**Project Background**

Agent-based models (ABMs) are ideally suited to modelling the behaviour and evolution of social systems. However, input data are noisy and sparse, and human behaviour is itself extremely uncertain. One of the key challenges facing the discipline is the quantification of uncertainty within ABMs. This work presents initial steps towards the development of new methods that will allow real-time data to be assimilated into ABMs.

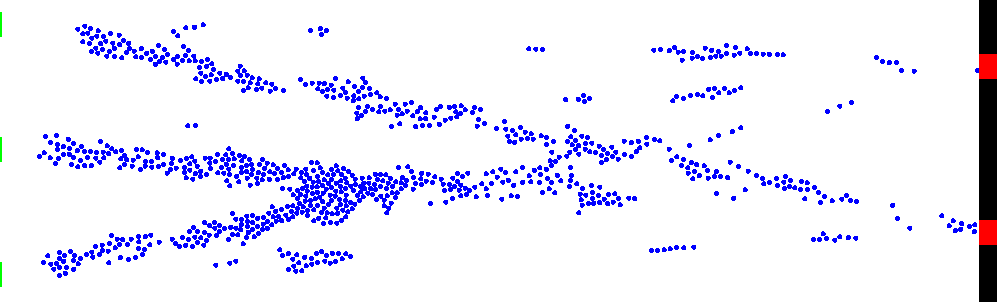
**Data and Methods**

The broad aims of this research are to model

An agent-based model of a hypothetical train station was created to model crowding (Fig 1). While simple in nature, this model was designed to include stochastic elements and so produced differing results on subsequent runs.

To address the aims of this work in reducing the uncertainty in ABM outputs, a probabilistic programming library currently being developed by Improbable was utilised.

Our ABM was run to generate ‘truth’ data as our equivalent reality. This data was then observed when using Improbable’s library to create a posterior distribution that was sampled using a Metropolis Hastings algorithm. These samples allow us to see the constraints in the model applied by observing the truth data.

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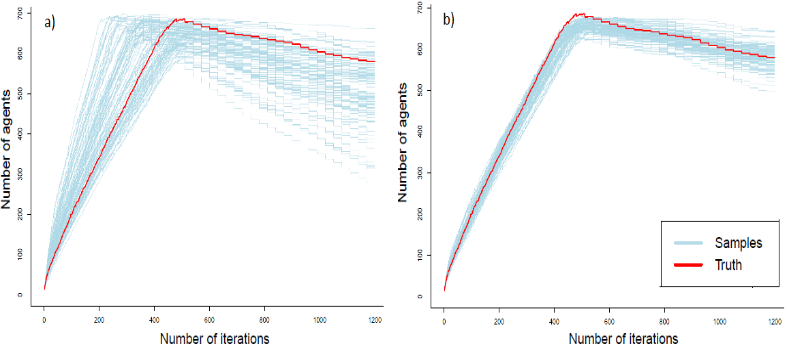
*Fig. 1: A snapshot of the simple, hypothetical model that is used here. Agents arrive from the green entrances on the left and move towards the red exits on the right. During the course of the runtime crowding occurs in different areas.*

**Key Findings**

Through the use of Improbable’s library, Bayesian inference was used to constrain model output. This was achieved through estimation of the random numbers used within the model when the truth data was generated. Through these methods the model was successfully constrained, allowing us to reduce the uncertainty in predicting outputs from the ABM in respect to the truth data.

These methods were demonstrated using an output of the number of people in the simulation at each step. Observing the truth data for this output, the model was demonstrated to have been constrained in respect to this output. (Fig 2)

In addition, truth data was produced of the number of people passing through each entrance and exit. Observing its output and sampling from the posterior for the total number of people that passed through a particular grid space in the simulation also showed constraint in the model.

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*Fig. 2:* *Results of sampling the posterior without (a) and with (b) observations. When the ‘truth’ data are used to constrain the posterior distribution, the sampling routine is much better able to estimate the input model state, so the outcomes of the samples are much closed to the ‘truth’ data.*

**Value of the Research**

This work helps to address the question of assessing uncertainty in agent based models and represents an important initial step for applying these methods to smart city modelling. By utilising these methods we can produce more robust agent based modelling for urban systems which can be of greater use when making policy decisions. This work also provides value to Improbable by creating a use case for their probabilistic programming library.