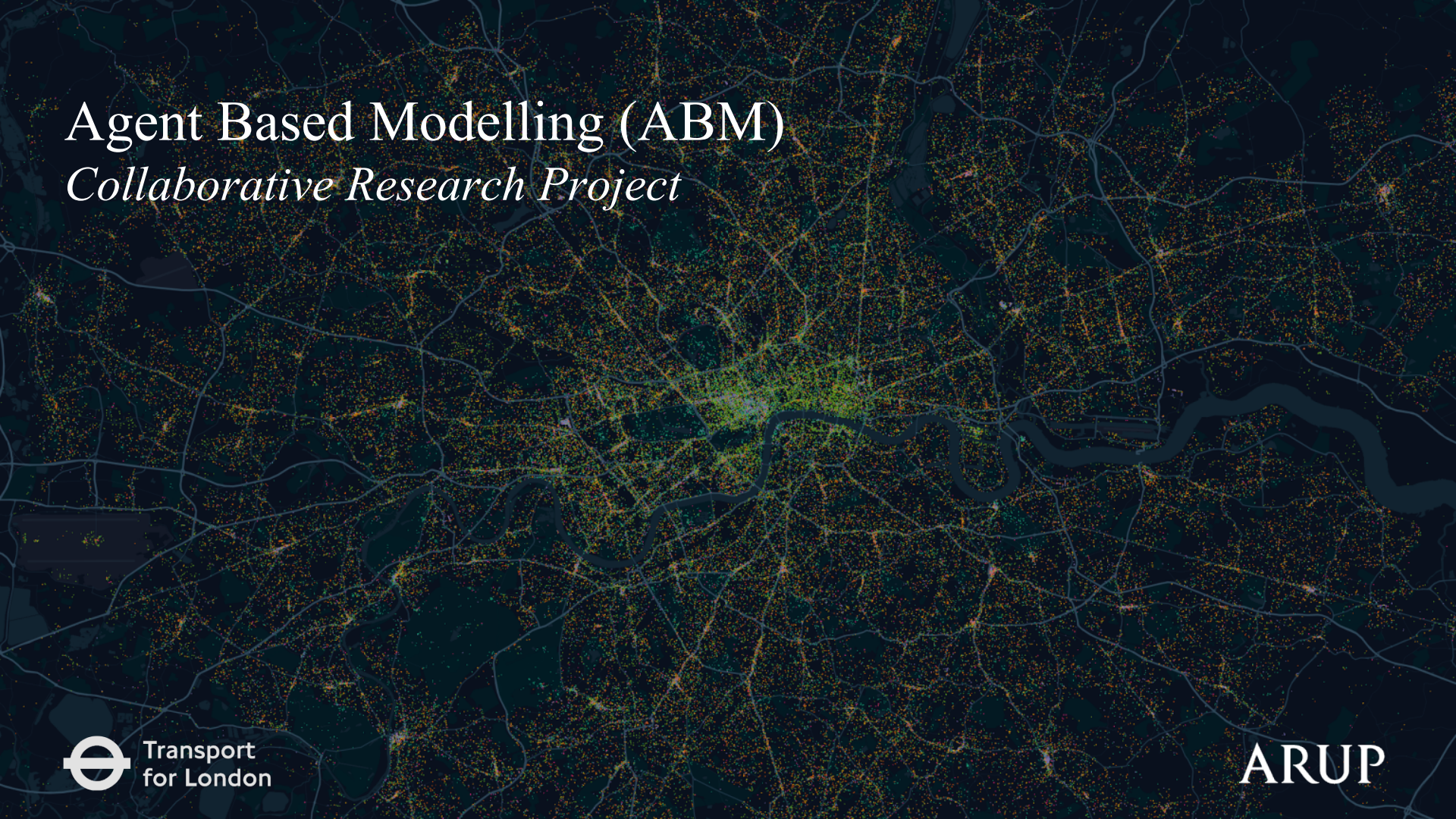
Agent Based Modelling (ABM)

Collaborative Research Project



Transport for London

ARUP

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Agent-Based-Models

why?

Policy questions such as these **cannot** be answered using **traditional** models:

"What are the equity impacts of this road pricing scheme or infrastructure upgrade?"

"Will my policy decision have a detrimental impact on those who have to travel?"

"How does this decision affect the network outside the traditional peaks?"

"How many trips on Euston Road are necessary trips? Can trips be made by public transport to improve air quality?"

Problem statement

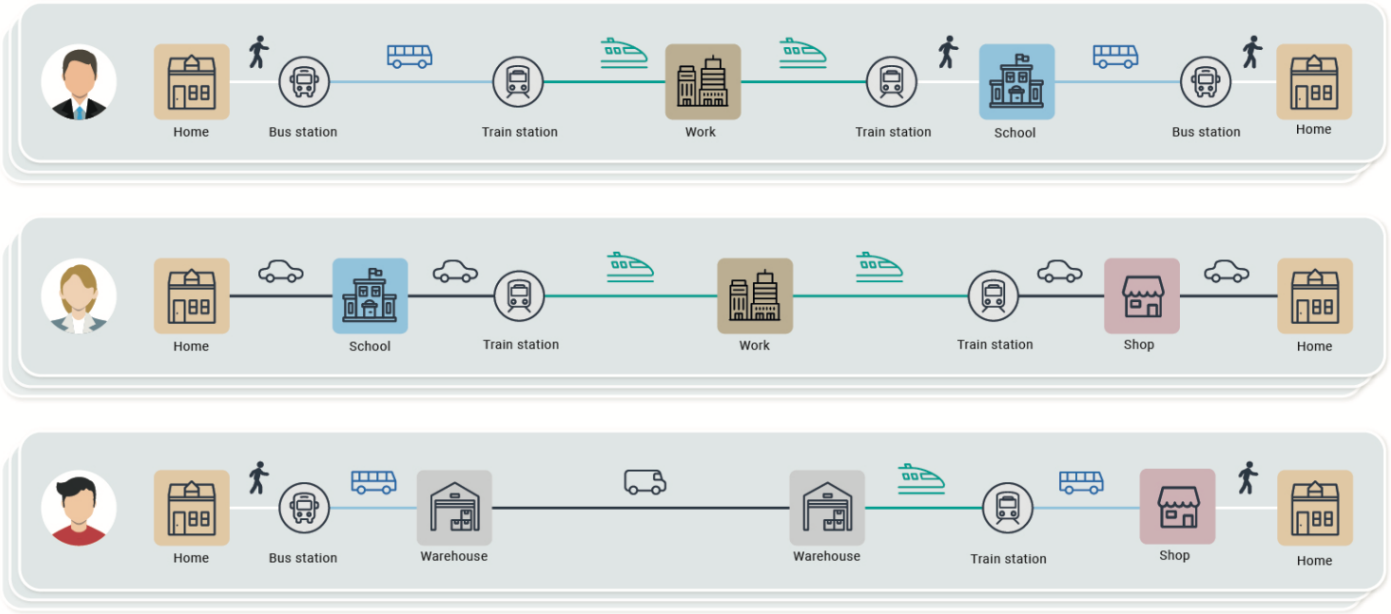
Traditional transport models consider groups of travellers with general characteristics - not individuals.

System performance is considered as discrete time periods rather than a continuum.

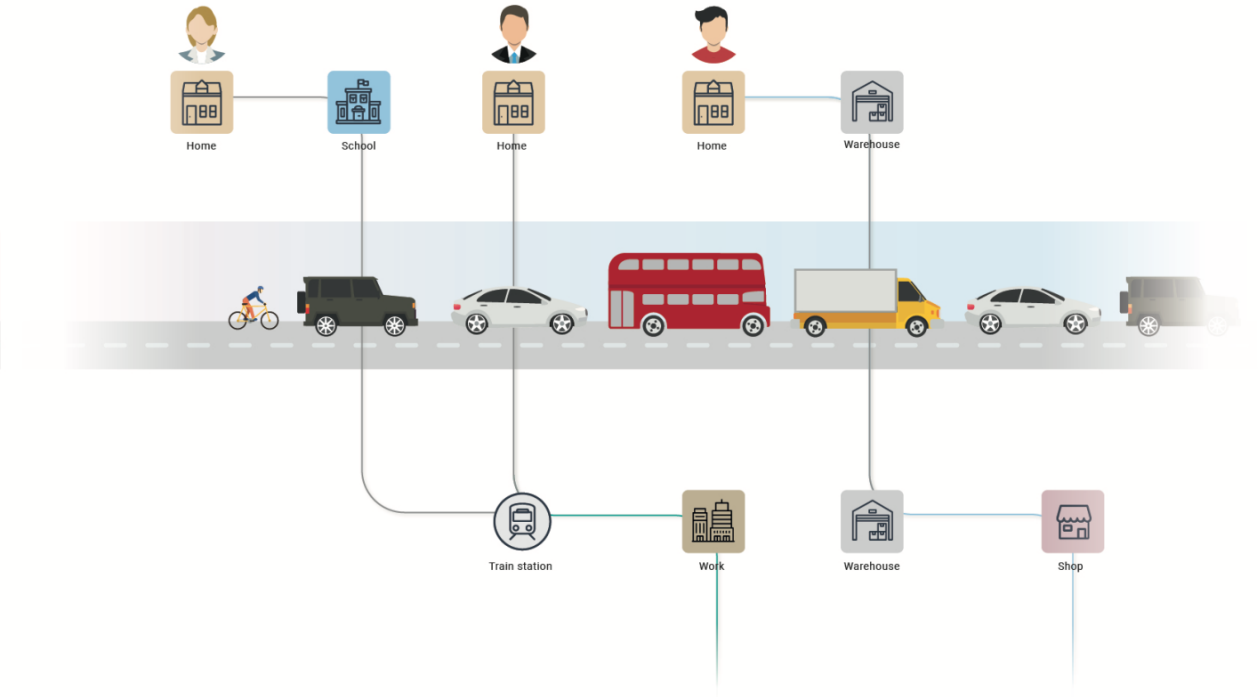
Micro level decision making that can be driven by technology - e.g. dynamic information / choice is difficult to represent within the system.

Equity impacts in particular are difficult to ascertain using traditional approaches.

People often use different modes over the day and their journey's are not often symmetrical



Different people with different purposes, demographics and requirements…

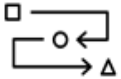


Why an Agent Based Model?

Based on a fundamentally different modelling approach, that focuses on individuals and the activities they complete throughout the day.

They can address some of the functionality gaps seen with traditional transport models, namely:

Continuous modelling

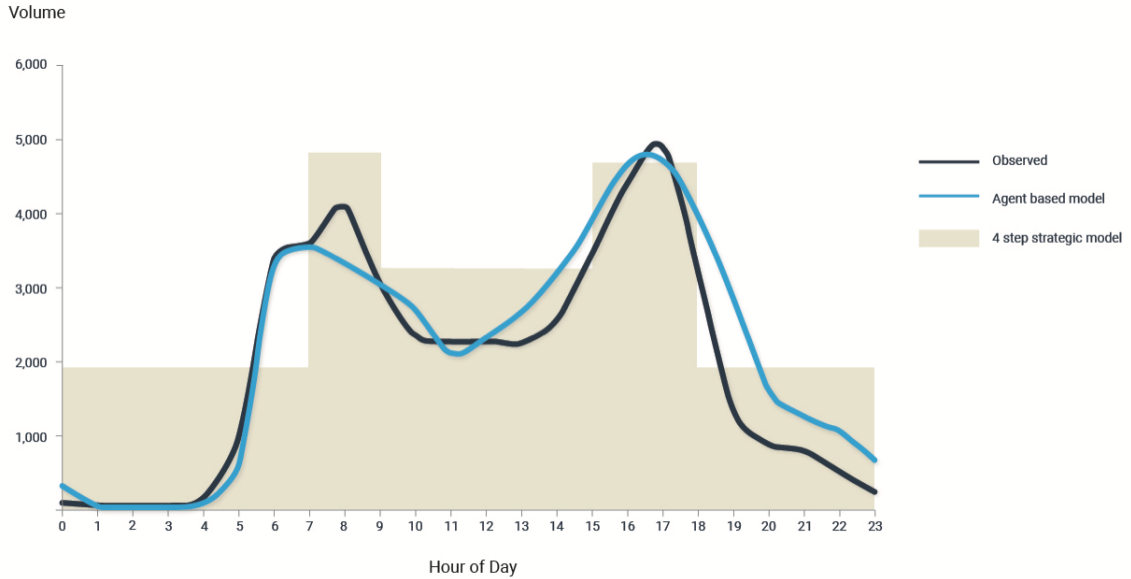


Finer decision-making

Demographic analysis

Why an Agent Based Model?

Compared to traditional models they have the potential to more accurately match observed data over a full day:



Agent-Based-Models

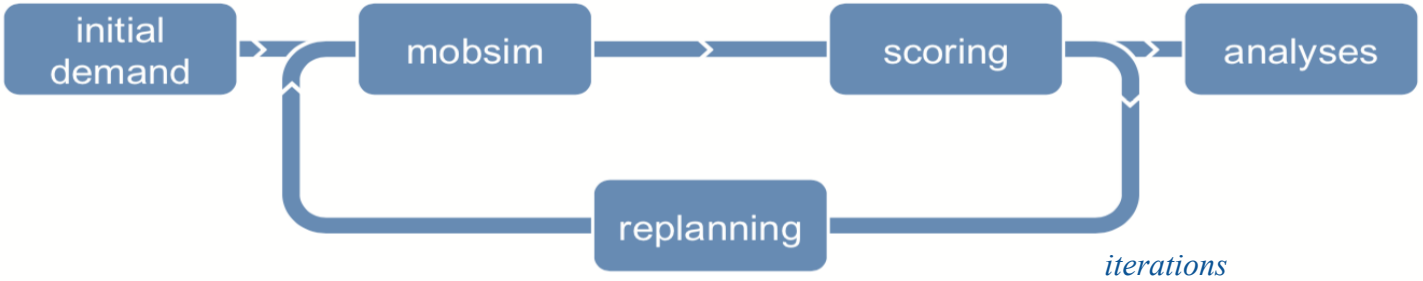
What platform enables this?

MATSim Fundamentals

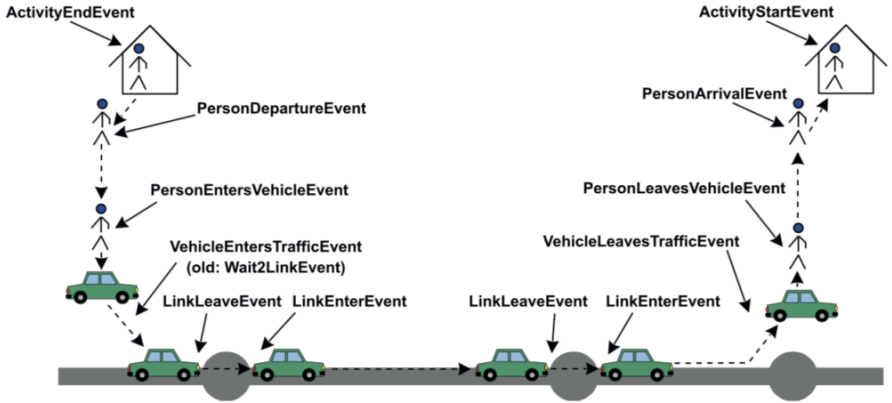
MATSim is an activity based, multi-agent simulation framework.

MATSim is based on the co-evolutionary principle. Agents co-evolve as they interact (compete) over time and space.

An agent within a simulation optimises for their own daily activity schedule, usually by changing journey times, route, modes and/or destinations with each iteration.



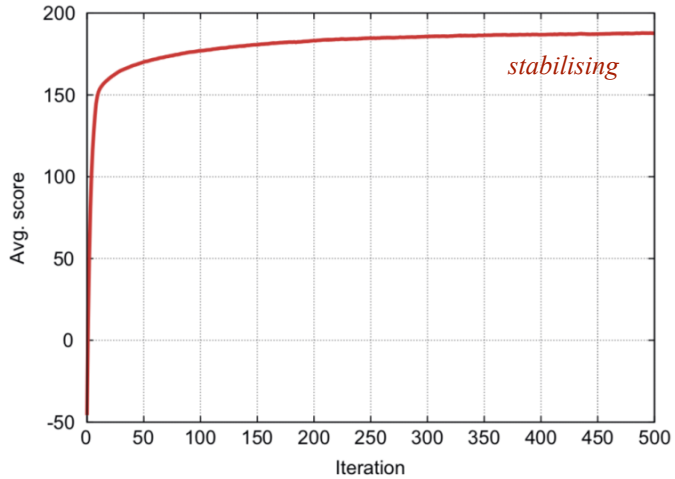
Ref: The Multi-Agent Transport Simulation



MATSim is event based. An agent will go through a series of different types of events as they attempt to satisfy their activity plan

With each iteration, an agent may make different decisions (time, route, mode, destination).

Typically, a simulation is run until the average population score stabilises.



Ref: The Multi-Agent Transport Simulation

What can agents do?

Time mutation - depart earlier/later for a given activity

Mode mutation - change mode

Route mutation - change route

Destination mutation - change activity destination *

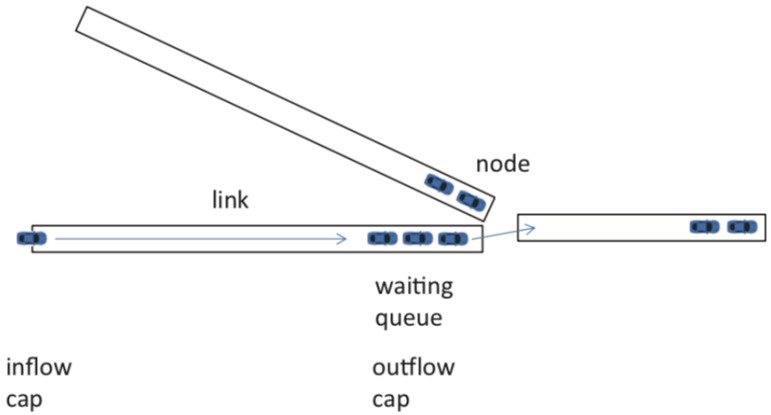
Ref: The Multi-Agent Transport Simulation

*Not implemented in this model

MATSim Mobility Simulation

In QSim, the traffic flow model uses a queue based approach. A vehicle arrives at the negative node of a link and must wait behind other vehicles before travelling across the link (at free flow speed). The link capacity defines how many vehicles can exit a link per time step. This means interactions manifest at nodes and there are no vehicle interactions on a link itself. Signals and multiple lane models have been implemented experimentally but are not standard in MATSim.

PT interactions follow a similar queue based approach with agents only able to board if there is capacity (both seating and standing) but with no change in the in-vehicle time cost due to crowding.



Ref: The Multi-Agent Transport Simulation

Scoring

An individual agent learns by maintaining multiple plans, which are scored by executing them in the mobsim (QSim), and then selecting/modifying their plan dependent on its respective score in subsequent iterations.

The scoring methodology is a form of utility function and with time agents should begin to move towards choices with better scores and away from choices with poorer scores.

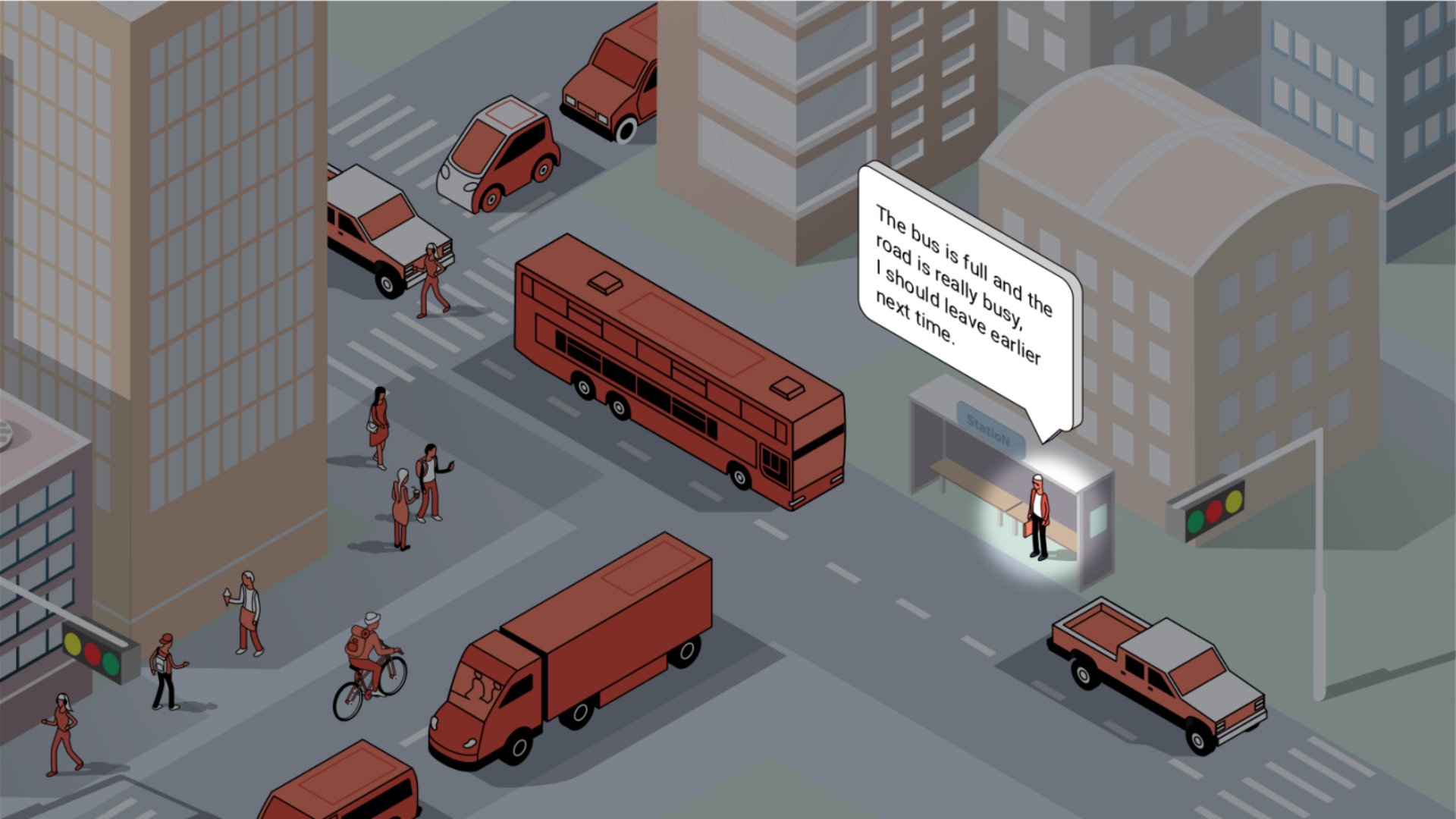
The most basic utility function utilised in MATSim is a modified version of the Vickrey model for road congestion. It is optimised for departure time choice and is extended for other choices (mode, departure location etc).

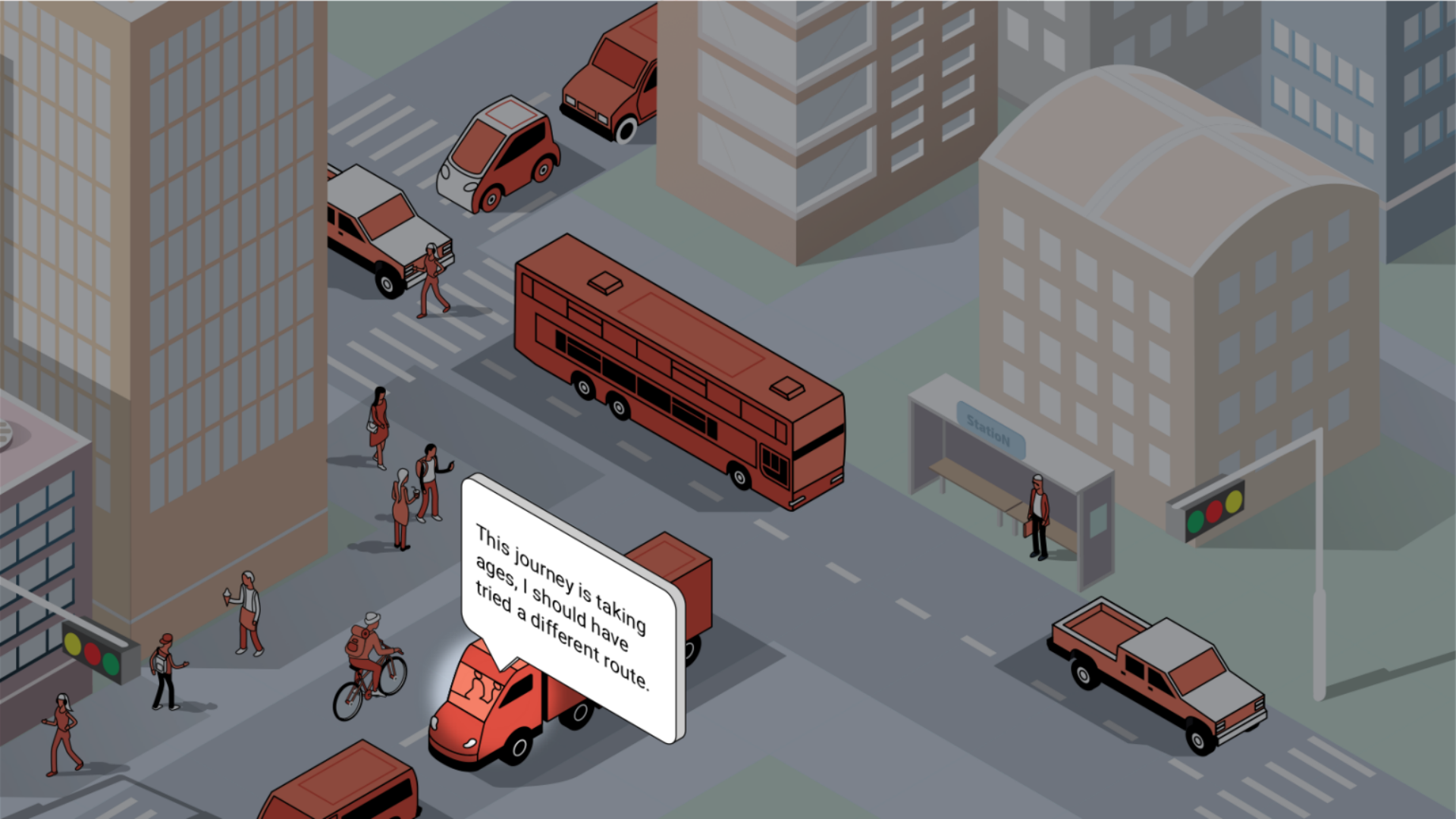
There are a wide range of modifiable general utility functions and context specific utility functions available within the standard MATSim module. MATSim also supports the use of completely custom scoring.

Ref: The Multi-Agent Transport Simulation

Agent-Based-Models

Individual level, interactive decision making

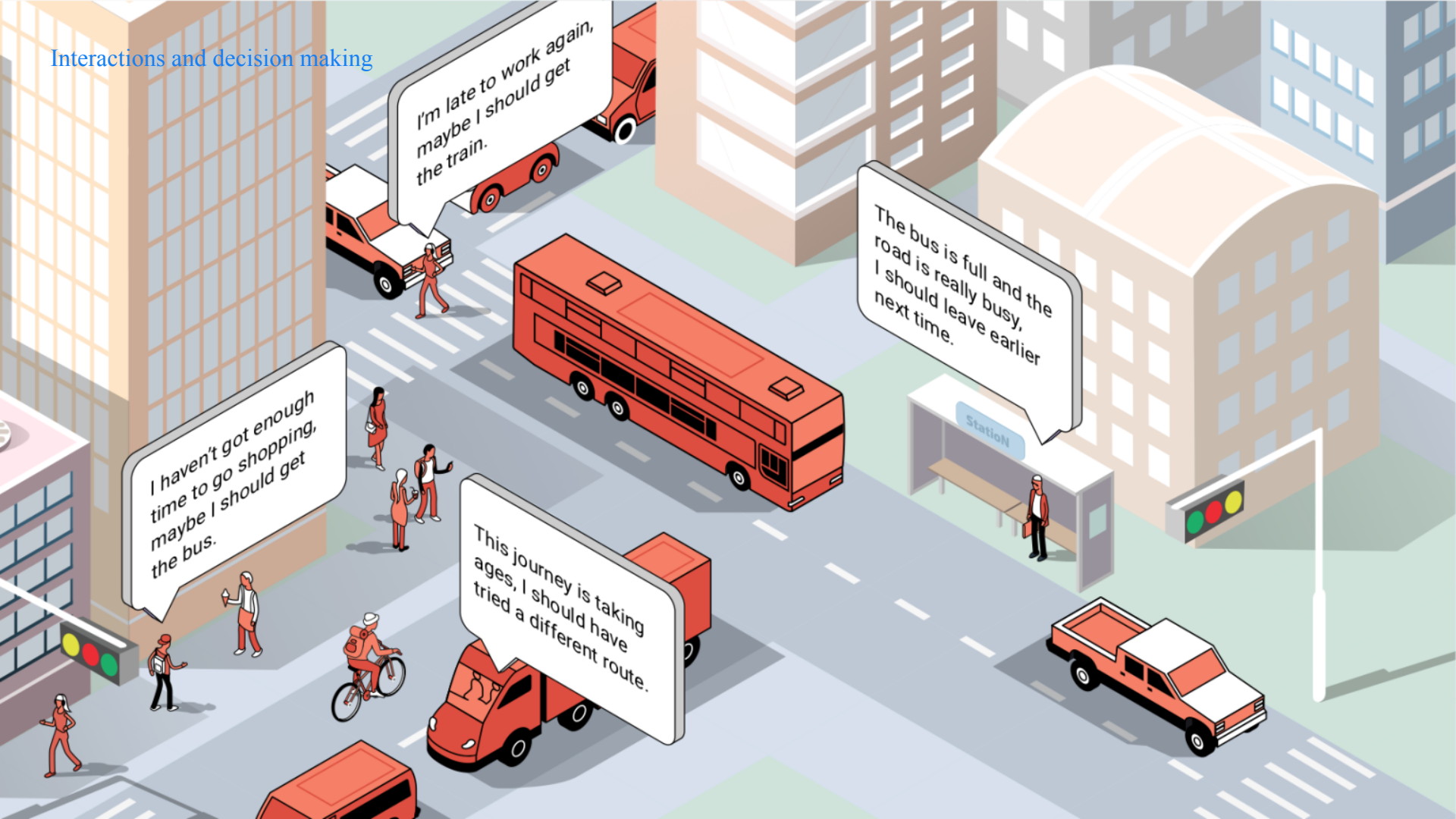

The bus is full and the road is really busy, I should leave earlier next time.
Station


This journey is taking ages, I should have tried a different route.
Station


I haven't got enough time to go shopping, maybe I should get the bus.
Station


I'm late to work again, maybe I should get the train.
Station

Interactions and decision making



Exploratory case study with TfL

Building an agent based model for London

What did TfL and Arup set out to achieve with this research work?

1. Share key learning from the development of an agent-based transport model in Melbourne.

1. Establish the feasibility of adopting an ABM approach to modelling in London as a complementary capability to the established tools.

1. Develop skills of both London Arup and TfL staff in the ABM space.

TfL Research Team:
David Christie
Claire Cheriyan
Collins Teye

Arup Research Team:
Chris Bruce (PD)
Fatema Karim-Khaku (PM)
Gerry Casey (ABM Technical lead)
Fred Shone (ABM Support)
Simona Ciocoiu (Graphics)
Tom Hall (Cloud infrastructure)
Lucy Pike (ABM advisor)
Michael Byrne (ABM advisor)
Nick Bec (Product Manager)

Networks:

Car

PT

Plans:

Activities

Locations

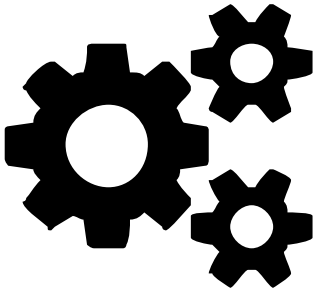
Attributes:

Beh aviours

Val ues

(Transport Supply)

Population (Transport Demand)



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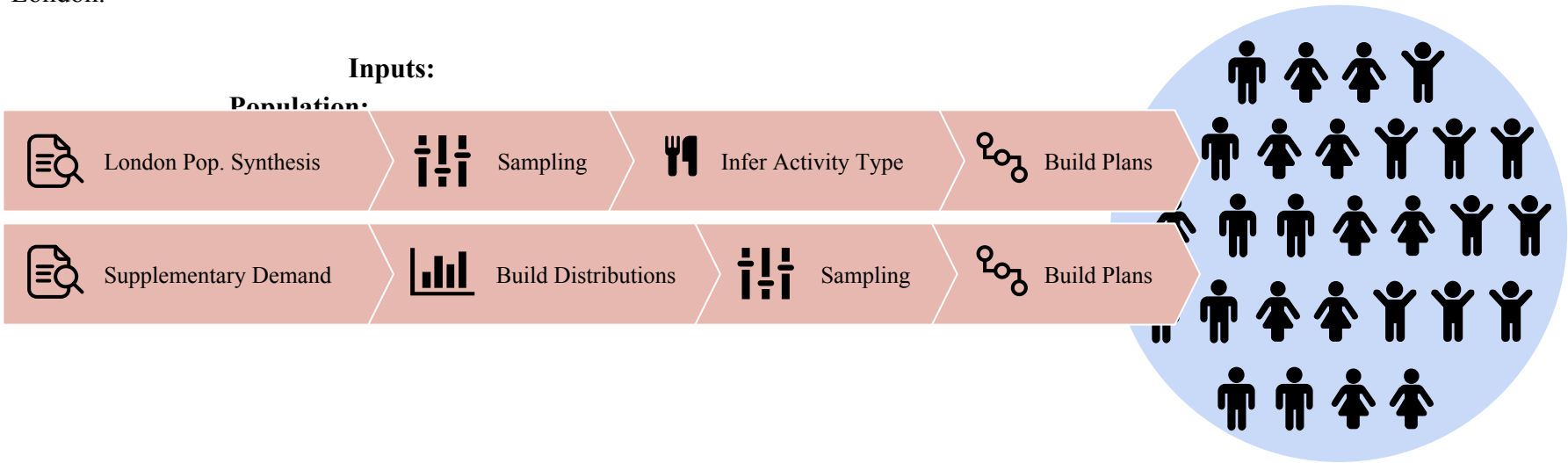
Building the demand

Building the London ABM Population:

We have two primary sources of input for our population:

Diary Based (LoPopS): Synthesised Person Plans and Attributes for London Households from Transport for London.

Demand Based: Supplementary travel demand from existing transport models, for example for Freight or Commuters from outside London.



Building the London ABM Population:.

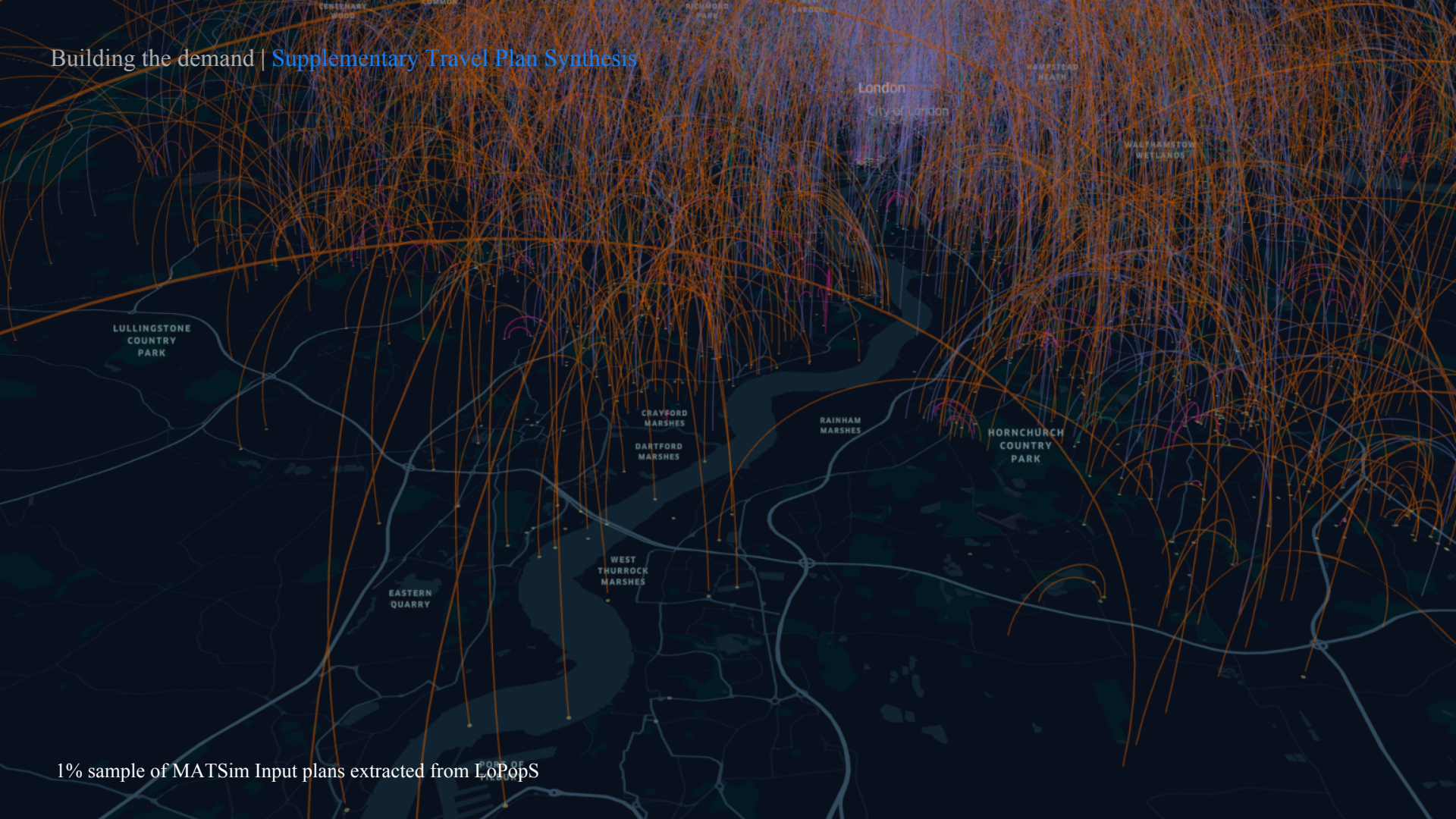
We use a variety of stochastic **sampling** techniques to build a representative (and reasonably sized) population. This typically involves randomly sampling from inputs based on a given distribution, for example a distribution of plans with frequencies from LoPopS.

For some inputs and data we **build distributions** to allow sampling, this might be to sample a point from within an area or to sample demand from a collection of trip demand matrices. We use four main types of distributions and sampling:

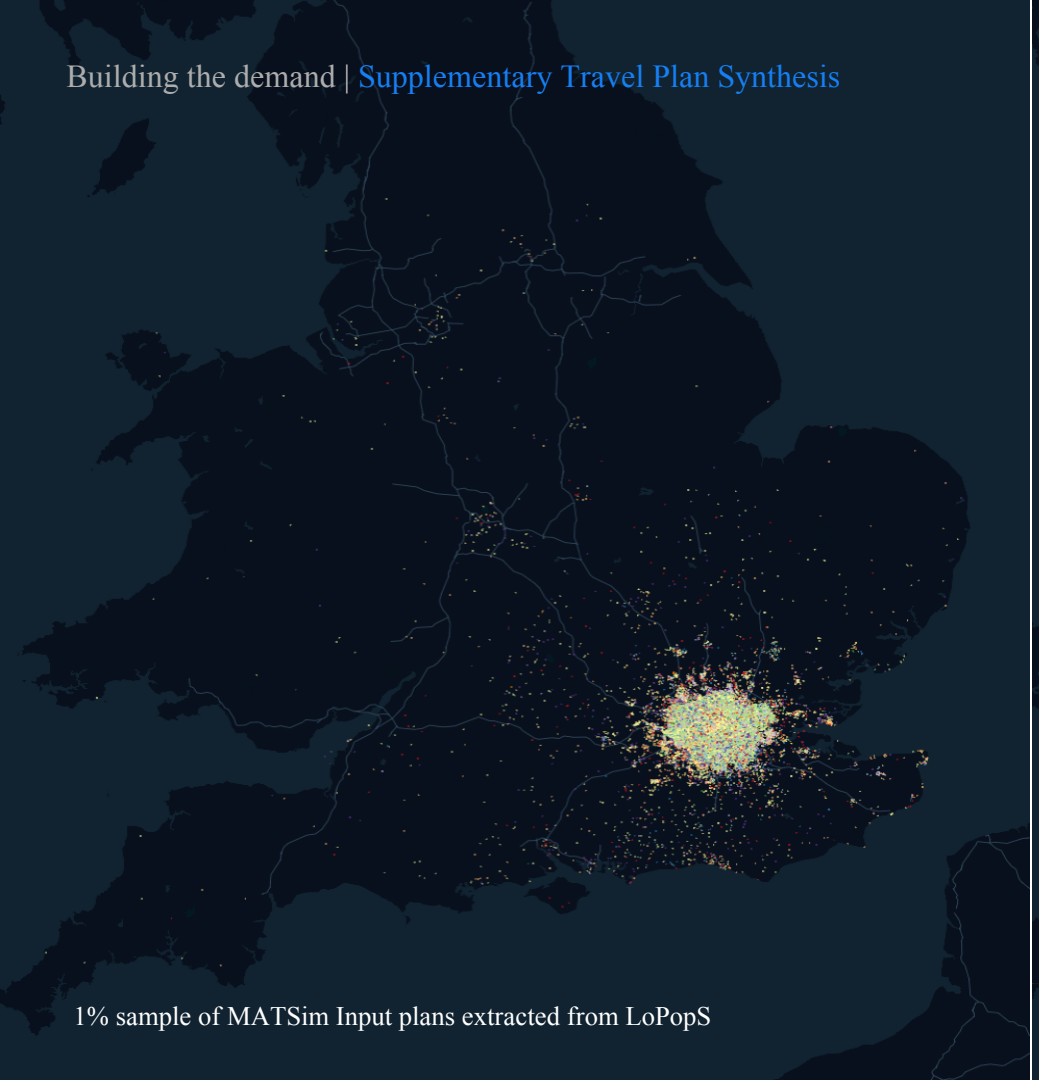
1. Frequency based distribution sampling, for example from records of synthesised plans
2. Demand profile sampling, for example for building trips from O-D matrices
3. Spatial sampling, for example to distribute origin and destination locations
4. Temporal sampling from known or built distributions of times

For synthesised trips data we **infer activity types** from the trip information and their order

Finally, with the above techniques we **build plans** for each agent. In the case of supplementary demand inputs this requires us to make careful assumptions about likely agent behaviours and attributes which we then validate.



1% sample of MATSim Input plans extracted from LoPopS



1% sample of MATSim Input plans extracted from LoPopS

1% sample of MATSim Input plans extracted from LoPopS

Supplementing the Population Plans with Freight Demand:

Import Demand Matrix (extracted from LoHAM)

Spatial Filter for London origins and destinations (assume **not** covered by LoPopS)

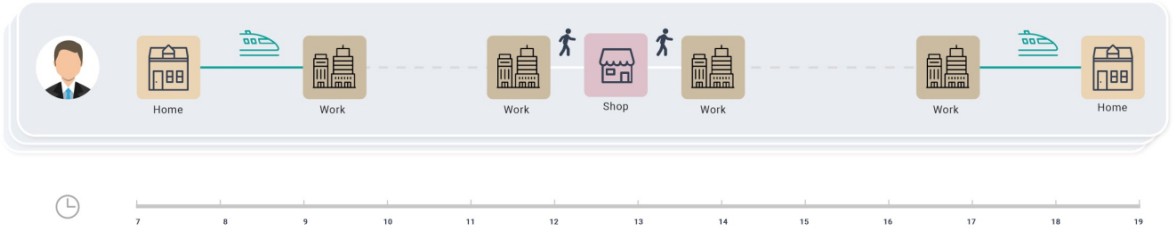
Generate and Sample from Time Distributions

Sample from appropriate O-D matrix, add return leg

Build MATSim Plans:

Supplementing the Population Plans with MoTiON Demand:

- Import Demand Matrices per segment
- Spatial Filter Out Existing London Households (assume covered by LoPopS)
- Randomly Sample Origins and Destinations
- Generate and Sample from Time Distributions (configurable)
- Generate trip and add return leg, can also synthesise other legs such as lunch breaks
- Build MATSim Plans, including population attributes



Building a network

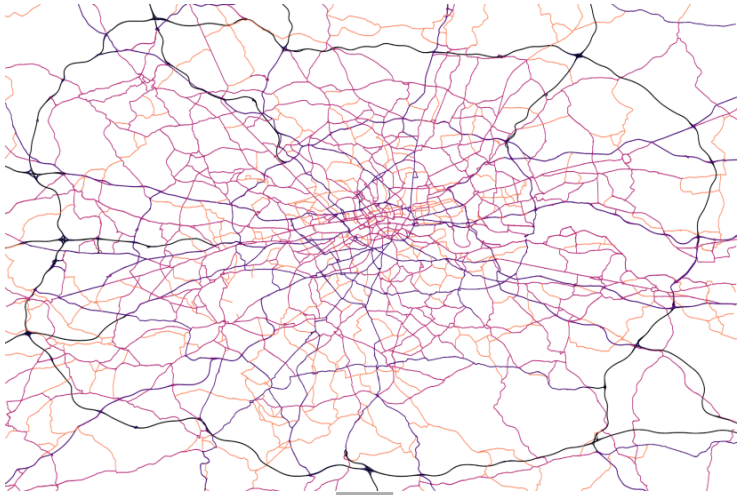
Road Network

Open Street Map (OSM) is a collaborative project to create a free editable map of the world.

A road network can be extracted via the use of routing and other tags. This network is then converted to a custom MATSim format.

Road free flow speed, road capacity are converted from OSM and assumed by road type.

Number of lanes and modes are taken from OSM when available and assumed when not.



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        " >Brindwood Road</attribute>
    </attributes>
</link>
```

Network Summary

Greater London Road network - 129,053 vertices and 297,119 edges

Great British PT network - 321,687 vertices and 701,031 edges (159,866 routes)

Sub selected London PT network:

155,605 vertices and 284,356 edges

1,106 operating agencies and ~15,000 routes (taken on 14th December 2018)

Consisting of 14,784 bus routes, 21 Tram, Streetcar, Light rail routes, 7 rail routes, 2 cable car routes, 4 ferry routes, 317 coach routes, 12 Underground routes and 104 urban rail routes.

Operating agency, route and route mode definitions defined as per GTFS.

Transport supply - Networks and services | Public Transport Network

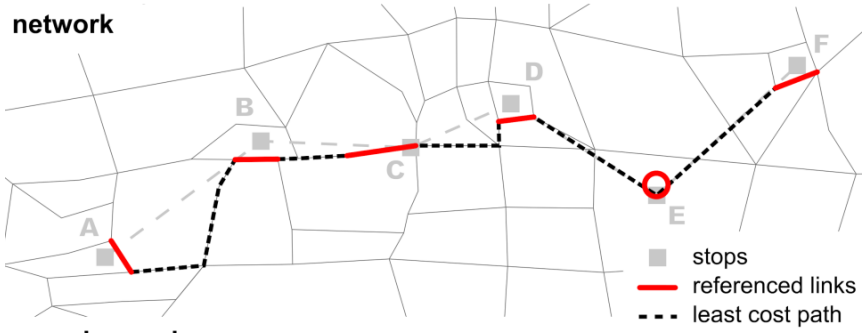
Public Transport

- Schedule + Vehicles:

A schedule and vehicles dataset is generated from a UK wide GTFS dataset. Vehicle capacities are specified per type and/or service.

- Network:

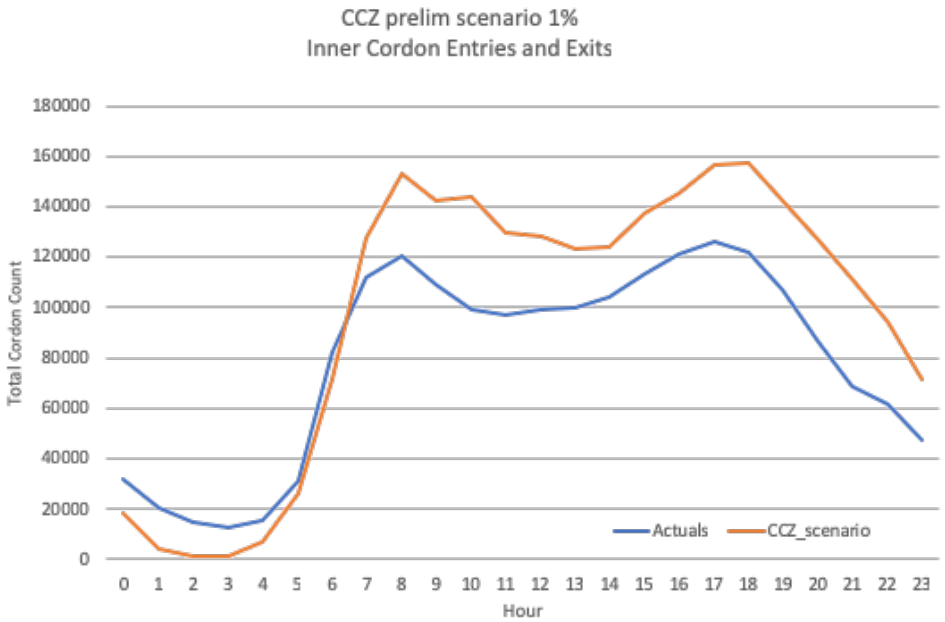
GTFS does not include routing information between stops as standard. Thus, the GTFS is compared against the network for the appropriate mode and then mapped probabilistically.

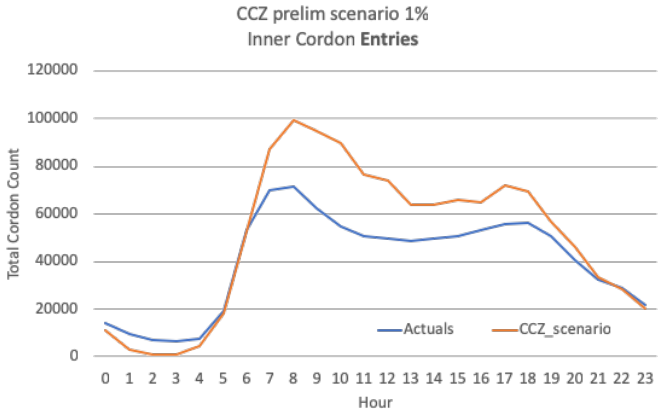


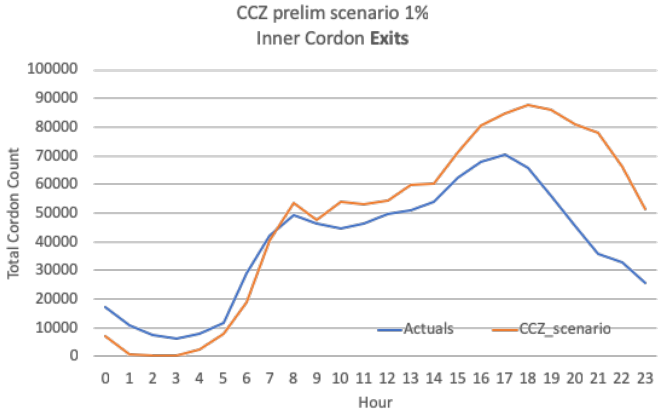
MATSim public transport network building process

Ref: pt2matsim

Validation/Benchmarking







Initial attempt at benchmarking traffic the Inner Cordon counts

Great match for attempt #1 | further verification needed | promising results

Source: 2016 Inner Cordon database, TfL

What are the opportunities?

Going forward, it will become increasingly important to model transport at a more individual level to capture the impacts of:

Road Pricing

Car-sharing

Autonomous Vehicles

New Modes of Transport

Development of agent-based models will be **crucial** in this space.

> This proof-of-concept ABM for London can be enhanced, optimised and validated to observed data and this is only the start of the ABM journey.


ARUP