Department for Transport

MOTT MACDONALD

SOIF SCHOOL OF INTERNATIONAL FUTURES

Building A Robust Integrated Transport Digital Twin Programme (ITDT)

Report

Issue and Revision Record

FS47 Building a Robust Integrated Transport Digital Twin Programme

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1	02/04/2026	JJ / RE/ GL	SR	AS	Version 1
2	24/04/2026	GL	JJ	AS	Version 2
3	13/05/2026	GL	JJ	AS	Version 3

This document is a summary of the Futures Study on ‘Building a Robust Integrated Transport Digital Twin Programme’.
For further detail, please refer to the final report.

Contents

Executive Summary

UK transport networks and services are increasingly complex and challenged by changing conditions and demands in an uncertain world. Digital twin capability holds the prospect of being better able to monitor and manage them through timely interventions, including in crisis situations.

The Department for Transport (DfT) has begun an ambitious undertaking called the Integrated Transport Digital Twin (ITDT) Programme. This aims to create and trial a **national** capability comprised of multimodal **regional** digital twins and a national crisis response digital twin that, supported by data sharing infrastructure, can **enhance** capability to reactively and proactively support the resilience and efficiency of transport assets and services, and their use. The intention is to **improve** data sharing, and **support** better optimisation of multimodal journeys, network capacity management, faster incident management, lower freight emissions, and realisation of climate and environmental benefits.

In November 2025, DfT commissioned its Futures Support consultants - Mott MacDonald and partners - to develop a set of divergent, explorative 2030 scenarios that would reflect the uncertainty landscape and act as a resource to challenge thinking and assumptions surrounding ITDT Programme decision-making.

To help ensure a tailored approach to the development of these resources, materials related to the Programme were reviewed and a set of ten interviews was undertaken to understand the nature of the ITDT Programme and some of the key issues it faces**.**

This was followed by creating a longlist of uncertainties of potential relevance, drawing upon other recent DfT transport futures studies as well as supervised AI suggestions. An uncertainty is a variable or 'driver of change' whose future state is unknown. **Thirteen critical uncertainties** were subsequently shortlisted by the project and client teams in conjunction with an online workshop with experts within and beyond the DfT. These were as follows: (1) political and organisational ambition and investment; (2) pace of technological change relative to human and organisational capacity to adapt; (3) intensity and sophistication of cyber attacks; (4) adaptability to ageing infrastructure; (5) availability of digital, data, and systems skills; (6) public trust and social licence; (7) resilience of supply chains; (8) public willingness to share mobility resources; (9) climate resilience of infrastructure operations; (10) frequency of acute shocks; (11) ethical, regulatory and governance constraints on AI-driven decisions; (12) underlying reliability of digital infrastructure, systems, and Large Language Model behaviour; and (13) market control and influence of private corporations.

Executive Summary

An innovative approach (for the transport sector) was used to generate the explorative scenarios. This involves growing scenarios from sets of three seed uncertainties. Four seed sets provided strong representation across the critical uncertainties and were used as the basis for producing (again with the support of supervised AI) the final set of **four explorative 2030 scenarios** (see end of Executive Summary):

- Restart, Retrofit and Re-spec
- Muddled Management
- Proprietary and Pooled
- Climate Beats Capacity

The scenarios have been sense-checked against wider DfT guidance on scenario development and analysis.

Alongside the scenarios, a **set of wildcards**, reflective of disruptive potential events, was developed to provide further challenge for the Programme. These were: (1) emergency rule change suspends data-sharing clauses overnight; (2) coordinated deepfake attack triggers public panic over transport safety; (3) court injunction halts algorithmic rerouting after discrimination claim; (4) vocal public demands for strict limits on mobility data collection and automated decision making; (5) global GPU shortage announced overnight; (6) a rapid surge in global demand for digital skills results in a mass talent drain from UK public institutions; (7) a dominant mobility platform unexpectedly withdraws from UK data-sharing agreements; (8) solar atmospheric anomaly injects frequency noise, crippling IoT sensing worldwide; (9) global harvest failures trigger food import shortages; (10) multiple disruptive events in one regional corridor in one day; and (11) step-change in AI with massive and unexpected increase in AI capability.

The bespoke scenarios and wildcards were used to stress-test the different components of the ITDT, giving rise to the following potential **'least regrets' modifications** for the Programme to consider:

1. Prioritise smaller/quicker pieces of work where possible as part of the Programme delivery pathway, while maintaining clarity over their contribution to the overall strategic direction of delivery and to the overall adaptive capacity of the Programme.
2. Ensure timely understanding of the motives and capabilities of key private sector actors (such as journey planner providers) upon which the Programme could depend and establish trust relationships as appropriate.
3. Establish sufficient expertise within the Programme to ensure strong governance and associated regulatory measures as required to create a healthy and dependable climate of co-operative data sharing across public and private actors.
4. Give potentially greater attention to the distinction between right-time and real-time data availability and prioritise data availability over whether data is 'best in class'.

Executive Summary

5. Put in place steps necessary to establish a shared learning by doing approach to Programme delivery steps that sees regularity of sharing and learning opportunities.
6. Ensure regular briefings to senior leadership about the (changing) public expectations that are associated with the Programme over time to ensure support for the Programme excelling to meet such expectations and deliver benefits.
7. Prioritise the importance of non-personal data sharing to ensure anonymity while also ensuring data reflects the diversity of transport system users (passengers and goods) and can provide support for inclusive decision making.
8. Build in greater provision for the importance of human capability and capacity to flexibly and responsibly address digital shortcomings and uncertainties.
9. Put in place cybersecurity best practice across ITDT components.
10. Ensure Human-Machine Interface (HMI) developments within the Programme (involving appropriate usability testing) reduce dependence on specialist operatives for ITDT functions and in turn improve operational resilience.

The scenarios and wildcards are now available to the Programme for future use for stress-testing decision options, considering how these would play out in the different scenarios and be affected by the disruptive introduction of wildcards.

Guidance was developed for how the futures resources created by this project can be used to complement and enhance the wider monitoring and evaluation of the ITDT Programme by helping accommodate future uncertainty in pursuit of robust decisions that shape Programme delivery with outcomes in mind. This guidance includes suggested indicators and intelligence gathering that could help the Programme track how the 13 critical uncertainties are playing out over time.

This project demonstrates how futures methods can be used to help strategic planning and decision making, especially for developments that are breaking new ground and set to encounter significant contextual change dynamics with potentially important consequences in terms of decision outcomes.

Explorative 2030 scenarios:

Images created using Co-pilot

Restart, Retrofit and Re-spec

Scenario shaped by:

- **Low** political and organisational ambition
- **Low** adaptability to legacy assets
- **High** supply chain disruptions

Scenario further characterised by:

- Difficulty in charting a consistent course amid fast-paced innovation
- A messy political landscape that dampens efforts to modernise
- A largely benign environment for transport network operations devoid of major disruptions
- Progress on digital capability development but slowed by uncertain components' availability
- **Digital capabilities for monitoring and managing transport slower to become their best selves**

Proprietary and Pooled

Scenario shaped by:

- **High** private sector influence
- **Low** governance constraints
- **High** social willingness to share resources

Scenario further characterised by:

- Balance between transport supply and demand that is dynamically managed but largely by private sector hands
- Consumers who co-operate in the face of resource scarcity and in solidarity in the face of corporate control
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- **Public sector capability to monitor and manage transport that has one hand tied behind its back**

Muddled Management

Scenario shaped by:

- **High** cyber-attacks intensity
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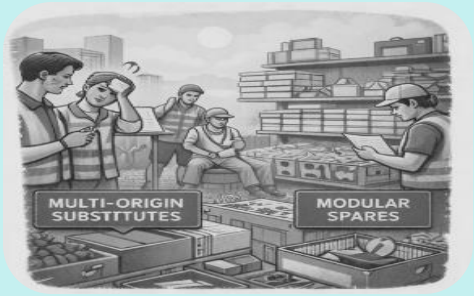
Scenario further characterised by:

- Digital fragility from years of being too hasty with pursuing digital progress
- People living with digital uncertainty
- Resurgent appeal of low(er)-tech approaches to adaptability
- Human co-operation and verification
- **Very different skills mix and diminished emphasis on digital capabilities for monitoring and managing transport**

Climate Beats Capacity



Scenario shaped by:

- **High** frequency of climate shocks
- **High** skills shortage
- **Low** supply chain disruptions

Scenario further characterised by:

- Crisis response more routine than exceptional
- A public weary of disruption and reliant on recovery support
- Unevenness of recovery, related to unevenness of specialist skills availability
- Constant rebalancing of transport supply and demand
- **Crisis response capability comes into its own but such capability needed at corridor level as well as nationally**

Introduction

Background Context

This report reflects futures work to support the robustness and effectiveness of the Integrated Transport Digital Twin Programme with a focus on examining uncertainty concerning the future context faced by the Programme in the period 2026-2030 and beyond.

A Digital Twin (DT) is a digital representation of a real-world entity that enables a two-way communication flow into and out of the real world in a timeframe that is appropriate for the required decisions and assumptions.

The National Digital Twin Programme (NDTP) "is the centralised government-led effort committed to growing national capability in digital twinning technologies and processes throughout the country".

The Department for Transport (DfT) is considering what would be involved in developing DT capability that would allow transport authorities to get the best from transport networks and services in a dynamic, changing, and sometimes disrupted context.

Our transport networks and services are increasingly complex and challenged by changing conditions and demands in an uncertain world. DT capability holds the prospect of being better able to monitor and manage them, including in crisis situations.

Growing digital capability including new artificial intelligence (AI) enabled possibilities and data sharing offers an important opportunity to make the most of the UK's transport system assets across modes by improving functional reliability and efficiency through routine monitoring and management and in times of disruption.

The DfT has begun an ambitious undertaking called the Integrated Transport Digital Twin (ITDT) Programme. This aims to create and trial an ITDT capability comprised of multimodal Integrated Corridor Digital Twins (ICDTs) and a national Crisis Response Digital Twin (CRDT) that – supported by Data Sharing Infrastructure (DSI) – offers enhanced ability to reactively and proactively support the resilience and efficiency of transport assets and services.

As the DfT's Futures Support consultants, Mott MacDonald and its partners were asked to support the ITDT Programme and this report sets out what was done in providing such support.

This included agreement to make use of supervised AI and to provide reflections on doing so. These are included in Annex 3.

Introduction

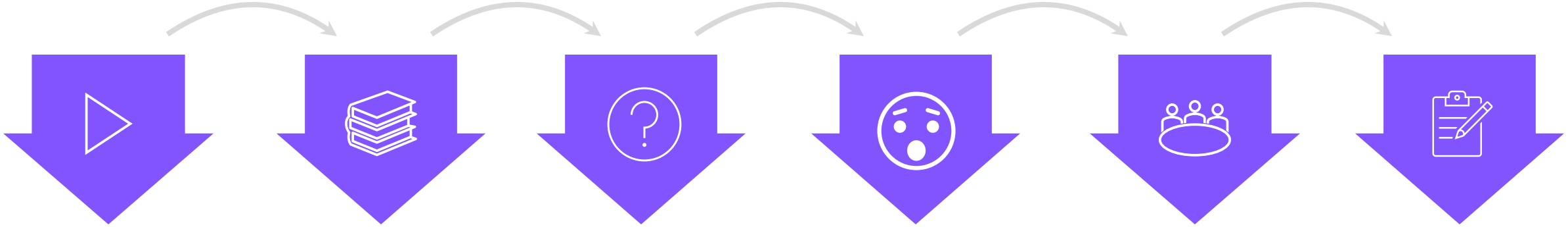
Project Requirements

The principal requirement of the project was to explore the wider contextual uncertainty faced by the ITDT Programme. Specifically, the requirements of the project were to:

1. longlist and then prioritise uncertainties of relevance to the ITDT Programme;
2. use the prioritised uncertainties to generate a set of explorative (qualitative) 2030 scenarios that reflect divergent and contrasting possible futures;
3. produce an accompanying set of wildcards depicting unexpected and high impact possible future events;
4. apply the scenarios and wildcards in a stress-testing workshop centred on Programme decision options; and
5. draw upon the project insights from addressing the above requirements to offer advice on how to build in adaptive capacity within the Programme's undertakings and offer a conceptual approach to monitoring and evaluation in terms of addressing uncertainty.

Methodology

Project Approach



Inception workshop

An inception workshop between the DfT client team and the project team was held to establish a shared understanding of the ITDT Programme and its core components.

Literature review & expert interviews

A short review of relevant literature (internal and external to DfT) was accompanied by a series of ten interviews to establish a summary account of the ITDT Programme and its considerations of relevance to the work in this project.

Critical uncertainties

A longlist of uncertainties was gathered from earlier DfT projects and internal sources including AI. This list was then shortlisted and presented at an experts' workshop for further prioritisation and identification of critical uncertainties. **Refer to page 15.**

Scenarios and wildcards

Based upon the critical uncertainties, a set of 2030 scenarios was developed reflecting divergent, contrasting future possible contexts for the ITDT Programme. A set of wildcard events was also developed to accompany the scenario set. **Refer to page 17.**

Stress-testing

The scenarios and wildcards were used in an in-person workshop with DfT staff to stress-test the three main components of the Programme (ICDTs, CRDT and DSI) against each of the future scenarios with the accompaniment of wildcard disruptions. **Refer to page 26.**

Accounting for uncertainty in monitoring and evaluation

Guidance was developed on how the resources generated by the project can be used to provide further enhancement to the Programme and its monitoring and evaluation. This included a session between the project and client teams to review the draft guidance. **Refer to page 30.**

ITDT PROGRAMME

ITDT Programme

The Integrated Transport Digital Twin (ITDT) Programme sets a pathway to the creation, operation and evaluation of a UK ITDT comprised of a series of Integrated Corridor Digital Twins (ICDTs) associated with multi-modal transport corridors, a national Crisis Response Digital Twin (CRDT) as well as Data Sharing Infrastructure (DSI) that together offer enhanced capability to reactively and proactively support the resilience and efficiency of transport assets and services, and their use. The aim of the Programme is to develop, trial and evaluate an Integrated Transport Digital Twin (ITDT) by 2030.

An overview of the Programme is shown on the next page. This summarises the case for change, the Programme's SMART objectives, the composite elements of the ITDT, and the delivery and value proposition, with associated risks and monitoring and evaluation.

The ICDTs will be used to manage key local transport networks and link between regions. The CRDT will be used to prepare for and respond to crisis events across the transport network nationally. The DSI will allow and support data sharing for the components above and externally. Further components include an innovation funding programme (through DfT's Transport Research and Innovation Grants (TRIG)), an evaluation contract for the ITDT, and engagement activities.

The ICDTs will link local stakeholders across modes (unlocking capacity); move from a siloed and reactive approach to an integrated and proactive approach; and operate as an Integrated Transport System Model representing the regional network physically and logistically. They will address use cases including: network capacity management; multimodal customer journey optimisation; multimodal incident management; planned works and maintenance management; freight management at ports; and data sharing.

The CRDT will: provide AI-enabled decision support for national emergencies; improve cross-government collaboration, preparedness and co-ordination in crisis response; utilise DfT and external (including non-transport) data; and build a 'knowledge graph' that shows relationships between entities (e.g. how a road closure affects a port).

The DSI will: allows the CRDT and corridor DTs to talk to each other; ensure a common data scheme to improve interoperability and avoid ambiguity; and through authentication and access control ensure the right people see the right data.

Ten interviews with internal and external stakeholders were undertaken to surface possible issues and concerns. These are set out on a subsequent page.

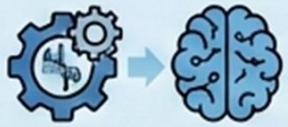
ITDT Programme

Overview

WHY: STRATEGIC CONTEXT & SMART OBJECTIVES

The Case for Change (Problem & Opportunity)

CURRENT:
Siloed operations, Poor data access, reactive to crises, suboptimal performance.

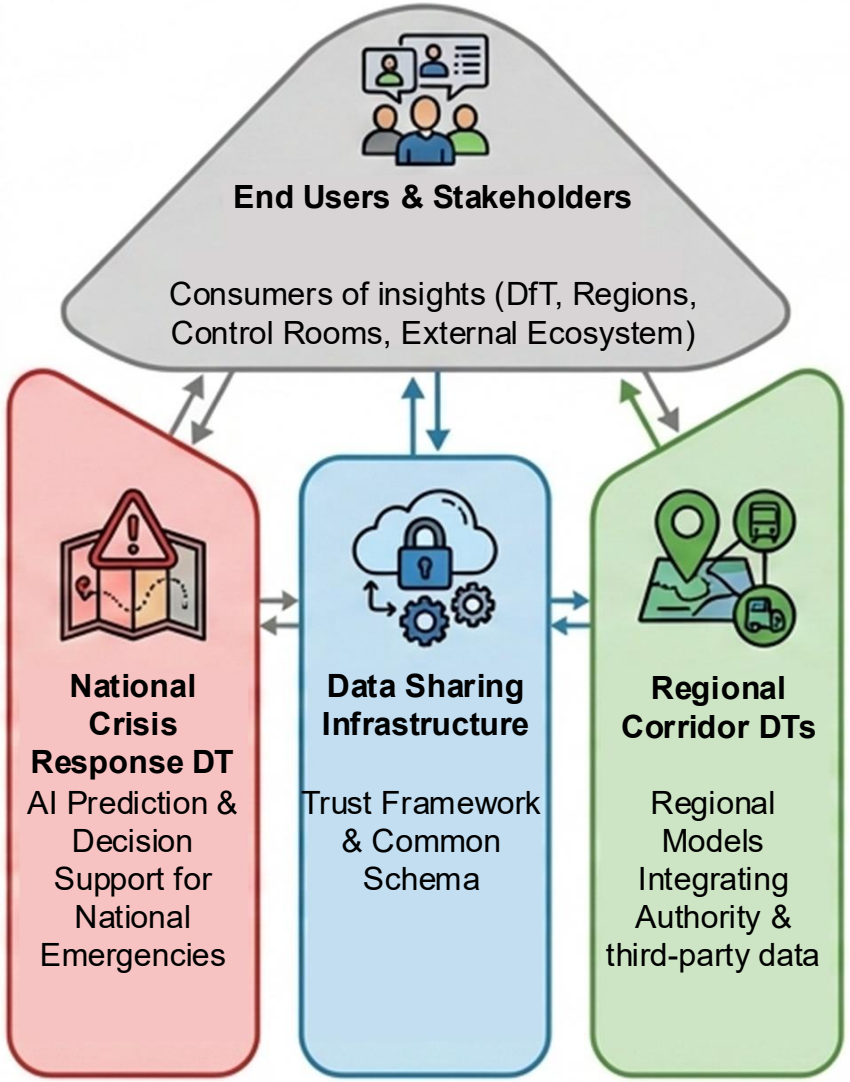


OPPORTUNITY
Real-time connectivity, proactive optimisation, integrated transport network, enhanced resilience.

2030 SMART Objectives

- **SM01 (Regional):** Trial involving Integrated Corridor DTs (ICDTs) to unlock capacity.
- **SM02 (National):** Develop DfT Crisis Response DT (CRDT) for multiple risk scenarios.
- **SM03 (Data):** Establishing Data Sharing Infrastructure (DSI) unlocking multiple datasets.
- **SM04 (Growth):** Fund projects through Innovation Funding Programme (IFP).

WHAT: ARCHITECTURE & SOLUTION (FEDERATED MODEL)



HOW: DELIVERY, VALUE, RISK & ASSURANCE

Programme Delivery & Service Value

Programme Delivery: Project Management; Technical Design; ICDT Trials; CRDT Development; Innovation & Engagement.
Service Value: data sharing, optimised multimodal journeys, network capacity management, faster incident management, lower freight emissions, Climate and environment benefits

Key Risks & Mitigations

Risks: Uncertain external environment, emerging tech maturity, complex stakeholder alignment.
Mitigations: Agility, continuous Monitoring & Evaluation, strong governance, leverage National Digital Twin Programme (NDTP) architecture, co-design with operational communities.

Monitoring & Evaluation

Focus Areas: External Environment (weak & strong signals), Process (delivery tracking), Impact (scalability, data value), and Value for Money (VfM) assessment for future funding.

Possible Issues and Concerns for the ITDT Programme

1. Technical data and architecture

- Weak data sharing leads to siloed pilots and failure to scale
- Break-glass (bypassing established procedures) / crisis-time conditional access design is hard (temporal, purpose-limited access)
- Centralised “nodes-first” architectures deferring federation
- Single point of failure if relying on NDTP to integrate everything (dependency / lock-in)
- Multimodal interoperability challenges (constraint integration)
- Poor data quality (undermines trust)
- Non-uniform formats (integration burden)
- Operators lack basic asset data (not even drawings)

2. Delivery capability and adoption

- Uneven capability (regional ‘islands’)
- In-house skills gaps
- ‘Business as usual’ pressure (resource limits)
- Low literacy (frontline resistance)
- Control room workflow (tool rejection)
- Individuals’ fear of employment displacement

3. Security, legal and assurance

- Cyber safety implications (connectivity)
- Cyber sophistication (data integrity)
- Privacy mosaic effect (data sensitivity)
- Automation liability (who is liable)
- Fitness-for-purpose (assurance for crisis use)

4. Commercial and procurement

- Over-reliance on external consultants (loss of ownership)
- Procurement / contracting constraints (e.g. PFI) limiting integration / change
- Vendor dependence / proprietary lock-in
- Sovereignty uncertainty (what must be UK-controlled versus globally sourced) creating architecture / procurement ambiguity
- UK supplier marketplace and significance of foreign primes
- Open-source ‘overreach’ (insisting everything be open can slow delivery and reduce incentives)

5. Evaluation and learning

- Success criteria ambiguity – smooth delivery in easy contexts may yield little learning; disruption can be valuable but look like failure
- Missing capturing lessons from non-delivery
- M&E scope – operation focus only and missing wider institutional benefits (standards, skills, data access, policymaking)
- User acceptance testing limitations (late discovery)
- Outcome-focus versus component-focus failure mode – building artefacts versus improving decisions / resilience outcomes

6. Strategic / political / funding

- Governance, leadership and alignment - no clear ‘North Star’ (unifying purpose or goal), parallel government initiatives without co-ordination, multi-authority complexity/delivery friction, inter-authority politics/collaboration barriers
- Political volatility and funding continuity – changing political leadership/structures, funding continuity risk/short-termism, reduced funding flexibility / ‘blocky’ budgets

7. External uncertainties

- Frequency of climate shocks
- Geopolitical volatility – data sharing and multinational suppliers
- Economic shock – reduced appetite for R&D
- Competing infrastructure resources – EVs, AI
- Rapid technology change – obsolescence pressure

Issues and concerns identified by external and internal interviewees

CRITICAL UNCERTAINTIES

Critical Uncertainties

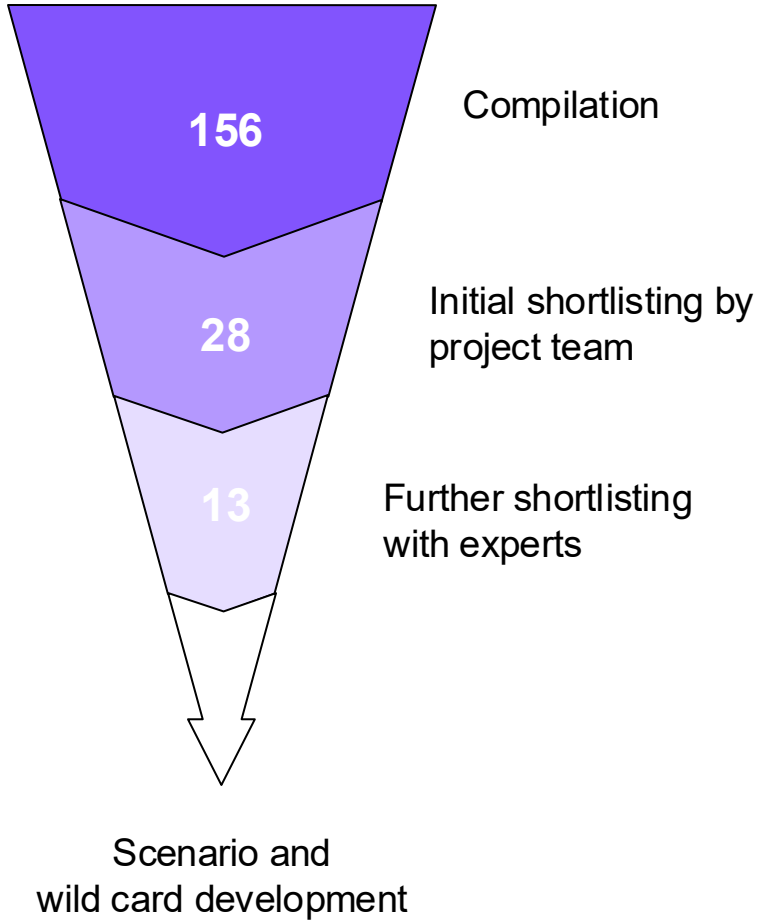
Overview

As the ITDT Programme is delivered and operated it will be faced with uncertainties that shape the nature of the wider context in ways that could have important implications.

Having addressed familiarisation with the ITDT Programme and its components, the next part of the project was to establish a set of critical uncertainties (drivers of change considered most uncertain and most important to the Programme):

- **Compilation** – a longlist of 156 uncertainties was first drawn up
- **Initial shortlisting** – the longlist was then processed and scoring criteria guided creation of an initial shortlist of 28 uncertainties
- **Further shortlisting** – a workshop then took place with experts who further reduced the list, arriving at a set of 13 critical uncertainties

Further explanation of this process is provided on the following pages. The set of critical uncertainties subsequently formed the basis for developing possible future scenarios and also wildcards.



Critical Uncertainties

Compilation and initial shortlisting by project team

Longlisting

Candidate uncertainties identified from previous DfT Futures projects, Mott MacDonald internal foresight work, and AI prompting.

Processing

Uncertainties processed using supervised AI*, followed by a manual review:

1. Duplicates / overlaps identified and removed.
2. Political, Economical, Social, Technological, Legal, Environmental (PESTLE) categories assigned.
3. System Level categories (Global vs Programme) assigned.
4. Uncertainty titles, descriptions, projections produced, ensuring uniform format.

System level categories were defined as:

- **Global:** An external uncertainty that lies largely outside the Programme's control and shapes the context in which the Programme must operate
- **Programme:** an uncertainty that arises from how the Programme is designed, governed, and implemented, where outcomes are (partially) steerable through Programme choices.

Scoring

Judging uncertainties against four criteria (using supervised AI* and manual review) with Y/N and scoring:

Delivery: as the uncertainty plays out, could it materially change Programme delivery? (Y assigned a score of 1)

Operations: as the uncertainty plays out, could it materially change the Programme's operational performance outcomes? (Y assigned a score of 1)

Near Term: does this uncertainty playing out have potential to have high impact as it evolves in the next five years? (Y assigned a score of 2)

Unfamiliar to Programme delivery Team: is the uncertainty likely to be less familiar or unfamiliar to the team ('outside their wheelhouse')?
(Y assigned a score of 1)

Shortlisting

Total score calculated for each uncertainty and then creating a shortlist of uncertainties comprised of those that were considered Global and that scored 4 or 5.

This diagram sets out the steps that were taken to scope uncertainties of potential relevance to the Programme and then produce a shortlist of 28 suitable for subsequent consideration by a wider group of experts

* See Annex 2 for further details

Critical Uncertainties

Further shortlisting with experts

An online 2.5-hour workshop was organised and took place on 21 January 2026 with the purpose of engaging a wider group of stakeholders from within and beyond DfT to consider the shortlist of 28 uncertainties and judge which of them were critical to the ITDT Programme in terms of impact on **delivery and trial** of ITDT functionality (before 2030) and impact on **operation** of the ITDT (after 2030).

The table on the right shows the final list of critical uncertainties based upon those uncertainties judged as critical by at least two groups and a further two uncertainties deemed important to retain in a discussion between the client and project teams immediately following the workshop. These 13 critical uncertainties subsequently formed the basis for creating a set of possible future scenarios.

See Annex 1 for projections of each of the 13 critical uncertainties.

No	ID	Uncertainty	D1	D2	O1	O2
1	**P4**	Political and organisational ambition and investment	✓	✓	✓	✓
2	**T2**	Pace of technological change relative to human and organisational capacity to adapt	✓	✓	✓	✓
3	**T7**	Intensity and sophistication of cyber attacks	✓		✓	✓
4	**T6**	Adaptability to ageing infrastructure		✓	✓	✓
5	**Ec1**	Availability of digital, data, and systems skills	✓	✓	✓	
6	**S3**	Public trust and social licence	✓		✓	
7	**T3**	Resilience of supply chains			✓	✓
8	**S4**	Public willingness to share mobility resources		✓	✓	
9	**En1**	Climate resilience of infrastructure operations	✓	✓		
10	**En2**	Frequency of acute shocks	✓	✓		
11	**P2**	Ethical, regulatory and governance constraints on AI-driven decisions		✓		✓
12	**T5**	Underlying reliability of digital infrastructure, systems, and LLM behaviour	✓			
13	**Ec4**	Market control and influence of private corporations		✓		

ID: unique ID of each uncertainty reflective of PESTLE category
O1, O2: Workshop groups considering impact on operation
D1, D2: Workshop groups considering impact delivery

EXPLORATIVE SCENARIOS AND WILDCARDS DEVELOPMENT

Creating Scenarios and Wildcards

Overview

The 13 critical uncertainties provided the basis for creating a set of four explorative **future scenarios** offering a diverse representation of possible future contexts the ITDT Programme could encounter.

There are different approaches used in scenario development. For this project the 'seeding' approach was used which involves developing diverse bottom-up scenarios based upon combinations of three uncertainties (drawn in this case from the 13 critical uncertainties) each with a chosen projection (which here are referred to as triads). Each triad must be credible in terms of the interplay of its three uncertainty projections which are the seeds for growing a scenario narrative.

The following page gives a high-level overview of the steps that were undertaken, and the subsequent page summarises the scenario set produced. The scenarios are presented in full detail in Annex 2.

Alongside the four scenarios, a set of 11 **wildcards** was developed.

A longlist of candidate wildcards was initially generated using supervised AI, with the aim of producing a broad and imaginative range of low-probability, high-impact events relevant to delivery and operation of Digital Twins in the UK.

These were then manually reviewed by the project team and further inputs provided by client team, with those selected on the basis of being the most stretching events that would most significantly disrupt ITDT Programme assumptions, or expose vulnerabilities not captured elsewhere in the analysis.

The 11 wildcards are presented on pages 23 and 24.

Creating Scenarios

Methodology

01

The two projections of each of the 13 uncertainties were treated as distinct “seeds” to work with, meaning a total of **26 seeds**.

02

A set of **15 triads** (groups of 3 projections) were originally produced through supervised AI, each were then manually assessed by the project team against two broad criteria: whether it opened up a genuinely distinct scenario space, and whether it added something not already covered by another triad in the set of 15.

03

This review process yielded **four triads**, each capturing a different underlying narrative framing.

Care was taken to represent as many of the 13 uncertainties as possible (each with one if its projections) in the four. Together, the four triads were chosen to represent meaningfully different risk exposures, maximising range of conditions able to be stress-tested against.

04

Each of the four triads were then used as a basis to grow a **scenario narrative.** The narratives in terms of structure and content were initially developed using supervised AI. Subsequent to this, they were critically reviewed with substantial further human revision and enhancement made to each of them.

Explorative Scenarios (see Annex 2 for further detail)

Images created using Co-pilot

Restart, Retrofit and Re-spec

Scenario shaped by:

- **Low** political and organisational ambition
- **Low** adaptability to legacy assets
- **High** supply chain disruptions

Scenario further characterised by:

- Difficulty in charting a consistent course amid fast-paced innovation
- A messy political landscape that dampens efforts to modernise
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- **Public sector capability to monitor and manage transport that has one hand tied behind its back**

Muddled Management

Scenario shaped by:

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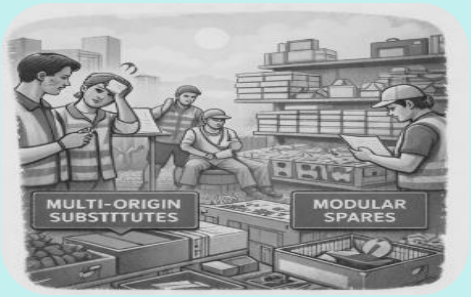


Scenario shaped by:

- **High** frequency of climate shocks
- **High** skills shortage
- **Low** supply chain disruptions

Scenario further characterised by:

- Crisis response more routine than exceptional
- A public weary of disruption and reliant on recovery support
- Unevenness of recovery, related to unevenness of specialist skills availability
- Constant rebalancing of transport supply and demand
- **Crisis response capability comes into its own but such capability needed at corridor level as well as nationally**

Wildcards (1 of 2)

Emergency rule change suspends data-sharing clauses overnight

A fast-tracked directive pauses all new public–private data-sharing clauses pending review, freezing live pilots.

1

Coordinated deepfake attack triggers public panic over transport safety

Coordinated deepfakes spoof official alerts and signage feeds, seeding confusion and triggering widespread public complaints and opt-outs.

2

Court injunction halts algorithmic rerouting after discrimination claim

A successful challenge pauses the use of certain optimisation outputs for passenger services pending audit.

3

Vocal public demands for strict limits on mobility data collection and automated decision making

Public campaigns call for “transport data rights”, resisting centralised mobility data aggregation and pressuring policymakers to enforce opt outs or stricter consent models, compromising data availability.

4

Global GPU shortage announced overnight

A major supply chain failure chokes the availability of high-performance computing chips, delaying capacity expansions and availability of spares for maintenance.

5

A rapid surge in global demand for digital skills results in a mass talent drain from UK public institutions

International private-sector salaries outcompete domestic pay structures, causing sudden loss of key staff in public sector initiatives.

6

Wildcards (2 of 2)

A dominant mobility platform unexpectedly withdraws from UK data-sharing agreements

Following a forced change in strategy, a major tech player ceases participation in shared data ecosystems that removes long-established and relied-upon critical real-time feeds and destabilises interoperability assumptions.

7

Solar atmospheric anomaly injects frequency noise, crippling IoT sensing worldwide

A novel solar atmospheric event scrambles multiple globally used IoT sensors. Autonomous vehicles go into safe halt mode, smart grids fail to balance load, and digital twins lose real world anchoring.

8

Global harvest failures trigger food import shortages

The UK government institutes national stock control and freight prioritisation. Road haulage and rail freight are placed under central command structures, displacing commercial logistics models.

9

Multiple disruptive events in one regional corridor in one day

A series of events (a flash flood, power failure across multiple railway stations, and high demand for a major sporting venue) lead to crowd management and safety concerns.

10

Step-change in AI with massive and unexpected increase in AI capability

A sudden step-change in AI reasoning, capability and autonomy allows for advanced multimodal awareness and control with minimal human input.

11

DfT Guidance on Scenario Development and Analysis

The scenarios developed in this work are qualitative and intended (at this point) for early-stage appraisal of design and delivery options for the ITDT Programme (policy future proofing).

Their primary function is to provide a structured means for those involved in the ITDT Programme to open minds and challenge thinking and in turn foster an adaptive culture in Programme delivery that can better proactively and reactively respond to unexpected change.

They are not currently intended for use in business cases and testing value for money.

Therefore, while the scenarios have been developed considering the content of the available DfT uncertainty guidance, which includes the TAG unit M4 forecasting and uncertainty (originally published in 2019 and updated in May 2026) and the uncertainty toolkit (originally published in 2021 and most recently updated in May 2026), they do not seek to fully meet the criteria set out by DfT in section 3 of the uncertainty toolkit for national level demand uncertainty scenarios which are suitable to use in policy appraisal.

STRESS-TESTING

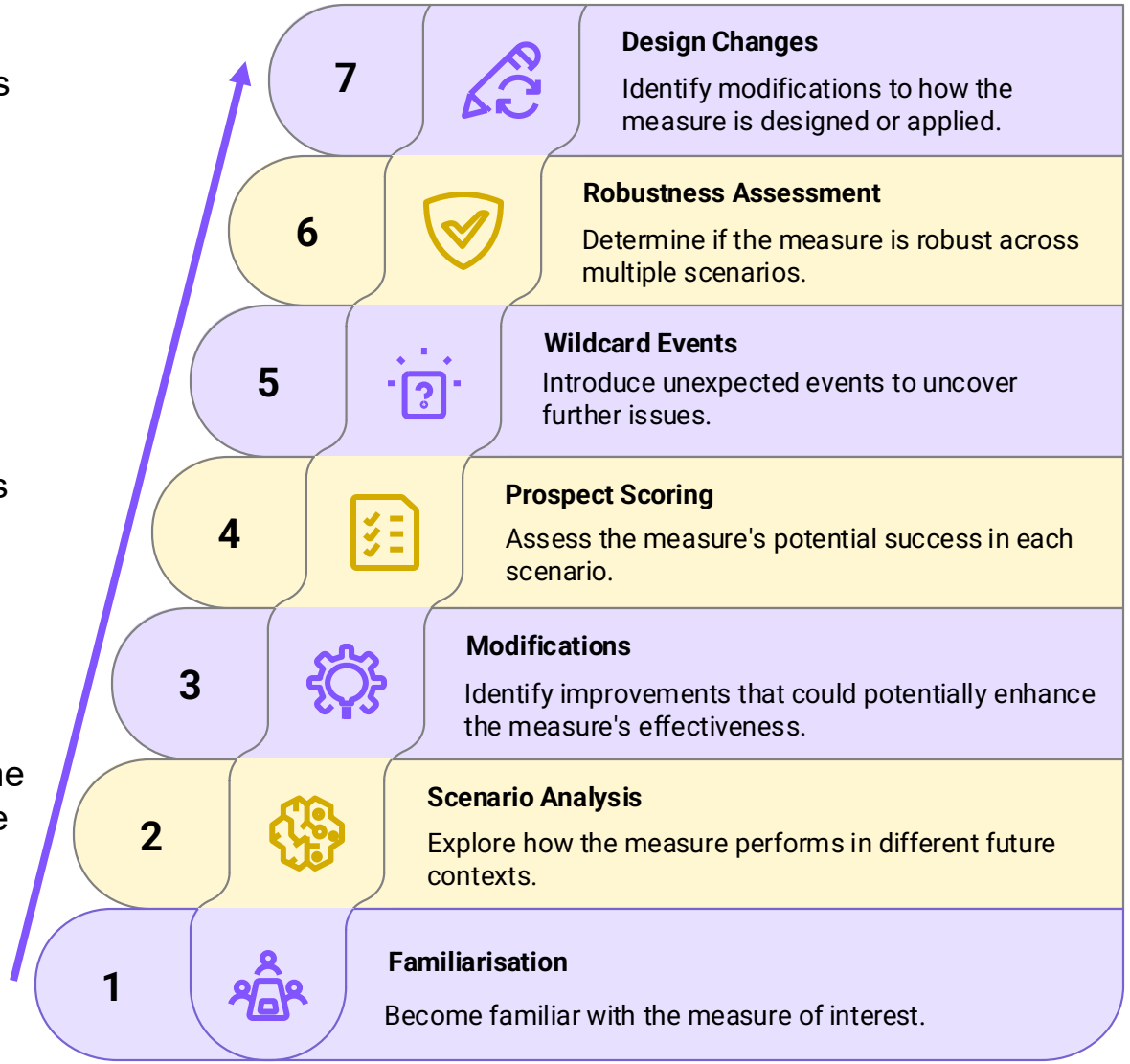
Stress-testing

The set of possible future scenarios allied with the set of wildcard events together become a resource with which to 'stress-test' components of the ITDT Programme. This is in terms of how the components perform and contribute to overall Programme aims in different future contexts. This in turn informs decision making about the delivery and operation of those components including need for modification or rebalance of emphasis.

Stress testing in futures studies involves examining how strategies, policies, or systems perform under a range of possible future scenarios to identify vulnerabilities, trade-offs, and areas of resilience. The process of steps is shown in the image to the right.

Stress-testing using the four scenarios and wildcard events was applied in an in-person 2-hour workshop with DfT staff (on 11 March 2026 at the DfT) which provided first-hand experience to better enable subsequent use by the Programme team in due course. Its purpose was to:

- critically examine the principal components of the ITDT Programme and their ability to fulfil objectives in the face of four possible future scenarios and disruption from wildcard events;
- begin to consider mitigation strategies to ensure the delivery of ITDT components is responsive to the scenarios; and
- act as a familiarisation session to provide hands-on experience of stress-testing to help enable further stress-testing later in the ITDT Programme work.



Stress-testing

Workshop approach and outcomes

During the workshop, there were four breakout groups. Each group considered one of the four scenarios and examined each ITDT component in turn. Participants were asked to consider, in terms of the ITDT Programme aims:

- what looks favourable for ITDT delivery in this future?;
- what looks unfavourable in this future?; and
- what might need modifying in terms of the ITDT?

The template shown on the right was used to structure the stress-testing conversations.

Groups were asked to provide an indicative score if possible, for each component for the scenario concerned. They were then presented, without prior sight of this, with a wildcard selected from the set developed in the project. They had a few minutes to consider what further impacts or implications present themselves in relation to or beyond the points already raised.

The following page lists possible 'least regrets' modifications that the Programme could consider in light of these summaries.

Scenario name:		
Integrated Corridor DTs	Crisis Response DT	Data Sharing Infrastructure
Favourable •	**Favourable** •	**Favourable** •
Unfavourable •	**Unfavourable** •	**Unfavourable** •
Might need modifying •	**Might need modifying** •	**Might need modifying** •
Score (-2 to 2):	Score (-2 to 2):	Score (-2 to 2):
Wildcard name:		Scoring: -2 Very poor prospects -1 Poor prospects 0 Middling prospects +1 Good prospects +2 Very good prospects
Wildcard impacts: •		

Stress-testing

Potential ‘least regrets’ modifications for the Programme to consider

1. Prioritise smaller/quicker pieces of work where possible as part of the Programme delivery pathway, while maintaining clarity over their contribution to the overall strategic direction of delivery and to the overall adaptive capacity of the Programme.
2. Ensure timely understanding of the motives and capabilities of key private sector actors (such as journey planner providers) upon which the Programme could depend and establish trust relationships as appropriate.
3. Establish sufficient expertise within the Programme to ensure strong governance and associated regulatory measures as required to create a healthy and dependable climate of co-operative data sharing across public and private actors.
4. Give potentially greater attention to the distinction between right-time and real-time data availability and prioritise data availability over whether data is ‘best in class’.
5. Put in place steps necessary to establish a shared learning by doing approach to Programme delivery steps that sees regularity of sharing and learning opportunities.
6. Ensure regular briefings to senior leadership about the (changing) public expectations that are associated with the Programme over time to ensure support for the Programme excelling to meet such expectations and deliver benefits.
7. Prioritise the importance of non-personal data sharing to ensure anonymity while also ensuring data reflects the diversity of transport system users (passengers and goods) and can provide support for inclusive decision making.
8. Build in greater provision for the importance of human capability and capacity to flexibly and responsibly address digital shortcomings and uncertainties.
9. Put in place cybersecurity best practice across ITDT components.
10. Ensure Human-Machine Interface (HMI) developments within the Programme (involving appropriate usability testing) reduce dependence on specialist operatives for ITDT functions and in turn improve operational resilience.

ACCOUNTING FOR UNCERTAINTY IN MONITORING AND EVALUATION

Accounting for Uncertainty in Monitoring and Evaluation

Overview

The ITDT Programme will be tracked and informed by a monitoring and evaluation contract running from 2026 to 2030.

Process evaluation will aim to learn lessons from Programme implementation and impact evaluation will examine its effectiveness in terms of outcomes.

The contract will identify what monitoring data and other evidence will be needed to consider the progress and effectiveness of the Programme.

A note was developed to explain how the resources developed as part of this project can contribute to and be integrated with the wider monitoring and evaluation of the ITDT Programme. This provide a means to:

- open minds and challenge thinking;
- guide determination of appropriate data collection and other evidence gathering;
- help inform explanations as part of process and impact evaluation; and
- foster an adaptive culture and inform reactive and proactive actions in response to (anticipated) change in external context (with opportunity for the wider evaluation to then consider how well the Programme adapted).

Each critical uncertainty has been examined as follows:

- Why it is critical;
- Potential indicator(s) of the uncertainty;
- Potential data/measure(s) for each indicator;
- Desirable/undesirable indicator status; and
- Response considerations.

The approach focuses primarily on internal Programme adaptation, where monitoring insights are used to adjust governance, delivery, capability, and decision-making so the Programme remains robust under changing external conditions.

This is consistent with a developmental / adaptive M&E philosophy, in which the Programme's success is judged by how well it responds to uncertainty, not by whether it eliminates uncertainty.

CONCLUSION

Conclusion

This project has provided an opportunity to begin addressing the risk to the ITDT Programme of a dynamic and uncertain external environment.

1

It has helped **put in place resources** that have been and can be used to better understand exogenous factors that could affect Programme performance and in turn inform steps that could be taken to help mitigate this risk.

2

It is important now for those involved in Programme delivery and in Programme monitoring and evaluation to consider **how the ITDT Programme can be further developed** with reference to the project outcomes.

3

This **application of futures** methods has been notably tailored to the needs of the ITDT Programme. Nevertheless, internal reactions to the work and what it has produced suggest that this output will be relevant to a wide range of data and digital projects with extended delivery and operational timelines, whether delivered by DfT or elsewhere.

ANNEX 1 – CRITICAL UNCERTAINTIES WITH PROJECTIONS

Critical Uncertainties

Final shortlist

No	ID	Title	Projection	
1	P4	Political and organisational ambition and investment	Sustained political and organisational ambition translates into long-term funding commitments and clear priorities.	Shifting political and organisational focus results in stop-start investment cycles.
2	T2	Pace of technological change relative to human and organisational capacity to adapt.	People and organisations adapt well to technological change.	People and organisations adapt poorly to technological change.
3	T7	Intensity and sophistication of cyber attacks	High intensity and sophistication of cyber attacks	Low intensity and sophistication of cyber attacks
4	T6	Adaptability to ageing infrastructure	Flexible integration approaches accommodate legacy assets.	Poor adaptability to legacy assets.
5	Ec1	Availability of digital, data, and systems skills	Adequate availability of skills relevant to digital twin capability developments.	Persistent skills shortages relevant to digital twin capability developments.
6	S3	Public trust and social licence	Transparent data governance, strong privacy protections, and visible public benefits boost acceptance.	Perceived surveillance, opaque decisioning, data privacy concerns, disinformation spread or incidents erode confidence and trigger restrictions.
7	T3	Resilience of supply chains	Resilient and diversified supply chains.	Frequent supply chain disruptions.
8	S4	Public willingness to share mobility resources.	High willingness to share mobility resources increases interdependence between users and services.	Reluctance to share mobility resources sustains fragmented mobility patterns.
9	En1	Climate resilience of infrastructure operations	Infrastructure systems adapt effectively to climate impacts.	Increasing climate shocks overwhelm infrastructure operations.
10	En2	Frequency of acute shocks	Acute shocks (extreme weather events, public health shocks, major system disruptions) become frequent/severe.	Acute shocks (extreme weather events, public health shocks, major system disruptions) are less frequent/severe.
11	P2	Ethical, regulatory and governance constraints on AI-driven decisions	Strong ethical, regulatory and governance constraints.	Relaxed ethical, regulatory and governance constraints.
12	T5	Underlying reliability of digital infrastructure, systems, and LLM behaviour	Digital infrastructure and systems behave in predictable ways with a normal range of error.	Digital systems behave in unpredictable ways because of service interruptions, unanticipated model behaviour, etc.
13	Ec4	Market control and influence of private corporations	Large technology firms exert significant influence over platforms and data ecosystems.	Public sector and other ecosystems become more open source and more interoperable

ANNEX 2 – EXPLORATIVE SCENARIOS

Brief Summary

The UK runs in a stutter: announce, mobilise, pause, re-announce. **Political headwinds**, constrained public resources and **fast-paced global innovation** make it hard for political ambition, through a consistent focus, to shine. **Shifting focus** stifles wider organisational appetite which compresses delivery plans for new, typically **low ambition, initiatives** into short, manageable commitment windows. Such initiatives are in the context of **ageing legacy infrastructure across sectors** that makes **modernisation slow and complex**. Once "standard" components have disappeared because of geopolitical churn, and widespread innovation is producing a mushrooming array of alternative component types. Together this creates an **uncomfortable mismatch between the old and the new** in evolving systems, including transport and its control.

Closer Look

UK

A **messy political landscape** in a world that is being **disrupted by digital age innovation** has left the UK struggling to hold onto a clear sense of direction and priority when it comes to charting a course for sustaining and improving cross-sector infrastructure and services. **Political and organisational focus shifts fast** and in turn investment arrives in bursts: big commitments, bright branding, attempted (often unsuccessful) rapid mobilisation, followed by quiet freezes when priorities swing or budgets tighten. Normalised practice as a result sees planning compressed into short commitment windows with programmes that are **designed to stop safely rather than finish boldly**.

That stop-start rhythm is compounded by two stubborn realities. First, **legacy systems**, within and beyond the transport sector, resist change. Decades of poorly documented work mean **modernisation takes time** and caution. Second, **supply chains are repeatedly jolted** by geopolitical churn: export controls, sanctions, and compliance resets can make a previously "standard", or indeed newly produced and standardised, component vanish overnight or reappear with constraints that delay use even after delivery. The national mood is pragmatic but taut: **progress still happens**, but it arrives in fragments and every fragment triggers a fight over what gets resumed or newly prioritised next. Ill appreciated good fortune is that **ageing infrastructure is holding up** and **serious episodes of extreme weather are in abeyance**.

Digital monitoring and management of transport systems

Stop-start investment pushes delivery of digital capabilities into blocks: capability is funded in chunks that prioritise "restartability", and procurement rules increasingly favour designs with approved substitutes and **on-shore spares** to survive geopolitical churn. **Poor adaptability to legacy assets** still creates system blind spots, so operators work around brittle interfaces using temporary control-room capability that can sit alongside older systems without rewiring them. In day-to-day transport management, teams run a hybrid system: manual control where legacy assets limit options and digital control where there are reliable data and tools. Monitoring and management thankfully contend with a **gracefully degrading rather than more dramatically failing** transport infrastructure and services system.

Takeaways

- Vignette: a peak-hour incident blocks a key corridor. Different solutions are offered: signal re-timings, bus priority corridors, and rerouting, but two rely on control modules now export-controlled, and the most aggressive plan leans on a legacy control chain flagged as unreliable - the duty lead chooses the slower, safer package and publishes the trade-off showing what's certified and what is not.
- Signature outcomes: gradually more consistent (sometimes slower) incident handling.
- Open tensions: half-finished projects; and rising costs from repeated rework or having to overcome legacy hurdles.
- Unintended consequence: "substitution readiness" becomes a competitive advantage, widening the gap between organisations that can stockpile / certify components and those that cannot.

Restart, Retrofit and Re-spec

Scenario shaped by:

- **Low** political and organisational ambition
- **Low** adaptability to legacy assets
- **High** supply chain disruptions

Scenario further characterised by:

- Difficulty in charting a consistent course amid fast-paced innovation
- A messy political landscape that dampens efforts to modernise
- A largely benign environment for transport network operations devoid of major disruptions
- Progress on digital capability development but slowed by uncertain components' availability
- **Digital capabilities for monitoring and managing transport slower to become their best selves**

Brief Summary

A strong climate of **private sector influence** from major technology platform providers in global markets has made their promise of progress hard to resist, **passing ever more control** from the public sector into their hands, including that concerning the transport system. **Public sector governance** that sought to enable responsible innovation has, in effect, proved easy to navigate for firms with their own agenda. The services they provide to consumers stay seductively convenient, but **public trust erodes** as power concentrates, accountability blurs, and access gaps widen. This happens within, and reinforces, a social context in which there has been a **growing willingness to share resources**, prompted by a combination of heightened cost of living and environmental consciousness.

Closer Look

UK

Affordability challenges, resource scarcity and environmental responsibility mean **sharing has increasingly become the backbone** of many people's everyday lives and **the backbone clearly has an owner**. Households pool mobility subscriptions and neighbourhoods coordinate mobility services. **Interdependence feels increasingly rational** as a result, ironically nurturing social cohesion in the face of a backbone owner that is viewed by many with cynicism (in spite of the convenience offered) because of increasingly apparent **inequities in service provision**.

Relaxed ethical, regulatory and governance constraints have accelerated concentration of providers in the market: temporary pilots becoming permanent operating modes and "self-attested" standards replacing external checks. **Technology firms have moved from vendors to governors**. They define digital identity, pricing defaults, and "service priority scores" that determine who get served first and on what terms. Local authorities still exist, but they regulate via system integration agreements and partnership clauses. **Public trust** runs low not because the system fails, but because it works while feeling unowned: rules shift without consent, and the line between public service and platform product becomes hard to see.

Digital monitoring and management of transport systems

Digital capabilities to monitor and manage transport operate within a system **largely shaped by major platforms**. The technology is powerful because **high levels of consumer engagement and sharing behaviour** generate rich, real-time insight into demand, who is willing to pool, and how much detour transport system users will accept. But **public authorities do not fully or even substantially control** how that information is used. Large platforms influence travel patterns through subscription tiers and priority rules built into their apps, so public-sector led transport authorities increasingly plan around how platforms allocate access rather than directing flows themselves. In practice, transport management depends on agreements with these firms. Adjustments to bus lanes, signal priority, or disruption responses have to navigate within the **operating rules set by the platforms that control user access and accounts**.

Takeaways

- Vignette: a multi-modal hub fails during the morning peak and a coordinated recovery plan is triggered, but the platform's default tiering automatically gives the least congested and fastest options to users with the highest priority scores first - recovery across the network may be quick, but who benefits first becomes politically controversial.
- Signature outcomes: efficient rebalancing; and deeper dependency on platform ecosystems.
- Open tensions: legitimacy crisis; opaque exclusion of users; and contested accountability between state and firms.
- Unintended consequence: public agencies become "thin operators" while platforms become "thick governors".

Proprietary and Pooled

Scenario shaped by:

- **High** private sector influence
- **Low** governance constraints
- **High** social willingness to share resources

Scenario further characterised by:

- Balance between transport supply and demand that is dynamically managed but largely by private sector hands
- Consumers who co-operate in the face of resource scarcity and in solidarity in the face of corporate control
- Social inequality in access to mobility options
- **Public sector capability to monitor and manage transport that has one hand tied behind its back**

Brief Summary

The UK lives with constant **cyber pressure** compounded by **digital fragility**. The cracks are now apparent from years of digital system providers attempting to progress too rapidly. Many anomalous events come from service interruptions and complex integrations within poorly understood existing, and now AI-dependent, systems; cyber-attackers use this system noise to hide themselves. People have learned to live with a background hum of **digital uncertainty**, placing much less confidence in guidance seen to come from digital services. Ironically, this revives reliance on, and effectiveness of, **low-tech approaches** to managing and using physical infrastructure, which is increasingly showing signs of age and **diminished reliability** – human solidarity within digital obscurity.

Closer Look

UK

Two problems have blurred into one. First, everyday **digital services are brittle**: chasing dreams of progress has created complex digital systems that human operators increasingly struggle to understand both in times of (apparently) 'running smoothly' and especially in times of outage, error codes, delayed feeds and evident AI-hallucinations. Systems stay online but behave oddly and people (the travelling public and transport system specialists alike) have evolved an ambient vigilance and reliance on **human verification and co-operation**. Second, **cyber-attacks are frequent** and sophisticated. The most damaging ones poison updates quietly, hiding inside the same glitches everyone already expects. Fire drills have been joined by cyber drills with offline hours for organisations and systems operators to rehearse **lower-tech continuity**.

Meanwhile across sectors, the **vast physical infrastructure asset base is showing its age**. 2020s potholes have become part of a wider chorus of safety concerns, made very visible by a series of subsidence episodes and a major bridge failure. Monitoring and managing infrastructure are rarely left in cutting-edge digital hands for obvious reasons. **Human know-how** has been brought out of retirement with a resurrected status, and technical and wider soft skills among the public provide crude but effective coping mechanisms for using infrastructure, while political debate rages about infrastructure **maintenance budgets**.

Digital monitoring and management of transport systems

Digital capabilities are struggling with a reputation of '**muddled management**'. Specialist skills able to make some sense of monitoring and diagnostic systems are in high demand and highly priced. With systems' trust among staff and an increasingly cynical public at a low ebb, problems encountered include missing sensor data, partial interruptions, and mismatched feeds which lead to recommendations that can drift or become overconfident. There is **perpetual anxiety** about compounding effects of detected and undetected cyber-attacks. Control centres are **hives of co-operation** between digital specialists and 'old school' asset management and traffic management expertise. Transport management becomes staged release - bus, rail or shared services only "go green" once data insight streams on network conditions and demands are verified. **Human resource is at a premium**.

Takeaways

- Vignette: a comms hiccup drops vehicle counts for a minute - a pattern that *could* be tampering or just missing data - the supervisor calls Red Tag Hour: automation pauses, fallback timings load, dispatch goes manual - it turns out to be a harmless glitch, and though traffic struggles it still flows - a leak to the press conjures up critical headlines.
- Signature outcomes: contained disruptions; slower, more conservative, human-centred but nevertheless effective operations.
- Open tensions: public and professional distrust of digital systems alongside muscle-memory appetite to digitally innovate; and investment in 'tech' competing with investment in maintenance.
- Unintended consequence: resurgence in human solidarity as a bedfellow to 'overheated' digital capabilities.

Muddled Management

Scenario shaped by:

- **High** cyber-attacks intensity
- **Low** digital systems predictability
- **High** adaptability to ageing infrastructure

Scenario further characterised by:

- Digital fragility from years of being too hasty with pursuing digital progress
- People living with digital uncertainty
- Resurgent appeal of low(er)-tech approaches to adaptability
- Human co-operation and verification
- **Very different skills mix and diminished emphasis on digital capabilities for monitoring and managing transport**

Brief Summary

Climate shocks arrive faster than institutions can recover from and reset, compounded by **public health challenges**. Forewarning is limited. In spite of other countries in similar positions, the UK is well-placed in terms of its **ability to source** materials, components and (where necessary) substitutes to **keep things operational** which provides some comfort to a **public growing weary of disruption**. However, a **persisting shortage of skilled professionals** for running complex data-hungry digital systems constrains the ability to use such systems to support response and recovery. Everyday life adapts through drills, rotas, and "good-enough" restoration, staying functional, yet increasingly uneven in which people and areas are affected and in turn able to recover most effectively. **Crisis response capability** is at a premium.

Closer Look

UK

The country learns a hard rhythm: flood, heat, recover, repeat. An already **stretched NHS struggles to respond** to victims of heat stroke and other climate shock consequences alongside facing patient access challenges. **Climate shocks** overwhelm operations in multiple sectors often enough that **contingency stops being exceptional** and tends towards routine. The general public are more **alive to the realities of climate change and the importance of resilience** and adaptation than ever before and look to service providers with hope and expectation.

The supply side, ironically, improves. Such sustained volatility has seen organisations building **resilient, diversified sourcing of materials and supplies**: modular spares, and substitution lists that make "we can't get that exact part" less critical. Service providers quietly normalise multi-origin substitutes; repair crews arrive with kits designed to fit more than one generation of equipment. The bottleneck is people. **Persistent skills shortages** mean the UK can buy tools, sensors, and packaged systems but cannot staff enough experienced responders to run them well everywhere. Capability concentrates; and elsewhere, organisations lean on shared on-call schedules contractors, and simplified procedures. A new kind of inequality emerges: not just who has assets, but who has *the skilled attention* to restore them quickly when the next shock hits.

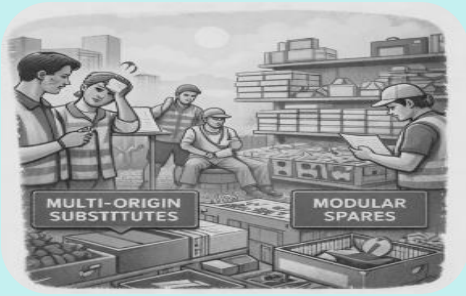
Digital monitoring and management of transport systems

Under **repeated climate shocks**, digital capabilities are used primarily for real-time incident triage - helping control rooms decide what to shut, protect, and restore first during sometimes overlapping shocks. **Resilient supply chains** ensure digital **infrastructure for monitoring and managing can remain serviceable**: sensors failing from temperature extremes can be detected and replaced; digital capabilities can be re-parameterised around approved substitutes. But **skills shortages dominate serviceability outcomes**. Only a few places have enough certified staff to keep systems current and trustworthy and in turn use them to greatest effect to support transport system functionality. Others lean on specialists (less familiar with local conditions) flown or dialled in under mutual-aid contracts when events spike. Transport management itself becomes a matter of **constant rebalancing**, shifting people or goods between modes and routes as climate shocks knock capacity in and out.

Takeaways

- Vignette: a heatwave and flash flood overlap and take out significant parts of the city centre road capacity - several management options are suggested but the local team cannot confirm the proposed response plan fast enough or weigh-up material resource needs from that available - they call in an on-call expert; until they arrive, the city runs a simplified offline plan and protects only the highest-risk corridors.
- Signature outcomes: slower decision cycles where skills are thin; more "good-enough" restorations enabled by modular spares.
- Open tensions: who gets scarce expert time first; uneven response capability; and fatigue from perpetual drills and controlled degradation.
- Unintended consequence: packaged solutions and shared on-call schedules grow, but local autonomy shrinks.

Climate Beats Capacity



Scenario shaped by:

- **High** frequency of climate shocks
- **High** skills shortage
- **Low** supply chain disruptions

Scenario further characterised by:

- Crisis response more routine than exceptional
- A public weary of disruption and reliant on recovery support
- Unevenness of recovery, related to unevenness of specialist skills availability
- Constant rebalancing of transport supply and demand
- **Crisis response capability comes into its own but such capability needed at corridor level as well as nationally**

ANNEX 3 – USE OF AI IN THIS PROJECT

Use of AI in this Project

Use of supervised AI has been the subject of growing attention. It was considered appropriate to make use of it as part of this project, while retaining emphasis on the importance of it being used responsibly as an input and complement to, rather than substitute for human effort. The project team drew on experience from similar previous projects.

AI was used specifically in: helping to generate and process an initial longlist of uncertainties; and supporting the early stages of scenario and wildcard development. It was found to be useful for:

- imposing structure and consistency on messy material, for example duplicate detection, categorisation, projection drafting and formatting uncertainty statements;
- helping accelerate divergent option generation at stages where breadth mattered, especially for triad generation; and
- helping with creative stretching, especially in generating contrasting triads and turning uncertainty combinations into more vivid, plausible first draft scenario narratives.

Limitations were nevertheless encountered:

- Outputs were not always sufficiently distinctive or decision-ready, and some required substantial checking, and subsequent elaboration or consolidation by the project team.
- For wildcard development in particular, the team found that tighter prompting could sometimes constrain the degree of stretch and surprise, so manual reworking remained important to ensure the final set of wildcards was appropriately imaginative and useful.

The key take away is that AI added most value as a support tool, not a substitute for expert judgement: while it does the initial heavy lifting, the outputs were strengthened through critical review, substantial human revision, and wider challenge through workshops and stakeholder discussions.