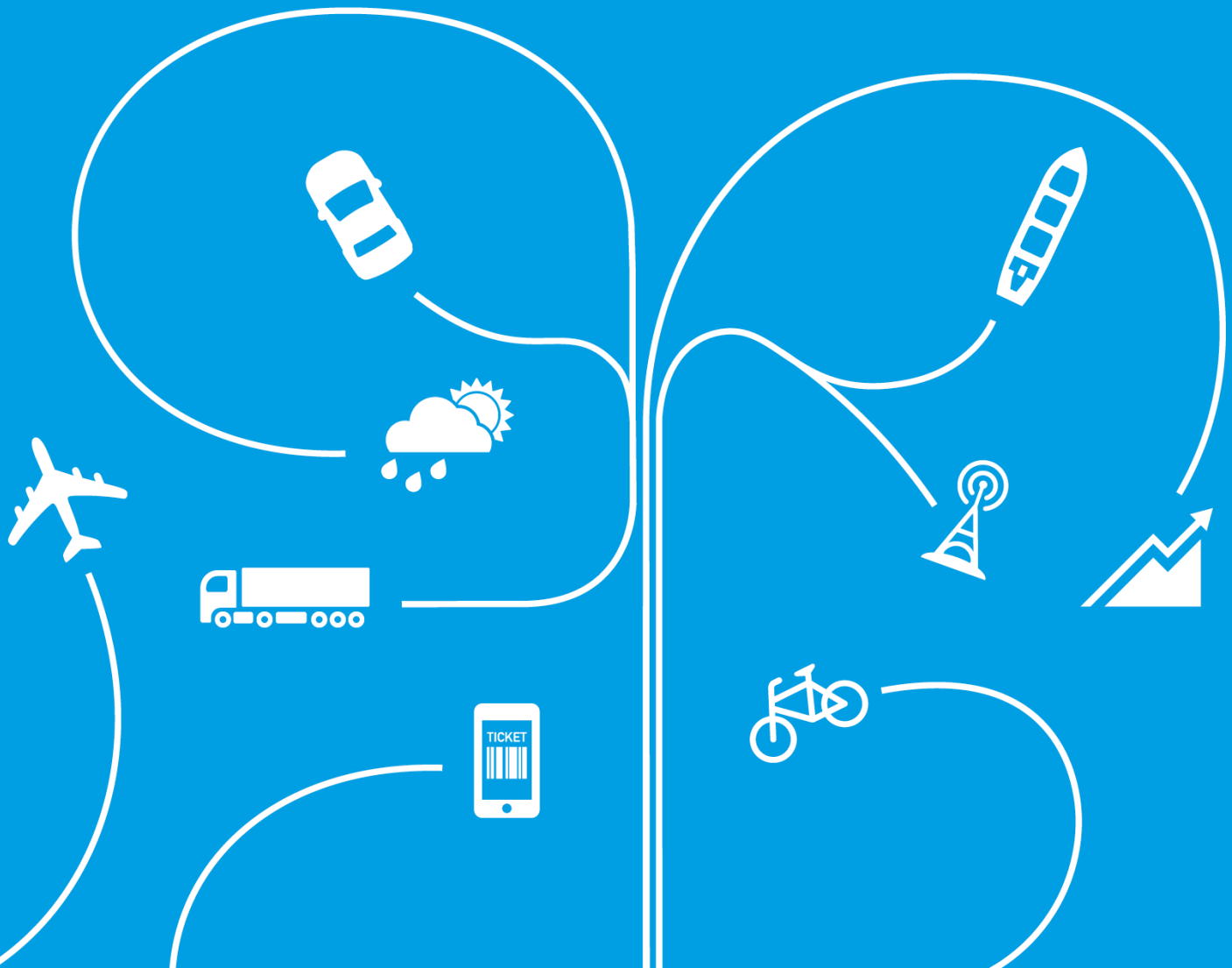
EXPLORING INTELLIGENT MOBILITY

CATAPULT Transport Systems

Highways England Strategic Road Network Simulation Sprint

Final Report



Highways England Strategic Road Network Simulation Sprint

Title:	Final Report
Release:	Final
Date:	19/07/2017
Author:	Abraham Narh
Checked by:	Paul Bate
Owner:	Paul Bate
Client:	Highways England
Document Ref:	MV49/RPT001
Version No:	A

Document Control

Document Background and Location

This final report of the prototype simulation of the Strategic Road Network highlights the challenges, barriers and lessons learnt to inform further development of the platform in Highways England's future program of works.

This document is only valid on the day it was printed.

Revision History

Date of this revision: 19/07/2017

Revision	Summary of Changes
A	Draft for client comment

Approvals

This document requires the following approvals.

Signed approval forms are in the project filing system.

Name: Paul Bate	Sign Off Statement
Date: 19/07/2017	I confirm that • the content of the attached Final Report is correct and fit for purpose given the current stage of the project. I approve • the attached Final Report for release.
Signature:	
Title: Project Lead	

Distribution (This Version)

This document has been distributed to:

Name	Date of Issue
Mark Braithwaite (Highways England)	19/07/2017

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1 Introduction

1.1 Overview

Transport Systems Catapult (TSC) in collaboration with Immense Simulations (Immense Simulations), Improbable, Télefonica and Kazendi Ltd are using the SpatialOS platform to deliver a large-scale prototype simulation of the Strategic Road Network (SRN). This prototyping phase is to help inform the HE's vision for a future programme of work to develop a national scale simulation of factors affecting SRN operations. This simulation will contribute towards the development of a "visionary platform" that includes interactive functionality to allow stakeholders at all levels to understand the consequences of different intervention strategies which may affect SRN operations, support better management of the network and ultimately provide an evidence base for future infrastructure investments.

This prototype project also attempts to address some key known barriers to realising this visionary platform and provide the confidence to proceed with a future programme of works to deliver this platform. From a use case perspective, this includes eliciting insights from stakeholders on what would be required from such a platform. From a technical perspective, this includes the ability to develop and run transport simulations with millions of moving entities at large (national) scale which are cost effective, responsive and able to be used by stakeholders of all levels.

1.2 Project purpose

The development of the prototype simulation will be undertaken as a research and development (R&D) project. The project represents a maturing of technology from low technology readiness level (TRL) to understand the barriers and challenges involved with developing the visionary platform which could support HE operations in the future. As with all R&D projects, there is a risk that deliverables for this project may not meet functional and performance expectations as a result of working on the cutting edge of technology yet to be proven in this domain application. The deliverables of this project must only be used to inform future decisions relating to the viability of the visionary platform. They must not be used to support any other decisions on the operation of or investment in the SRN.

1.3 Project objectives

The main objective of the sprint is to conduct a feasibility study of a proposed large-scale simulation of SRN operations in England and advise Highways England on its plans going forward. More specifically, the objectives are to:

1. Understand user requirements for:
    - The proof-of-concept system being develop in this research project; and
    - Insights into user needs for a fully developed system beyond the research project
2. Develop a large-scale prototype simulation of strategic road network (SRN) operations;
3. Ingest data feeds to inform the simulation across the SRN;
4. Develop a proof-of-concept user interface with limited functionality that demonstrates how users can specify and run alternative scenarios which could potentially affect the operation of the SRN;
5. Develop a proof-of-concept visualisation of the SRN simulation using mixed reality technologies;
6. Understand barriers and challenges to take this proof-of-concept prototype up the technology readiness level (TRL) scale as part of a future programme of work; and
7. Provide Highways England the opportunity to understand the benefits and challenges of undertaking a project that uses agile software development approaches.

1.4 Description of project teams

The project team is led by the Transport Systems Catapult (TSC) and the other partners are Immense Simulations, Improbable, Telefonica and Kazendi.

- **Transport Systems Catapult** are the project managers for the delivery of the prototype simulation. They drew upon their innovation expertise to run the initial workshop to gather the user requirements and definition of model scenarios; bring together the project team to deliver the large-scale simulation using mixed reality; conduct a review of project outcomes to inform a future programme of works and identify the benefits realized from the sprint.
- **Immense Simulations** are the main developers of the large-scale prototype simulation. They worked closely with Improbable to build the prototype on SpatialOS, which is Improbable's scalable compute platform for large scale simulations, and Telefonica to ingest their novel pseudo real time mobile network data that is developed purposely for this project.
- **Improbable** has built a distributed computing platform called SpatialOS, enabling developers to generate persistent, distributed simulations of a scale and complexity previously impossible. Improbable provided a licence to allow development using SpatialOS platform and expert support during the development period to help troubleshoot when using this state of the art platform.
- **Telefonica** developed a novel dataset representing a 'pseudo real-time' aggregation of demand for the strategic road network using mobile network data. The data was ingested into the simulation to help demonstrate the value of this new and emerging dataset.
- **Kazendi** are experts in the development of HoloLens, a device that layers interactive holograms over its environment to enhance visualizations in virtual and augmented reality. They integrated visualisation tools with the prototype simulation to enable visualizing of the impacts of SRN interventions on HoloLens.

1.5 Scope of work

The delivery of the prototype simulation was split over seven work packages which are designed to meet each of the objectives outlined in section 1.3. The seven work packages, the objectives they deliver against and the lead consortium partner are shown in Table 1 below.

Table 1 – Work packages

No	Title	Objectives	Lead organisation
WP1	Requirement gathering and scenario development	1	TSC
WP2	Prototype development	2, 3, 4, 7	Immense Simulations
WP3	Virtual Reality (VR) integration	5	Kazendi
WP4	Technical review and recommendations	6	TSC
WP5	Benefit realisation capture	1,2,3	TSC
WP6	Transfer of information	7	TSC
WP7	Project management and governance	n/a	TSC

1.6 Structure of report

The remainder of the report is structured as follows:

- **Section 2** describes the main activities carried out within this sprint;
- **Section 3** is focussed on the requirement gathering and scenario development workshop;
- **Section 4** presents a summary of the prototype simulation and visualisation platform;
- **Section 5** discusses the main achievements of the sprint work, and identifies the barriers, risks and lessons learnt that would be useful to further mature the capability of the prototype simulation and visualisation platform; and
- **Section 6** presents the conclusions, benefits and recommendations.

2 Delivery activities

The project was carried out through an 'agile' project management approach. This allowed for a rapid development of a prototype simulation by carrying out a number of short term focussed deliverables through an iterative process that ensured a minimum viable product was delivered within a short time scale. This is described in this section together with our collaborative working, engagement with relevant stakeholders and supporting HE at the Big-Bang exhibition.

2.1 Collaborative (and agile) working

The project was run from TSC offices in Milton Keynes, where a dedicated area was available for the operations of the project teams. This was the permanent base of the TSC and Immense Simulations, whilst the other project teams and the HE client team worked here jointly as well for periods during the project. This arrangement enabled regular engagement among project teams as well as with Highways England (the client) and visitors. TSC opened and maintained a live register of the project team members/visitors throughout the duration of the project to facilitate the engagement process.

2.2 Sprint

A 'Sprint' is a key part of working in an 'Agile' project management environment. This way of working has been pioneered in the software development industry. This involves an iterative approach to development, where each iteration is called a 'sprint'. In this project, we identified that only an agile approach to project management would allow us to deliver the project within the very short timeframe.

Periodic reviews of work progress for the project teams was conducted at every fortnight at the sprint review meetings, which offered the teams an opportunity to communicate their challenges, identified risks and plans for the next sprint. The teams reported significant progress during the sprint periods, which provided evidence to justify the agile working approach adopted for this project. In all, there were three sprints, each of two-weeks duration, and the process helped to provide visibility of each team's activity and to keep the client and partners on board how individual teams were progressing their work.

The first part of the agile process was holding a user requirements workshop. At this workshop, which was attended by staff from across HE departments, we identified a significant number of the potential requirements and use cases for a national simulation model. This allowed the client and project team to identify the capabilities that would be developed into the initial prototype simulation. Developing these capabilities formed the basis of the work which was undertaken in each sprint. The following list demonstrates the iterative nature of the development process:

- **Sprint 1** focussed on developing the national network within the simulation platform and processing data sources;
- **Sprint 2** saw the model uploaded onto the Spatial OS platform and integrated with data to enable traffic to be simulated across the network; and
- **Sprint 3** saw capabilities integrated into the platform such as lane control, speed limits etc.

2.3 Showcase at Big Bang Fair

As part of Highways England's presence at the Big Bang Fair, Kazendi showcased the HoloTraffic app alongside other holographic examples to introduce visitors to Mixed Reality and the capabilities of HoloLens. The Big Bang Fair took place from 15th – 18th March 2017, and it is the largest celebration of science, technology, engineering and maths (STEM) for young people (aged 7-19yrs) in the UK. More than 70,000 visitors attend over four days at the Birmingham NEC. Figure 1 presents samples of the footage showing interaction of Kazendi staff with the visitors during the exhibition. Over the period of the exhibition, about 500 participants aged between 4 and 19 years who had a trial at the HoloLens. We received very positive feedback from some participants that demonstrates that a good impression was made on the future scientists and engineers. Further details of the impact of the exhibition is available at: https://www.kazendi.com/blog/3-things-we-learnt-at-the-big-bang-fair-2017.

Figure 1: Footage from exhibition at the Big Bang Fair, NEC Birmingham

2.4 Engagement with relevant partners

The activities of the project also included showcasing the evolving product to various stakeholders and interest groups. We gathered from discussions with these groups that the work could potentially lead to the development of a national asset for a better coordination of the operations of the whole transport network. During the course of the sprint, we hosted the following groups at the site:

- Agility3;

- England's Economic Heartland[1];
- Graffica Ltd;
- Network Rail;
- Oxfordshire County Council;
- Highways England, including:
    - HS2 Engagement Team;
    - Information and Technology Directorate; and
    - Performance Analysis Unit.

There has already been keen interest in the development of an operational large-scale simulation from key organisations including Network Rail, Department for Transport, Transport for West Midlands, Oxfordshire County Council and other local authorities. Therefore, there is also the potential to engage and partner with these (and other) organisations in the future to produce a comprehensive and integrated national asset for highway network operations and strategic planning that also incorporates local authority roads and the rail network.

[1] England's Economic Heartland is a partnership of councils and local enterprise partnerships which represent the key growth corridor from Oxfordshire through Milton Keynes and across to Cambridgeshire.

3 Requirement Gathering and Scenario Development

3.1 Introduction

A workshop was held on 6th February 2017 to gather the user requirements for the prototype simulation and visualisation tools for the 'visionary platform', to support Highways England in the operations of the Strategic Road Network. The participants at the workshop included staff from Highways England and Network Rail in addition to those from the consortium working on the project. The overall objectives of the workshop were to:

1. Emphasise on what is more than theoretically feasible;
2. Identify functional requirements for the prototype simulation and visualisation;
3. Collate a shopping list of specific requirements for the simulation and visualisation model (The information gave insights into user needs and help to understand the requirements for a fully developed system);
4. Specific themes would be covered in three sessions at the workshop. For each of the themes, the participants were required to:
    - Identify the needs for these requirements and assign time lines for development into the simulation model; and
    - Categorise the requirements by the MoSCoW (Must have, Should-have, Could-have, Would-have) criteria.
5. Identify the scenarios feasible within the sprint project; and
6. Collate other scenarios for post-sprint planning.

Given the nature of the research it was necessary to provide an in-depth insight of the potential that exists to explore the SpatialOS platform for the large-scale simulation of the strategic road network. This was the focus of the morning session of the workshop, and members of the project teams made a number of presentations to explain the capabilities of the SpatialOS platform. The presentations particularly demonstrated the potential to scale up simulations using the SpatialOS platform as well as the ability to incorporate a wide of assets within one model by layering the features of each asset as an individual entity.

This provided a good background for the workshop sessions planed for the afternoon, each of which were to address specific sub-objectives of the overall purpose of the workshop. The descriptions of the sessions and their specific objectives are as follows:

3.2 Session 1: User case and scenario development

The specific objectives for the session on use case and scenario development are:

A. User Case – identify minimum viable product specification and acceptance criteria:
    1. Identify user/developer specifications for a prototype simulation; and
    2. Identify user/developer acceptance criteria for a prototype simulation.
B. Scenario development:
    1. Identify the likely implementable interventions in a simulation prototype;
    2. Define scenarios of SRN operations for playback simulation; and
    3. Prepare a generic register of 'what-if' scenarios (interventions) for testing in the simulation model.

3.3 Session 2: User Interface requirements

The specific objectives for the session on the user interference requirements are:

1. Identify the type of user interface to include in a simulation model;
2. Identify the type of information to visualise at run-time;
3. Identify the type of filters necessary in a simulation model;
4. Identify the types of animations useful within a simulation;

5. Identify the types of gestures necessary for visualisation in a simulation;
6. Identify the types of object dimensionality for visualisation in a simulation; and
7. Identify the types of tools needed to visualise the simulation output.

3.4 Session 3: Data requirements

The specific objectives for the data requirements are:

1. Identify the data requirements / available data for simulation model;
2. Identify datasets that would constitute a reasonable dataset for the simulation model;
3. Identify useful data currently available for the prototype simulation;
4. Identify data sources and/or where or how to obtain data;
5. Carry out a gap analysis of available data - identify useful data that is currently unavailable; and
6. What are the benefits of the available/unavailable datasets.

3.5 Session 4: Prioritising requirements

A further fourth session enabled participants to assign timelines and a MoSCoW style category to the information that was gathered during the three main sessions. This was carried out for the purposes of prioritizing the tools being developed for the project.

Table 2 provides a high-level summary of the number of items under specific themes.

Table 2 – Summary of information gathered at the user requirements and scenario development workshop

	Use Case	Scenario Development	User Interface	Data
1	Operational staff (8)	Network (re)configuring (10)	Drag & drop anything (11)	Traffic flow/signal data (18)
2	Designers/planners (9)	Simulate demand (5)	Specific user interface depending on roles/needs e.g. Annotation and documentation (7)	Accident/inventory incident (4)
3	Executives/management (7)	Simulate new development (3)	Data interface (10)	Mapping (7)
4	RIS team (3)	Extreme events (6)	Triggers/alarm prompt (emergency issues, etc. – action needed) (6)	Assets (2)
5	Environmental team (2)	Travel demand management (4)	Modelling interface (23)	Roadworks/schemes (6)
6	Safety practitioner (2)	Infrastructure/construction (6)	Evaluation interface (11)	Transport (9)
7	Site inspector (1)	Assets (2)	Project planning interface (6)	Others (8)
8	Customer (3)	Simulate innovations (1)	Integration with VR (6)	
9	Utility/insurance provider (2)	Other (4)	Customer communications interface (5)	
10	Asset management (4)		Interfaces to other tools and models e.g. APIs (8)	
11	Software developer (1)		Other (6)	
12	Transport provider (1)			
13	Innovation (1)			
14	Other (1)			

4 Large Scale Simulation

4.1 Introduction

The main development work comprised of a large-scale simulation of the entire strategic road network integrated with visualisation tools. The sprint project proved the viability of a large-scale simulation of the strategy road network, which is a proof of concept to showcase the potential of the SpatialOS platform to enable the build of persistent models for network operations in the transport industry.

SpatialOS enables developers to generate persistent, distributed simulations of a scale and complexity previously impossible. SpatialOS can integrate different models and disparate, static or real-time data sources, integrating and scaling them to create a truly informed virtual environment. This allows for predictive analysis and scenario testing demonstrating emergent behaviour, which is impossible to achieve with big data analytics alone. SpatialOS is useable as a live operational platform, enabling multiple users to manipulate and experiment within the simulation in real-time.

In summary, the research proved that:

- building a large-scale simulation platform is achievable and of value using the SpatialOS platform;
- it was possible to incorporate visualisation tools into the simulation, whilst the simulation could be viewed indirectly on the HoloLens; and
- a construction approach of iteratively developing the platform (known as 'agile' project management) allows for benefit realisation during project delivery rather than waiting until project completion. Specifically, a minimum viable product (MVP) version of the platform has been delivered early on with functional updates provided throughout the project to enable early demonstrations of the potential capability of the model.

4.2 Prototype Simulation

From the use case and scenarios developed from the initial workshop, Immense Simulations were focussed on the following deliverables for the six-weeks duration of the sprint project:

- Open platform simulation as an innovation within the industry;
- Import the entire strategic road network into a simulation;
- Simulate effect of lane closure on motorway;
- Simulate the effect of change of speed limits on SRN road links; and
- Simulate congestion propagation on SRN links.

Given the limited time frame for the sprints, the plan was to focus on what was achievable within the sprint periods and to ensure that there was a minimum viable product in place on completion of each sprint iteration. The sprints tested the possibility to deploy the SpatialOS technology, which is predominantly a gaming technology, for large scale transport network simulations as an innovation within the transport industry. By adopting an agile approach to development, we proved the ability of continuous build to incrementally advance the product from a low technology readiness level (TRL). The current focus therefore helps to instil confidence (at minimum cost) within Highways England that the visionary platform being envisaged was achievable within a suitable development period.

Immense Simulations have detailed in a modelling report the model specifications and functionality developed during the sprint. The report highlights the following:

- Data;
- Entities, comprising vehicles and links;
- Behaviours that drive the simulation including the vehicle generation and movements, and speeds;
- Scales considered in terms of network sizes and the number of modelled vehicles;
- Running the simulation;

- Deployment costs;
- Desktop visualisation with basic functionality; and
- Integration with mobile phone data.

4.3 Visualisation tools

Kazendi developed a HoloLens application to interact with the prototype simulation. The current state of development proved that mixed reality (HoloLens) could be used to visualise the traffic simulation of the entire SRN with vehicles on the SpatialOS platform, as developed by Immense Simulations. The map viewer is displayed at around the waist level, and at the macro level of zoom allows viewing of the complete SRN. The tool also allows the user to zoom into different locations and view the movement of 3D models of cars on the network. The HoloLens provides additional functionality to enable the user to select "links" and interact with the simulation on the SpatialOS server and implement for example lane closures and change of speed limits.

The deliverables were as follows:

- Visualisation of the road network created by Immense Simulations at the macro Level;
- Visualisation of detailed links (roads) network created by Immense Simulations;
- Visualisation of map of UK;
- Link start and end points correspond to geographic map;
- Model cars which move along links;
- Visualisation of congestion area in the network;
- Menus with buttons to:
    - Zoom in;
    - Zoom out;
    - Rescan room;
    - Reset position;
    - Close Road;
    - Setting speeds at 10mph increments from 20-70;
    - Set Lanes open/closed (lanes 1-6 where applicable); and
    - Return to macro view.

5 Appraisals

The TSC carried out an independent review of the sprints to evaluate the tasks completed and to understand the barriers, challenges and risks that were identified and addressed, and infer those that still potentially persist and how these could be handled for the additional planned work to further enhance the prototype simulation.

5.1 Communications plan

A communication plan was developed as part of the project. This is important for disseminating the research findings and an excellent way to showcase the unique capability being developed in this project. The plan is currently focused on the process behind the project rather than the technical outcome. In this plan, we document the process through:

- a video footage;
- develop a case study; and
- maintain a blog about the sprint process.

Interviews of the project teams was conducted on 16th and 30th March 2017. The blog entailed the following:

- What does the sprint activity entail?
- Why is this a unique idea?
- What was the solution being worked on in this instance?
- Who was involved in the sprint?
- Why is this kind of activity important/useful for the transport industry?
- What are our future plans for sprints?

A copy of the blog document is included in Appendix A. The documents will highlight the unique way of collaborative working and the accelerated timescale of the project in order to encourage other business in the transport sector to try similar processes. It also shows that significant achievement was attained through the high level of commitment of the collaborating project partners.

In formulating the communication plans, we talked about a press release as part of the solutions for disseminating the outcomes of this project. However, we do not envision doing any press activity until the system is in a position where all parties feel it reflects the quality of work we have undertaken.

5.2 Deployment costs

The cost of operating the platform will depend upon how often and how intensively it is used. The distributed platform is effectively a 'pay-as-you-go' processing power, therefore, the number of processors and the length of time in use will have a direct impact on cost. This means that there is not a single fixed cost, but a range of potential costs between, for example, $50,000 - $250,000 per year. Note that as the service is priced in US Dollars, fluctuations in the exchange rate will also have an impact on cost which cannot be predicted at this time.

5.3 Challenges, barriers, risks and lessons learnt

This project has been very successful and has demonstrated many significant achievements. However, there are still a number of challenges that were identified over the course of the project (some of which are still outstanding), together with further barriers and potential risks and there were identified throughout the process, together with numerous lessons that have been learned. The specific ones identified by the project teams are summarised in Table 3.

Table 3 – Summary of challenges, barriers, risks and lessons learnt

Challenges	Barriers	Risks	Lessons learnt
Telefonica			
Telefonica's usual approach is to process data historically which means events for a day or all analysed simultaneously. For this project, we only used events that would have been available in real time and were able to identify origins and predicts destinations based on these Outstanding There are still some technical challenges based around interpreting and transmitting the insight in real time, but we are working to build systems necessary to do this (remaining)	There is still a lot of work to be done to work out how to use the origin/destination data in a model in real time If the solution is to be truly 'real time' both Telefonica and IMSIM will need to build more automated analysis capability e.g. to calibrate the model in real time	Variation in the mobile data feed may increase the amount of interpretation needed to use the data in real time The compute platform used needs to be able to use the data provided by Telefonica	There is a lot of value in working closely with the project team to define outputs and approaches It is possible to interpret and use the mobile data in raw form (events) but different algorithms/processes are needed Advances in simulation technology mean that it will soon be possible to usefully consume real time data in a transport context
Immense Simulations /Improbable			
Development of a simulation at national scale Obtaining data from different sections of Highways England to support the simulation development Non-technical user interaction with the simulation Sharing simulation platform between third parties whilst protecting intellectual property	Configuring the deployment of the SpatialOS simulation to the cloud is currently challenging and based on experience rather than an objective workflow Ingesting real-time data feeds. The POC ingested pseudo-real-time data but work is required to develop the connectors to real-time feeds	Unity visualisation may be inappropriate for client needs so development of alternative visualisations (such as web-based dashboards) may be required Running costs of a persistent simulation may be high so further work is needed to understand the cost profile and value for money Novel technology such as HoloLens may not achieve widespread adoption	Significant stakeholder engagement is critical to gain buy-in and data access Dedicated project area has provided focussed environment for development and communication Tight collaboration between project partners is required to overcome barriers and challenges in cost and time efficient manner

Challenges	Barriers	Risks	Lessons learnt
Outstanding Building SpatialOS on HoloLens device is currently not possible Simulation currently cannot be easily packaged and executed by non-developers		so investigate alternative means to interact with the simulation	Remote working between partners slows progress Agile approach has allowed the client to tailor development throughout the project
Kazendi			
Creating a visualise the entire SRN and simulating over three million vehicles on the road network. Dealing with protected intellectual property issues i.e. SpatialOS platform (provided by Improbable) and Immense Simulations 's prototype simulation, which Kazendi was required to work from.	Inability to port the simulation visualisation directly onto the HoloLens. This was due to the current unavailability of the SpatialOS integration with the Universal Window Platform, which is a specific requirement to run the simulation on the HoloLens.	Improbable indicated that the barrier could be unblocked. However, this is identified as a potential risk, just in case the cost and time requirements tends out to be too expensive.	It is possible to visualise the simulation on the HoloLens indirectly by "remoting" it from a computer.

5.3.1 Important considerations for further redevelopment work

There are other pertinent issues that need to be addressed in any further development of the simulation model.

1. Data

Some of the key issues are with respect to third party, HE and weather data, and data streams from operating systems.

a. Third party data used in the simulation – there needs to be clear understanding of how this will be validated. Further, what, measure of confidence will be added into the programme?
b. HE data – there should be certainty the simulation will be Highways England master data sets, and it will be possible to interface this with other systems?
c. Weather data – In terms of the model ability to use weather data, there must be clarity on whether this will be from SWIS or external. If external, there must be proper mechanisms in place to validate the data. Further, adequate steps must be taken to ensure that this does not cause a conflict with other operational systems which rely on SWIS data?
d. If the simulations will take data streams from operation systems (such as live traffic data) will this cause a strain to the operational systems?

2. Imagery

Google maps (and open street maps) were used in this sprint as demonstration of the ability to import external mapping data into the simulation. Google street view for the SRN is out of date and not updated regularly. Highways England's AVIS system provides a high definition imaginary of the entire SRN, which is updated regularly. The outdated and less regularly maintained google maps may not be suitable, but the AVIS imagery data presents a much better option that must be considered in future development work.

3. Linking to other work streams

It is important that the platform is linked (or could potentially link) to other work streams within HE such as Connected Autonomous Vehicles (CAVs). As there are other related work streams (or ongoing research) within HE, it will be good to pre-position this platform to integrate naturally with them and not to completely overhaul the platform in order to integrate them at a later time. Therefore, there must be careful thinking in the development of the platform architecture, processes and algorithms to make future linkage easy, simple and seamless as possible. It is important that the emerging simulation platforms (such as being developed) must be proactive to avoid the tendency of significant investment/re-modelling required for to accommodate for example CAVs.

4. Licences

It will be important to ensure that the licensing cost of the software and SpatialOS platform is not too expensive to not become a barrier to roll over the use of the platform in HE. This may require that some mechanisms are in place, for example different level of authorisation is given to different users to minimise costs. Some of the pertinent questions with regard to licences are:

i. Are there any issues with the product being licensed?
ii. Will there be sufficient licences for staff to access?
iii. Will different staff have differing licences based on levels of access required?

5. Intellectual Property

Intellectual property rights did generate significant discussions in negotiating agreements for the sprint project. It is important to address how the IP status will allow for access, use and re-use of the data. Further, there must be clarity of ownership of intellectual property of the research outcomes, and how project teams can access the platform beyond the project. This will help to minimise risks to Highways England on the use and re-use of the platform by third parties.

6. On-going technical support

There is a potential risk to the use of the platform, if platform costs are not reasonable. Further, the use of the platform by the HE will require an initial and ongoing support from Immense Simulations and Improbable. It is important to be clear on the details of the services being provided by Immense Simulations /Improbable etc. in terms of technical support. Further, there needs to be clarity on the type of standard license agreement that will be in place and charges for updates to the system after going live will need to be acceptable.

7. User interface

A further risk is that if the user interface is not simple then there is a possibility that the product will not be attractive and useful for businesses due to its being complicated. There must be consultation with Highways England staff to tailor the user interface to meet their specific need. The level of engagement with some of the staff during this sprint project was helpful to acquire the HE system's data and others, and it will useful that this type of cooperation is encouraged in the design of the appropriate user interface.

8. Outputs

Further, the types and format of the relevant simulation output need to be clearly defined and tailored for the uses of the HE staff.

5.4 Impacts

This project demonstrated that there are a number of different areas where this project can provide useful information and experience for the transport industry. The main impacts achieved are:

5.4.1 Technical Feasibility

Through this project, we have demonstrated that it is technically feasible to develop, deploy and run a national scale traffic simulation on a distributed computing platform – An Industry First. Furthermore, we have shown that the performance of this type of model is orders of magnitude faster than the current modelling platforms with results available practically instantaneously.

5.4.2 Accelerated Development

This project has delivered a prototype of a national simulation of the HE road network over a six-week period. This is significantly quicker than it would currently take industry to do using the current modelling platforms and project management techniques.

5.4.3 Significantly Accelerated Model Run Times

Hosting the model on a cloud based distributed platform means that the only constraint on runtime performance is cost, i.e. how many cores do you want to bring on line to work on the simulation. Simulation model able to provide results virtually instantaneously, significant improvement on typical half day run-times on very latest generation of large scale models.

5.4.4 New Ways of Working (for HE)

This project was run using 'Agile' project management techniques that has proved to be successful. In this way of working we 'Sprint' to develop a minimum viable product and then develop iteratively on top of that to add additional functionality and capabilities. This project has run a series of three two-week sprints. The agile approach allowed flexibility in the design to incorporate changes/improvements when necessary, and thus provides a shift away from most conventional approaches where a finished product is delivered to the client at the end of the project when opportunities to incorporate preferences may be limited.

5.4.5 Real collaborative team working

This project demonstrates the ability to bring together different organisations with unique capabilities to work collaboratively in a transport research project. Significant periods of co-location of the client and

project team has paid dividends in terms of enabling the acceleration of the development process and creating a sense of shared ownership of the project outcomes.

6 Conclusions, Benefits and Recommendations

6.1 Conclusions

It can be concluded a large-scale simulation of the SRN is feasible, which is enabled by the SpatialOS platform (a distributed and scalable computer system). This research has demonstrated the transfer of a technology developed and deployed widely in the gaming industry to the transport domain. The technology can enable a persistent single simulation of the entire SRN to be developed, with an ability to interact and analyse the model in real-time.

The researched also showed that it was possible to develop a visualisation tool on top of the simulation model. A visualisation tool was developed as a dashboard with functionality to allow a user to select and run different options of the simulation model. There was an attempt to create the first SpatialOS visualisation in mixed reality. However, this was not possible because the platform does not integrate with the Universal Windows Platform, which is the software that runs the HoloLens.[2]

This sprint project has helped to understand the likely barriers and challenges that a full-scale developed platform will present, some of which have been de-risked, and thus provides clarity of direction for maturing the capability of the platform in Highways England's future program of works. Further development of the simulation could potentially lead to the delivery of an asset base for better coordination of network operators and local authorities.

Engagement with key organisations during the sprint project led to a cross-industry discussion on the benefits for integrating all road types and rail in one simulation model. The organisations include Network Rail, Department for Transport, Transport for West Midlands, Oxfordshire County Council and other local authorities. We envisage that this offers potential to engage and partner with these (and other) organisations in future to produce a comprehensive and integrated national asset for highway network operations and strategic planning that also incorporates local authority roads and the rail network.

Highways England must capitalise on the interests generated within the industry and build on the success achieved to lead the way for what could potentially become an all-purpose national simulation model of road/rail networks that can interact with existing public infrastructure assets, which could be layered into the model. A fully matured platform will have several benefits, which are discussed as follows.

6.2 Benefits

Significant savings could be realised by reducing the need to build, maintain and operate separate regional models of the country. This would build upon the savings currently being delivered by the regional models by moving to a single large-scale national simulation of the SRN. The single platform being proposed will in effect provide a solution to avoid duplication of efforts in operating multiple models along with the training and maintenance required for operations. This will provide efficiency savings enabling Highways England to adopt a single platform for strategic planning and operational decision making across the whole organisation. It would also reduce the need for disparate HE processes and analysis, each of which would carry an overhead of administration and maintenance which could be saved by a more integrated system.

A matured simulation will make available a single platform, which is available to all staff of all disciplines levels (e.g. scheme designers or traffic operations) to allow better decision making. This could potentially overcome operational challenges due to the absence of readily available tool for all to assess the impact of interventions affecting the operations and planning of the SRN and local road network.

This capability will provide Highways England with a tool that enables the potential outcomes of long-term planning or short-term operational solutions to be assessed very quickly before making timely decisions. A

[2] The issue related to the functionality of the windows software on the HoloLens hardware and its ability to interface with SpatialOS. A software solution has been identified to address this issue by Improbable and could be implemented (if required) in the future to resolve this issue.

significant advantage will be that turnaround times for key analysis will be quicker and more integrated resulting in a step change improvement in Highways England planning and operations.

The platform will enable traffic operators to have a better understanding of the network-wide impacts of proposed interventions and consequently inform decisions that will smoothen the flow of traffic to minimise the adverse impacts of congestion. This will potentially reduce the economic costs of consequences by enabling more proactive and real-time management of the network by simulating on-demand the likely impacts of different intervention strategies on SRN operations. There would also be significant environmental benefits due to the reduction in the levels of congestion.

This system would fundamentally change how Highway England, as an organisation, accesses and interacts with data on the operations of its network. A common set of tools and data will become available to all members of Highways England staff making information and insights available to all with significant benefits for the operation and planning of the network.

The large-scale simulation will provide a national all-purpose model to enable assessing and mitigating against adverse network conditions. Highways England would therefore benefit from a gradual shift away from the current dependence on the need to run several models in support of its network operations.

6.3 Recommendations

Based on the conclusions above, we recommend the following:

6.3.1 Maturing the prototype simulation

The research outcome proved that the potential for a large-scale simulation is plausible; however, the development is still at a low technology readiness level and therefore further development is required to accelerate the maturity of an innovative one 'model for all' for use within our businesses. We propose that there will be merits to bring on board additional functionality to support Highways England decisions affecting the SRN operations. This could potentially evolve as an asset base to integrate and provide tools to support planning for operational delivery of both investment programmes and tactical responses, which explicitly opens the way for cross-directorate, cross-organisational and cross-regional collaboration.

6.3.2 Use case and model scenarios

Significant information was gathered at the preliminary workshop designed to understand the user requirements for the prototype simulation and visualisation model. Due to the extremely tight time constraints for the prototyping phase, it was not possible to incorporate all the functional requirements collated from the workshop. However, there is a clear understanding of the additional functionalities required to mature the prototype simulation from a low to high technology readiness level. The information gathered could serve as good reference for the further development of the simulation and visualisation model. Further discussion of the use case and model scenarios will be useful to scope out fully the work to be carried out in the follow-on project.

6.3.3 Engagement with relevant parties

Highways England could consider collaborating with other organisations to accelerate the process to mature the platform. Given the interest shown by external organisations in the prototype simulation, and the willingness to see its full maturity, coupled with an aspiration to develop similar capability, we find that such collaboration will be very useful. We recommended that the conversations with them should be pursued and sustained going forward. Local authorities will be able to provide access to models/information in relation to local roads that could be ingested into the model in order to expand the coverage of the simulation to include roads other than the SRN. Other network operators such as Network Rail envision that a platform of this nature will be beneficial to support the operation of the railway network. Further engagement with these organisations could potentially lead to identifying partners to collaborate with to develop a comprehensive and integrated national asset for roads and rail network.

6.3.4 Agile approach

The agile project management approach adopted to execute the sprint project proved extremely successful. The approach was flexible and allowed new features to be added iteratively on top of the initial minimum viable product developed. This offers significant benefits compared with traditional approach where there is no guarantee that the expected product will be delivered at the end of the project. In this approach, Highways England had visibility of how the product evolved from inception to completion, which allowed progress to be monitored as well as make the necessary suggestions on time to refine the products as and when was necessary. We found that this approach was beneficial to all partners and it is highly recommended that such good practise is retained for the further development of the prototype simulation.

Appendix A

Blog document

What does the sprint activity entail?

The purpose of this project was to develop a prototype simulation model of the entire strategic road network (i.e. all Motorways and Trunk Roads within England). This simulation should be able to be integrated with visualisation tools to assist Highways England in the operation of their network. The simulation takes advantage of the distributed computing platform provided by 'SpatialOS' that enables the hosting of large scale and detailed simulations, which overcomes the limitations of current traffic modelling platforms. In the long-term, the national simulation offers Highways England the opportunity to bring together its current traffic models and other network systems and databases together in one place to provide a single source of information to support its business operations.

A 'Sprint' is a key part of working in an 'Agile' project management environment. This way of working has been pioneered in the software development industry. This involves an iterative approach to development, where each iteration is called a 'sprint'. In this project, we identified that only an agile approach to project management would allow us to deliver the project within the very short timeframe.

The first part of the agile process was holding a user requirements workshop. At this workshop, which was attended by staff from across HE departments, we identified all of the potential requirements and use cases for a national simulation model. This allowed the client and project team to identify the capabilities that would be developed into the initial prototype simulation. Developing these capabilities formed the basis of the work which was undertaken in each sprint. The following list demonstrates the iterative nature of the development process:

- Sprint 1 focussed on developing the national network within the simulation platform and processing data sources
- Sprint 2 saw the model uploaded onto the Spatial OS platform and integrated with data to enable traffic to be simulated across the network
- Sprint 3 saw capabilities integrated into the platform such as lane control, speed limits etc.

Why is this a unique idea?

This is unique from a technical perspective because Highways England (or indeed any other national transport network operator) have not (to date) developed a simulation model of the scale that is envisaged for this project. This is primarily of the scale of the computing resources that are required for such an endeavour, which are only now becoming available due to the advent of low cost cloud based computing. The national simulation will enable disparate Highways England systems to be brought together enabling a common set of tools for the assessment of the network impacts, which has the potential to provide significant efficiency savings within HE. The visionary platform envisaged is unique, has significant support of several external organisations, and could potentially become the main foundation for a national simulation model covering all of the strategic and local road network.

The project is also unique for HE due to the project management approach that was adopted. The agile approach adopted for this project enabled a rapid development of a prototype simulation by carrying out a number of short term focussed deliverables through an iterative process that ensured a minimum viable product was delivered within a short time scale.

What was the solution being worked on in this instance?

To develop a full-scale prototype national simulation of the SRN. The prototype consists of the minimum viable product, which is a simulation of the entire SRN, together with representative traffic, but with limited functionality. This comprises all SRN links and junctions; ability to close/open a lane; implement speed changes on road sections; incorporate congestion propagation algorithm and vehicle routing.

Who was involved in the sprint?

There were six organisations involved in the sprint project - Transport Systems Catapult, Immense Simulation, Improbable, Telefonica, Kazendi and the client, Highways England.

The Transport Systems Catapult are project manage this prototype project. They draw on their innovation expertise to run the initial user requirements workshop; bring together the project team to deliver the large-scale simulation; conduct a review of project outcomes to inform a future programme of works and identify benefits realised by conducting this project.

Immense Simulations are the main developers of the large-scale prototype simulation. Immense Simulations will work closely with Improbable to build the prototype on SpatialOS, Improbable's scalable compute platform for large scale simulations, and Telefonica where they will try to ingest some of the novel pseudo real time mobile network data that will be developed for the purposes of this project.

Improbable has built a distributed computing platform called SpatialOS, enabling developers to generate persistent, distributed simulations of a scale and complexity previously impossible. Improbable will provide a licence to allow development using SpatialOS and expert support during the development period to help troubleshoot when using this state of the art platform.

Telefonica will develop a novel dataset representing a 'pseudo real-time' aggregation of demand for the strategic road network using mobile network data. The team will try to ingest this data (which may inform on real time origin's and destinations, traffic flows and speeds across the network) into the simulation to help demonstrate the value of this new and emerging dataset.

Kazendi will draw on their experiences in the development of HoloLens, a device that layers interactive holograms over its environment to enhance visualizations in virtual and augmented reality, to enable visualizing of the impacts of SRN interventions in the prototype simulation.

Why is this kind of activity important/useful for the transport industry?

There are a number of different areas where this project can provide useful information and experience for the transport industry, these are:

Technical Feasibility

Through this project, we have demonstrated that it is technically feasible to develop, deploy and run a national scale traffic simulation on a distributed computing platform – An Industry First. Furthermore, we have shown that the performance of this type of model is orders of magnitude faster than the current modelling platforms with results available practically instantaneously.

Accelerated Development

This project has delivered a prototype of a national simulation of the HE road network over a six week period. This is significantly quicker than it would currently take industry to do using the current modelling platforms and project management techniques.

New Ways of Working (for HE)

This project was run using 'Agile' project management techniques. In this way of working we 'Sprint' to develop a minimum viable product and then develop iteratively on top of that to add additional functionality and capabilities. This project has run a series of three two-week sprints. The agile approach allows flexibility in the design to incorporate changes/improvements when necessary, and thus provides a shift away from most conventional approaches where a finished product is delivered to the client at the end of the project when opportunities to incorporate preferences may be limited.

Real collaborative team working

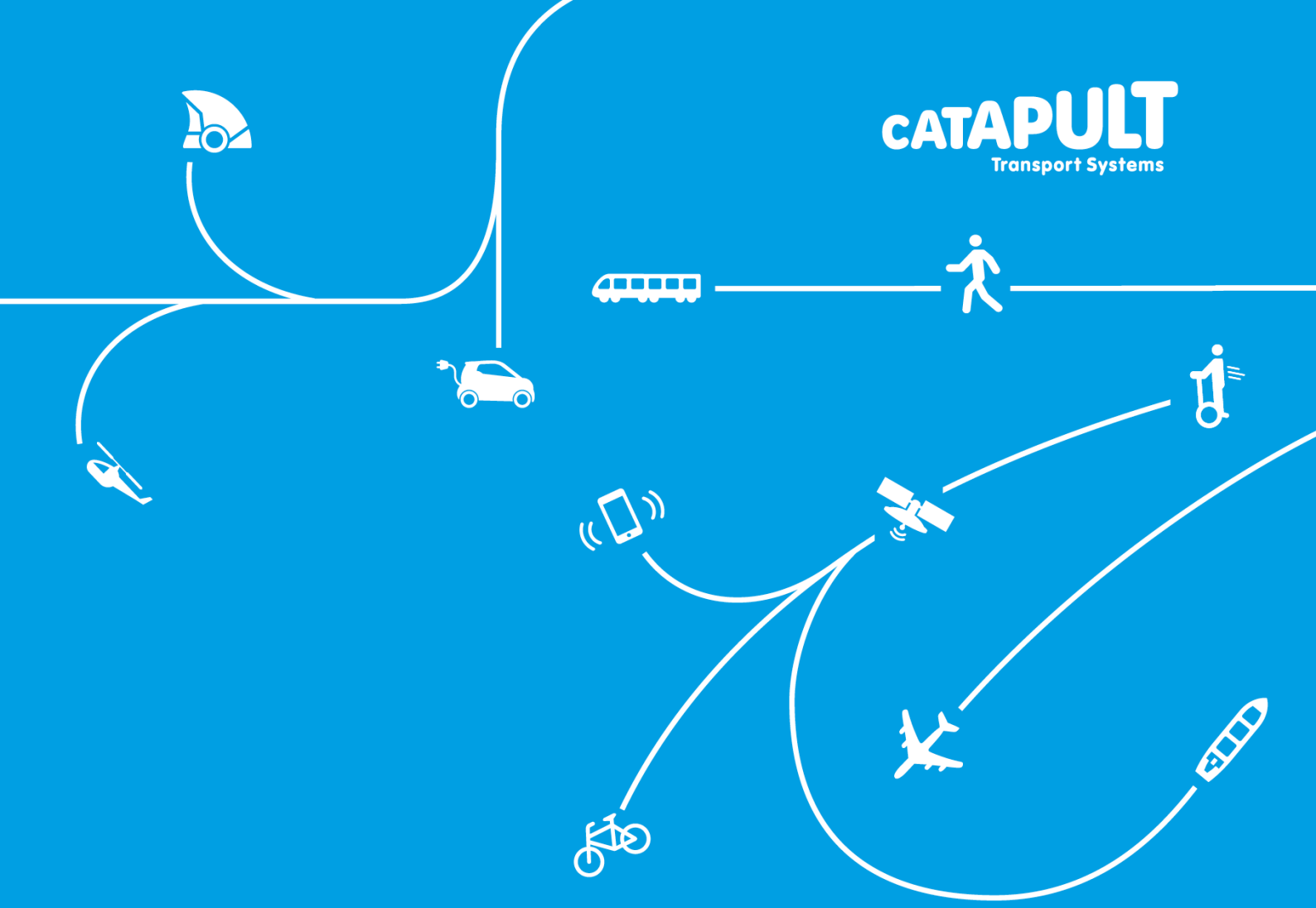
This project demonstrates the ability to bring together different organisations with unique capabilities to work collaboratively in a transport research project. Significant periods of co-location of the client and project team has paid dividends in terms of enabling the acceleration of the development process and creating a sense of shared ownership of the project outcomes.

What are our future plans for sprints?

The success of this project has highlighted to both the project team and client the benefits of working in an 'agile' project management environment to enable accelerated delivery programmes. The TSC will be

continuing to use this methodology for other projects that it is undertaking and have highlighted to Highways England that we would use this methodology in any further developments to the Digital SRN simulation.

CATAPULT
Transport Systems



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