	No ☐
25.	Maintain or enhance cybersecurity for the railway and its users?	Yes ☐	Neutral ☐	No ☐

Wider Considerations

Does your proposal...

26.	Improve the energy efficiency and reduce the environmental impact of the railway?	Yes ☐	Neutral ☐	No ☐
27.	Enhance rail's role in an integrated transport network?	Yes ☐	Neutral ☐	No ☐

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Fig. 3. Checklist for Application of Operational Philosophy.

The sequence of requirements and the listing of questions in the questionnaire is consistent with the 'Plan-Deliver-Review' cycle and the nine operational themes or 'strands' described above (RSSB, 2014b). It starts with industry customers and demand, and then moves from capacity analysis and planning to operations/delivery and review, including the collection and provision of information, the assurance of safety and security, and consideration of wider issues, including the railway's environmental performance and role in an integrated transport system. It can be seen, and the observation was made during the OP's development, that, while the OP is overwhelmingly forward-looking in its outlook and approach, it also in some ways goes 'back to the future', envisaging a more 'generalised' and flexible railway, in contrast to the recent focus on simplified/rationalised operations specialising in passenger or freight transport. Examples of this include the anticipation of increased use of flexible, demand-responsive locomotive-hauled train formations in preference to the use of fixed-formation multiple-units, and foreseeing the reemergence of railway stations as vibrant, multi-purpose hubs of their local communities, serving both passenger and (high-value, low-volume) freight traffic needs. Delivery/collection points for products ordered online have already been trialled at various stations in Britain, with apparently varying degrees of success. Locomotive-hauled passenger trains have also seen something of a resurgence, with cascaded British Rail Mk 3 coaches already in use on Chiltern Railways and planned for ScotRail (in the form of shortened High-Speed Train sets), and the imminent use of new locomotive-hauled coaches on TransPennine Express services, although these sets comprise fixed five-coach formations (Modern Railways, 2018c). Of the more 'forward-looking' requirements in the OP, numbers 13 and 18 have recently been implemented on the central core of the north-south Thameslink services through London, as noted above, using ETCS Level 2 and ATO.

5.2. Application of the Operational Philosophy

As indicated above, the Operational Philosophy was published on the RSSB website in 2014, together with a Briefing Note and Briefing Pack (RSSB, 2014d, 2014e), setting out its nature and purpose, and how to use and apply it. As noted in all three documents, it was intended that the Operational Philosophy would inform the development of the National Operating Strategy (NOS), in the course of which it would be taken forward and implemented. The aim of the NOS, as described in the Operational Philosophy (RSSB, 2014c), was to "transform the operation" of Britain's railways, improving safety, reliability and responsiveness to users' needs and creating the "operational railway of the future" by means of:

- *Extensive modernisation of operational methodologies*
- *Cultural and behavioural change programmes*
- *Organisational and industry process change*
- *Exploitation of existing and emerging technologies*

By "describing the operational conditions anticipated in the long term", the Operational Philosophy (OP) was seen as "an important first step in the NOS development programme", which would "take the requirements set out in the OP and develop strategies to meet them." The OP was also seen as sitting alongside, and sharing a long-term view with, the 2012 Rail Technical Strategy (RTS), and it was envisaged that it would "drive the development of future versions of the RTS." The NOS was subsequently absorbed into Network Rail's Digital Railway programme (RSSB, 2015), but was still "being informed by and … building on the FuTRO Operational Philosophy."

The overall objectives of the Digital Railway initiative are set out in strategy and programme documents produced by Network Rail (2018a, 2018b). The primary aims of the programme are to further enhance safety, reduce costs (particularly those associated with signalling infrastructure renewals), increase capacity and improve performance (i.e. reduce delays). It thus directly addresses two of the RTS's '4Cs', Cost and Capacity, and, via improved performance and reduced journey times, Customer satisfaction, while also implicitly addressing Carbon emissions reduction. The technologies referred to in the programme include ETCS, TMS and ATO (as deployed in the Thameslink core – see above), Connected Driver Advisory Systems (C-DAS), smart infrastructure and rolling stock using Remote Condition Monitoring (RCM) and predictive maintenance, improved telecommunications and data security and integrity, improved working practices and capabilities among staff, and "data connectivity for passengers and freight customers." These are all consistent with the requirements of the Operational Philosophy, and it can be seen that the Digital Railway programme is thus a means of implementing the OP's objectives. The strategy document also refers back to the Network [sic] Operating Strategy.

As noted above, the Rail Technical Strategy has been updated since the publication of the Operational Philosophy, with the publication of a Capability Delivery Plan (RTS CDP; RSSB, 2017). The CDP identifies 12 key capabilities that the industry

> *needs to develop in order to meet the industry's objectives of increasing capacity and improving customer service in a sustainable and affordable manner.*

These capabilities reflect the RTS strategic goals (i.e. the 4Cs) and six identified market segments:

1. *Mixed traffic (e.g. Great Western Main Line)*
2. *High Capacity, Commuter (e.g. Wessex Route between Woking and London Waterloo)*
3. *Dedicated (large and heavy freight)*
4. *City to City (e.g. East Coast Main Line between London and York)*
5. *New Markets (e.g. Borders Railway)*
6. *Light Demand (e.g. Heart of Wales Line)*

The CDP, including the capabilities listed and the differentiation between market segments and routes, reflects and has been influenced by the contents of and requirements listed in the Operational Philosophy, as was envisaged when the OP was published. The 12 capabilities are listed below, together with the numbers of the OP requirements that they reflect:

1. *Running trains closer together* (OP requirements 4, 6, 7, 13, 18, 24, 25)
2. *Minimal disruption to train services* (7, 10, 11, 12, 13, 14, 16, 17, 18, 19, 20, 22, 25, 26, 27)
3. *Efficient passenger flows through stations and trains* (1, 2, 3, 4, 6, 7, 8, 9, 11, 13, 15, 21, 22, 23, 24, 25, 27)
4. *More value from data* (1, 2, 3, 4, 6, 7, 8, 9, 11, 12, 13, 14, 15, 17, 18, 19, 20, 21, 22, 23, 25, 26, 27)
5. *Optimum energy use* (10, 11, 13, 18, 21, 22, 26, 27)
6. *More space on trains* (1-6, 22)
7. *Services timed to the second* (4, 6, 7, 11, 13, 15, 18, 21, 22, 26)
8. *Intelligent trains* (2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 17, 18, 21, 22, 23, 26, 27)
9. *Personalised customer experience* (1-4, 6, 8, 9, 12, 14, 15, 17, 21, 22, 23, 24, 25, 27)
10. *Flexible freight* (1-18, 21-25, 27)
11. *Low-cost railway solutions* (4-7, 10 and general focus on improved operations rather than additional infrastructure capacity)
12. *Accelerated research, development and technology deployment* (especially 19, 20, 21; but also all the rest)

The influence of the Operational Philosophy, and its development and requirements, on the long-term vision and plans for Britain's railways can thus clearly be seen.

6. Conclusions

Britain's railways have experienced major and almost continuous organisational change in the two decades since the system was privatised, in the course of which there have been significant increases in passenger and freight traffic and in train service frequency, putting significant pressure on infrastructure and operating capacity. At the same time, the fragmentation of the industry, together with a process of natural wastage through redeployment and retirement of staff, led to a dispersal and loss of system knowledge and experience, and, at times, a focus on the short term, rather than on a long-term vision and strategic direction for the industry. This process of ongoing change is to some extent reflected in the changing 'ownership' of the Rail Technical Strategy, and in the absorption of the National Operating Strategy in the Digital Railway programme.

The development of the RTS and the Operational Philosophy provided a means of redressing this organisational fragmentation and flux. They do so by taking a consistent, strategic approach to developing and adapting Britain's railway industry to meet the needs and expectations generated by socio-economic and demographic change (and environmental concerns), and to exploit the opportunities and meet the challenges presented by rapid technological change.

The OP drew upon previous research in these areas, as well as industry and stakeholder knowledge and experience (and challenge), to provide an agreed framework and set of criteria, within which detailed infrastructural, technological and operational proposals could be developed and implemented, and checked for compliance with the industry's (and society's) long-term aspirations and needs.

The OP does not appear (yet) to have been widely applied in the manner originally envisaged, i.e. as a set of criteria against which proposals can be tested for consistency with the industry's long-term strategy (this is probably a consequence of the ongoing process of change within the industry, as described above). Nonetheless, its aims and contents, and the work undertaken for its development, are reflected in the Digital Railway programme and in the latest iteration of the RTS and its Capability Delivery Plan. It also continues to provide useful context, and a helpful set of principles and requirements, for the initial development and assessment of research and other development proposals. It should also be applicable to railways outside Britain, given that the global industry faces a broadly similar set of challenges and opportunities in the provision of additional capacity and improved customer satisfaction, while reducing its costs and both its own and wider levels of carbon emissions.

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