D3.10: Modelling future mobility

Designing logistics models for a driverless fleet

March **2018**

This report is a deliverable for the GATEway project consortium based on the findings of the trial 3 research study. It was written and designed by DG Cities and reviewed by the project lead TRL.

DG Cities Ltd is the commercial arm of Digital Greenwich, the Royal Borough of Greenwich's in-house smart city team**.** As a team, DG Cities Ltd offers a broad mix of skills in smart city strategies, urban innovation, economics & business development, sustainability, the modern built environment and technology management. Our focus areas are in the disciplines which support smart city innovation, including: the economics of the digital economy**;** smart mobility and autonomous transport**;** sustainable spatial development and integrated planning**;** citizen facing services and government as a platform**;** urban energy systems**;** multi-city collaboration and procurement.

GATEway is an £8 million project funded by Innovate UK and industry and led by TRL. Based in the Royal Borough of Greenwich in London, it comprises of a team of leading companies and academic institutions. It is a technology-agnostic programme of automated vehicle research and test criteria development that enables industry, government and society to gain critical knowledge, safely accelerate innovation and deliver smart city integration.

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1. Introduction

This is an addendum to the "**GATEway Trial 3: One decade toward a driverless world**" by DG Cities on behalf of the GATEway consortium.

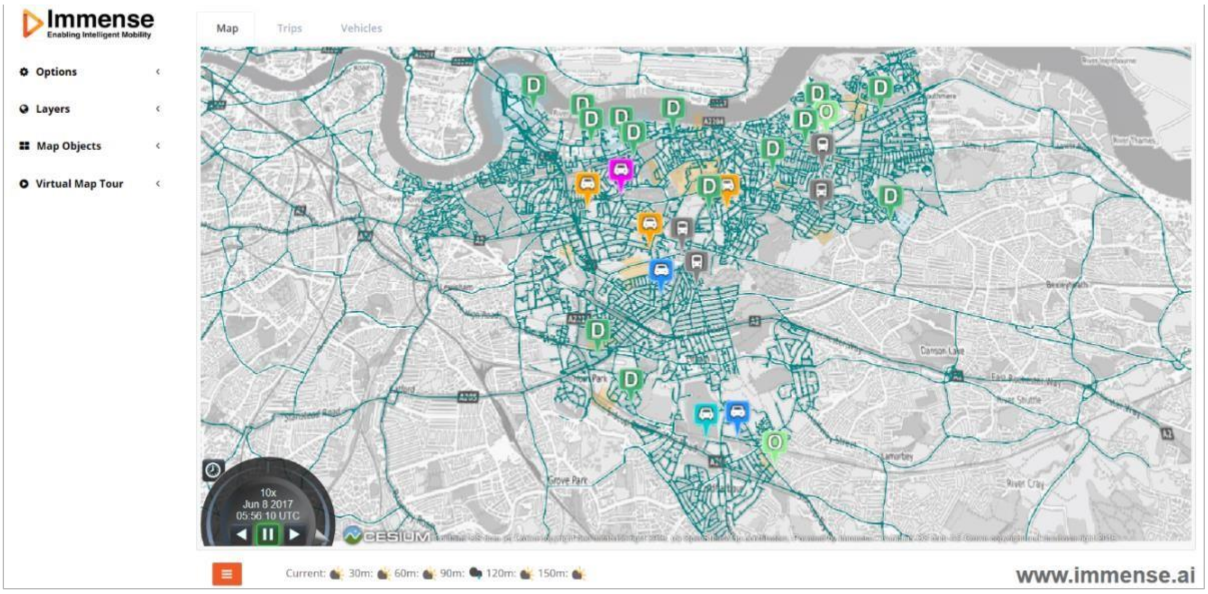
Scope

GATEway Trial 3: Last Mile Logistics aims to develop knowledge of citizen and industry perceptions of the use of Connected Autonomous Vehicles (CAVs) in the context of last mile delivery of goods to people. Although live trials have been carried out for autonomous grocery deliveries in Greenwich as part of GATEway, DG Cities wish to understand the wider implications for 'last mile' delivery and logistics within RBG.

To facilitate this, DG Cities wishes to leverage Immense Simulations' domain knowledge and simulation capability to model such logistics scenarios. Immense are launching a cloud-hosted software platform that deliver insights for decision support and optimisation for the movement of goods and have history of project delivery for major transit and local authorities interested in testing scenarios for the future of their road networks. DG Cities have therefore requested that Immense develop a tool enabling simulation configuration to assess some potential impacts of third parties operating 'last mile' delivery and/or logistics operations in the RBG.

Figure 1 - The approach enables DG Cities to test the impact of different last mile logistics scenarios

within RBG



Objectives

Overall, DG Cities defined the following objectives for the work carried out with Immense Simulations:

No.	Objective	Benefit
1	**Demonstrate the viability** of using different logistics solutions for last mile delivery in urban environments including the use of autonomous vehicles (AVs), bicycles and conventional motor vehicles	**More informed business case** for last-mile logistics within the RBG
2	**Identify potential impacts** within the RBG in adopting different last mile logistics solutions	**Better evidence** for communication to the public and key stakeholders and **more targeted mitigation planning** for previously unknown or unquantified adverse impacts
3	Facilitate the **identification of potential infrastructure and policy changes** to accommodate future logistics solutions	**Improved environment and** control to operate last mile logistics within RBG
4	Enable DG Cities to **access decision support tools** to ask their own what-if questions	**Reduced dependency on experts** to run simulations and thus reduce assessment times and costs

Further to these objectives, the following policy options have been identified for assessment:

- The reduction of day time trips by moving logistics operations to night time running
- The reduction in trips and fleet size required through optimising fleet operations through the use of consolidation centres
- The reduction in CO_2 emissions through moving from diesel fuelled vehicles to electric vehicles

These policy areas were tested through the development of 'what if' scenarios (detailed in section 2) which were modelled within Immense Simulation's platform. Section 2 outlines the modelling approach, section 3 covers the results and findings and section 4 presents recommendations based on the findings.

2. Modelling Approach

This section describes the modelling approach that DG Cities and Immense Simulations have taken to fulfil the objectives outlined in Section 1 of this addendum.

Overview of Approach

The geographical scope of this project is the RBG. The types of logistics scenarios to be simulated was be driven by DGC's requirements and the availability of relevant data. As part of informing this proposal, DGC have conducted an initial high-level review of likely data availability pertaining to different existing logistics scenarios and the likelihood of being able to influence future operations. This high-level assessment is summarised in Table 2 below.

Table 2 - Existing RBG logistics - likelihood of data collection and scope for influencing how deliveries are made

Data Source	Likelihood of Receiving Data	Scope to Influence How Deliveries are Made
SE London freight consolidation scheme: data on Council deliveries	***High***	***High***
Delivery data from the Low Emission Neighbourhood Project	***High***	***High***
Sainsburys: data on logistics movements in the borough	***High***	Low
Data from other retail orgs e.g. Ocado	Low / **Medium**	Low
Data from other logistics orgs e.g. Yodel	Low	Low

Global 78: data on food and drink deliveries in Greenwich Town Centre	***High***	**Medium**

From the initial high-level assessment summarised in Table 2, the highest value uses cases in terms of both likely data availability and scope to influence were: Council deliveries; and deliveries associated with the Low Emission Neighbourhood.

These types of delivery formed the focal point to help drive an initial project exercise of identifying required simulation features. Having tangible use cases helped elicit feature requirements. Ultimately the configured scenarios delivered by this project allowed DG Cities, to:

- replay current logistics operations of the selected use cases (which may operate differently in different parts of the RBG) and benchmark, to be agreed, key performance indicators (KPIs); and
- test the impact on the KPIs of simulating alternative logistic operating models.

A list of adjustable parameters that were considered for implementation is shown in Table 3

Table 3 - Possible parameter set for configuring RBG delivery scenario

Parent Parameter	Child Parameter	Possible range of values / description	Implementation likelihood
Fleet configuration	Size	Number of vehicles per fleet	***High***
	Vehicle composition	% distribution of vehicle types	**Medium**
	Depot locations	Coordinates of depot locations	***High***
Fleet vehicle configuration	Type	Bicycle, AVs, electric vehicles, conventional vehicles	***High***
	Maximum speed	Max speed in kph	**Medium**
	Accessible Infrastructure	Conventional road network, AV corridors, cycleways	***High***
	Capacity	Number of "parcel units" per vehicle	***High***
	Capacity per consignment	Number of consignments per vehicle by consignment type	Low

	Range	Number of kms on full tank	***High***
	Fuel type	Electric, diesel, petrol	***High***
Vehicle charging / refuelling	Charging points	Coordinates of electric vehicle charging points or petrol stations, recharge times and capacity	***High***
	Recharge time	Time to fully recharge / refuel	***High***
	Capacity	Number of charging / refueling bays	***High***
Consignment configuration	Type	Small parcel, large parcel, perishable etc.	***High***
	Delivery time window	Target delivery time from time of pickup	Low
	Size	Number of "parcel units"	***High***
Delivery strategy	Single	Vehicles that deliver only one type of goods	***High***
	Multiple Purpose	Vehicles that might deliver several types of goods (e.g. food and parcels)	Low
	Centralised distribuition	Goods would be first distributed to consolidation centres in the borough, and from there they would be distributed to the final recipient.	**Medium**

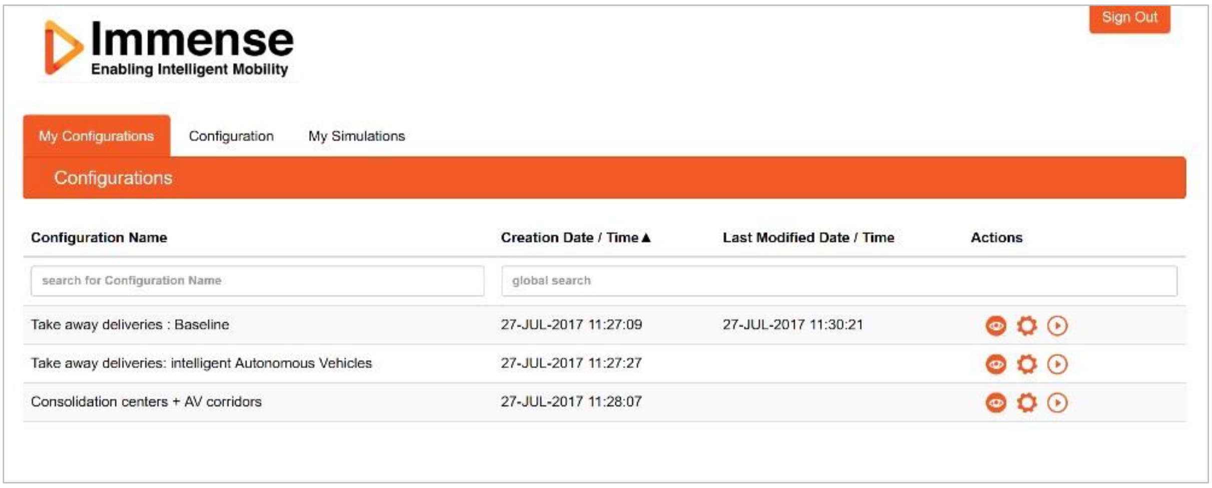
Deliverables

Table 4 - Project deliverables

Deliverable	**Description**
D1	Scenario configurations developed during the project
D2	License to our online platform to run simulations (expires 3 months after project end 2018)

The main deliverable of the project was access to the simulation platform and the ability for DG Cities to configure and run different last mile logistics simulations within the RBG. A screenshot of the online platform can be seen in Figure 2 below. The out puts of these runs are shown later in this report.

Figure 2 - Immense's online platform



Project Programme

The work was split into two work packages:

Work Package 1 – Requirements gathering and platform preparation

Requirements gathering and Platform preparation

A workshop with DG Cities to understand the configuration requirements of the simulations to be developed associated with the selected use cases and to identify the KPIs required to measure simulation performance.

Following the requirements gathering workshop ImSim provided estimates of the features and KPIs which were to be accommodated within the project and refined this list with DG Cities.

Work Package 2 – Simulation configuration and analytics dashboards

Develop baseline model

A baseline model was built by configuring a RBG network to include the conventional road network, AV corridors and cycleways using a combination of datasets likely to include Open Streetmap and AV corridor routes developed through the Gateway project.

The level to which the simulation replicated current delivery operations was limited by the availability of sufficient data. Once the baseline model was developed, benchmarked KPIs were displayed in an analytics dashboard (see below) which scenario testing results can be compared against.

Test logistics configurations

Upon completion of the baseline model, ImSim tested different simulation configurations by setting different parameter values delivered as part of the Platform preparation work undertaken in Work Package 1. The tests were for the purposes of ensuring the functionality of new features added to the platform were correctly invoked within the specific simulations being built for this project. The tests are not exhaustive but instead provided confidence that the configurations chosen for simulation included the desired functionality.

Development of tools and/or dashboards for comparison of solutions

The development of dashboards provides an easy to understand visualisation of the results, which would allow DG Cities and stakeholders to quickly gain insight into the impacts of the scenarios being tested. Immense has already developed some dashboards (see Figure 4 as an example of the developed dashboard).

Figure 4 - Immense's analytics dashboards

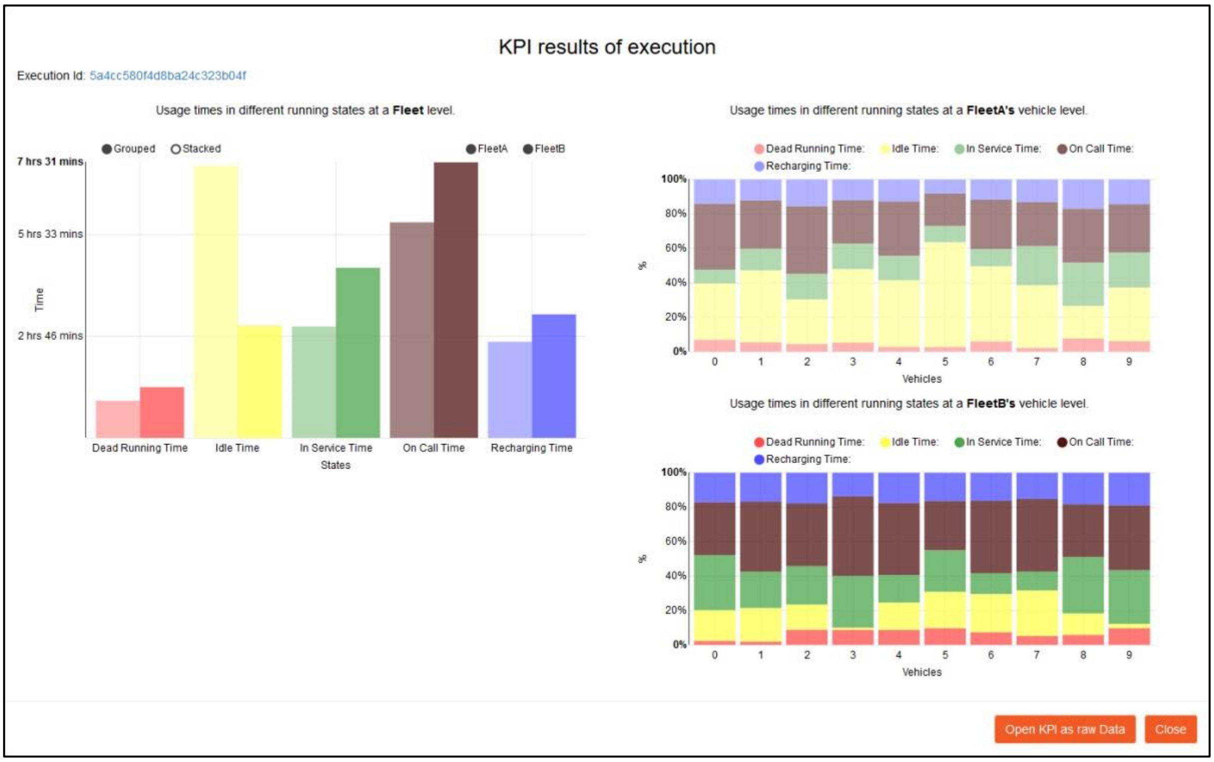
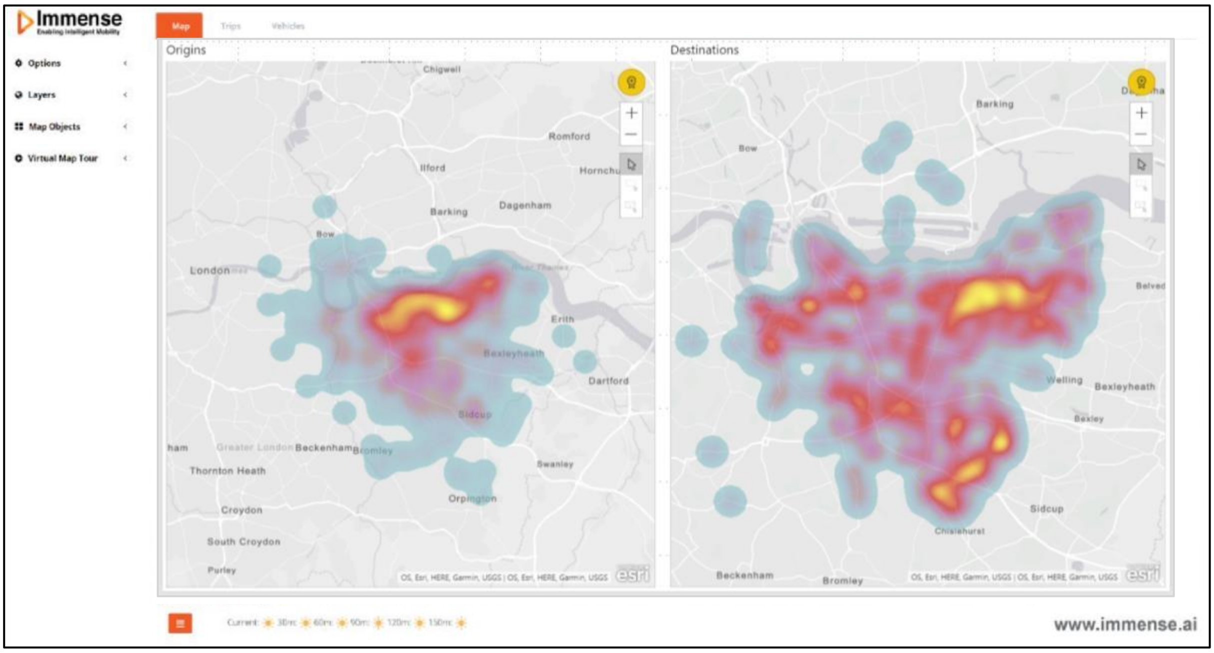


Figure 5 - Immense example visualisation output



Data Collection

DG Cities, as part of the GATEway Trial 3 Last Mile Logistics work, undertook interviews with experienced logistics staff working in the retail and logistics industry. These interviews focused on gaining qualitative insights into the awareness and readiness of CAVs within the industry and their potential application within last mile logistics.

A subsequent exercise was undertaken with these interviewees to acquire data to support the modelling exercise covered in this addendum. The data requested included:

- Number of trips within Greenwich
- Origin and destination of trips
- Times of deliveries
- Trip times
- Depot locations
- Store locations

The data obtained from two organisations that were interviewed was used in the construction of the scenarios.

Design of Scenarios

Three potential scenarios were initially identified for modelling:

1. The impact of a goods-in, waste-out consolidation centre within the Greenwich Peninsula
2. The impact of mini consolidation centres positioned strategically around Greenwich Town Centre
3. The potential impact of using CAVs for the optimisation of movement of vulnerable individuals around Greenwich who rely on Local Authority services The data obtained ultimately supported the design of two scenarios:

1. **Scenario 1** – The optimisation of a retailers local last mile delivery from their depot in Greenwich to their local stores. The baseline scenario recreated their current daytime

delivery patterns and the comparison scenario moved deliveries to the night time. Vehicles were also moved from diesel to electric CAVs operating as an optimised fleet within the model

2. **Scenario 2** – The creation of three mini consolidation centres located strategically around Greenwich Town Centre to receive and consolidate deliveries to town centre locations**.** In this scenario, the policy objectives were:

    a. Reduce day time HGV trips in the borough, and eliminate day time HGV and LGV trips in Greenwich Town Centre during the day time, by moving to CAV night time deliveries to mini consolidation centres rather than direct to town centre destinations

    b. Reduce day time trips within Greenwich Town Centre by running a smaller optimised CAV fleet to deliver goods from mini-consolidation centres to local businesses during the day

    c. Reduce emissions by moving from a diesel-based fleet to electric fleets The following assumptions have been made in the creation of this scenario:

- 100 business locations receive deliveries daily within Greenwich Town Centre
- Each business receives 3 deliveries per day
- Goods can come from anywhere such that all the main access roads to the borough are used as 'origins' within the model
- Electrified delivery vehicles to local businesses re-charge at the mini consolidation centres

Development Process

To deliver the first application of the simulation engine for logistics, Immense used an 'Agile' development approach, whereby the process of defining tool requirements, their development and evaluation is a live process involving the Immense development team working very closely with DG Cities. Development was split into a series of 2-week sprints, whilst a direct pipeline was set up to allow DG Cities to feedback on bugs, issues and feature requests, which then get prioritised and fed into product development pipeline during sprint planning. This ensures that the developed logistics product is aligned with expectations of the GATEway project and enables Immense to always have a working version of the product for continual improvement.

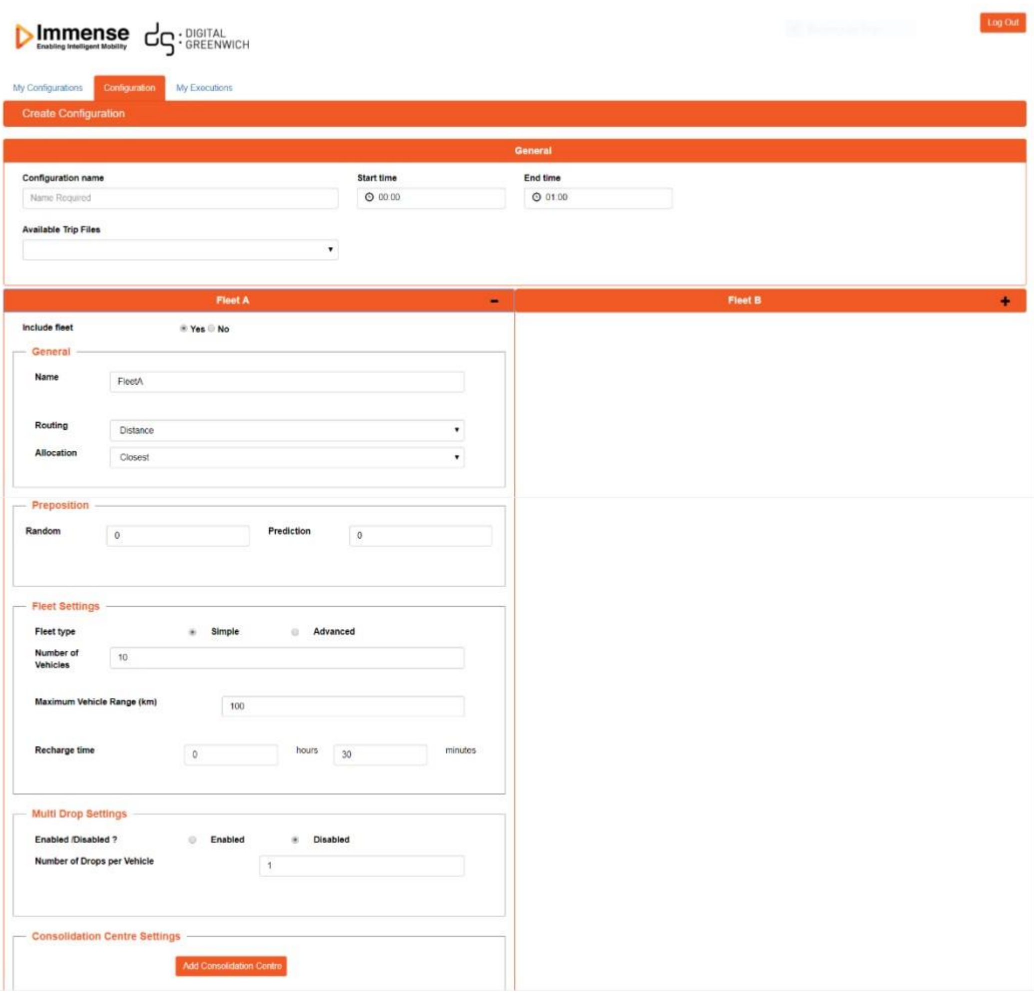
The Immense City Activity Platform (CAP) has historically been used to configure and test scenarios for passenger fleet deployment, with a standard set of embedded features as follows:

- Scenario Configurator ○ Location ○ Time of Scenario ○ Trip demand profile
- Fleet Configurator ○ Number of Vehicles
- Vehicle Configurator ○ Range (xxx km) ○ Recharge Time (xx mins)

In order to customise the tool for advanced logistics and GATEway in particular, several key features were developed to complement existing capability and enhance usability. Specifically, the features generated were:

- Customer able to configure and upload trip demand profiles
- Vehicle Configurator ○ Vehicle Multi-Drop Capacity
- Consolidation Centre Configurator ○ Locate Consolidation Centre ○ Assign Consolidation Centre to fleet
- Queuing mechanism to run multiple simulations

- Fleet charging/refuelling at consolidation centre The final configuration tab layout is shown below.



As part of the development process, a tailored user guide was created to enable trouble-free use of the various existing and new features.

Key Performance Indicators

To compare the two modelled scenarios with the baseline scenarios, the following Key Performance Indicators (KPIs) were chosen:

- **Vehicle Hours** – This is the sum of all the individual trip times across all trips on the network
- **Vehicle Kilometres –** This is the sum of all the individual trip distances across all trip on the network
- **CO_2 Emissions –** This is the reduction in CO_2 emissions by moving from diesel-based fleets to electric fleets. It is assumed that the electricity generated to support the charging of electrified vehicles comes from 'clean' sources and does not just transfer carbon emissions from direct (the vehicle) to indirect (power generation facilities) sources

The purpose of measuring these KPIs, including the assumptions made, are to demonstrate the potential societal impacts from policy decisions outlined in the scenarios

3. Findings

Scenario 1

The local operations of a large retailer were modelled to understand the potential impact and benefits that CAVs enable in terms of night time running. The reduction in CO2 emissions has also been estimated by moving from diesel to electric drive trains.

The depot is located within the Greenwich Peninsula and there are 5 stores within the borough all serviced by 1 HGV which makes 5 trips each day, one to each store from the depot.

Through moving to night time running, the retailer could reduce the number of vehicle hours they have to operate by **38%** for travelling the same distance and routes. This is driven by smoother traffic conditions during the night compared to the day time.

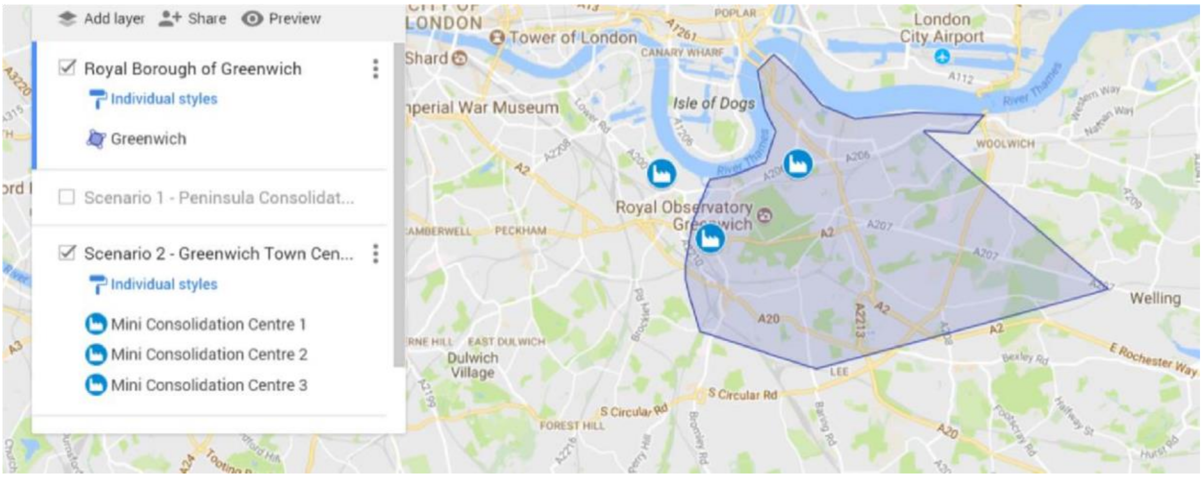
The retailer could also reduce their CO2 emissions by up-to 13.7 tonnes annually just within Greenwich by converting to electric rather than diesel drive trains. (This assumes clean energy can be used to recharge the vehicle).

Scenario 2

Scenario 2 represents an expanded worked example based on the data we obtained. As outlined in section 2, scenario 2 is focused on understanding the following policy options:

- Reduce day time HGV trips in the borough, and eliminate day time HGV and LGV trips in Greenwich Town Centre during the day time, by moving to CAV based night time deliveries to mini consolidation centres rather than direct to town centre destinations during the day
- Reduce day time trips within Greenwich Town Centre by running a smaller optimised CAV fleet to deliver goods from mini-consolidation centres to local businesses during the day
- Reduce emissions by moving from a diesel-based fleet to electric fleets

The figure below shows the extent of the Borough of Greenwich and the location of the miniconsolidation centres



Below is a recap of the assumptions made in the building of this scenario:

- 100 business locations receive deliveries daily within Greenwich Town Centre
- Each business receives 3 deliveries per day
- Goods can come from anywhere such that all the main access roads to the borough are used

as ‘origins’ within the model

- Electrified delivery vehicles to local businesses re-charge at the mini consolidation centres
- The delivery fleet to the consolidation centres is a mixed HGV / LGV fleet
- The size of the baseline delivery fleet is 50 vehicles
- Consignments come in various sizes and we assume full utilisation of both the baseline fleet and the optimised town centre fleet
- The optimised fleet within the town centre is an LGV only fleet (up to 4.25 Tonnes)

Results from this scenario:

- **By moving from day time to night-time deliveries, HGV and LGV daytime vehicle kilometres and vehicle hours are reduced by 92%**
- **Elimination of HGV trips in Greenwich Town Centre during the day**
- **A reduction in the number of vehicles needed to enter the town centre from 50 to 8**
- **By moving from diesel-based drive trains to electric drive trains (assuming clean energy production to recharge the vehicles) CO_2 emissions within Greenwich can be reduced by 424,910 tonnes annually**

4. Recommendations

The modelling work undertaken as part of GATEway Trial 3 has used the insights gained from industry interviews to construct scenarios that utilise:

- Increased night time running enabled by CAV technology due to the lack of need for a driver
- Mini consolidation centres to hold goods delivered at night so local businesses can still receive deliveries during normal working hours
- A dedicated LGV CAV fleet to serve specific areas of Greenwich (in the case of scenario 2, it is the Town Centre), reducing HGV and LGV traffic within these areas
- Moving from diesel-based drive trains to electric based drive trains, assuming clean energy production for recharging to reduce CO_2 emissions

The results from the two scenarios modelled (see section 3) demonstrate positive improvements in the policy areas identified. These results enable the following recommendations to be made:

1. **Night time running:** The results of this modelling exercise support a policy decision towards night-time running of CAV enabled logistics fleets. This has efficiency benefits for logistics operators (38% reduction in vehicle hours on the network based on scenario 1) as well as removing daytime HGV and LGV traffic from local roads during the daytime.
2. **The use of mini consolidation centres**: This study confirms that mini-consolidation centres are a valuable element in the logistics chain, enabling night time deliveries to be made to these depots, and also enabling smaller more optimised fleets of vehicles to serve local businesses from these consolidation centres during the day.
3. **Last mile optimised fleet:** Through the use of mini-consolidation centres, and fleet optimisation algorithms, the fleet size required to serve local businesses (see scenario 2) can be significantly reduced and can eliminate HGVs within the target area.
4. **Moving from diesel to electric drive trains:** The modelling work carried out also enables reductions in CO_2 emissions to be made by moving from diesel drive trains to electric drive trains. Coupled with CAV technology and charging points at consolidation centres, and a requirement that vehicles are recharged using clean energy sources, the upper bound of reductions in CO_2 emissions in the results of the modelling represent significant potential savings through the combination of electric drive trains and CAV technology.

This work has demonstrated that the Immense Simulation platform provides Local Authorities with a useful tool and platform to conduct 'what-if' scenario analysis in the policy domain. Taken as a whole, the recommendations made in this report demonstrate that realistic policy choices can be tested and the benefits quantified.