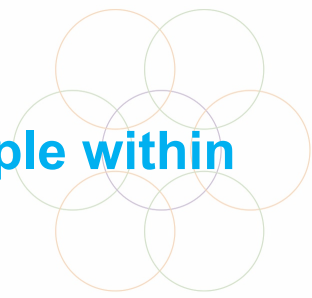


# Quantifying uncertainty – a worked example within a psychiatric intensive care unit



When forecasting the flow of patients through a psychiatric intensive care unit (PICU) there are many factors which introduce uncertainty into the problem and make future predictions difficult to calculate. As a result, any predictions presented to the client should account for these uncertainties and indicate the level of uncertainty which is present.

This thought piece illustrates how and why we do this, using a worked example of a PICU over a 5-year period. This is done using data, which, although not drawn from a specific unit, is typical of the data we encounter.

## Why model the flow of patients?

Patient flow models are often used to gain insight into current and future bed occupancy. By building these we can better understand the required bed capacity, lengths of stay, staffing numbers, associated costs, and much more. Using these results, we can calculate the required bed capacity which reduces the turnaway risk to, for example, less than 1%. Here, the turnaway risk is the probability a bed is not available when required, resulting in a patient being “turned away”.

## Uncertainties which influence the patient flow which are present in a PICU

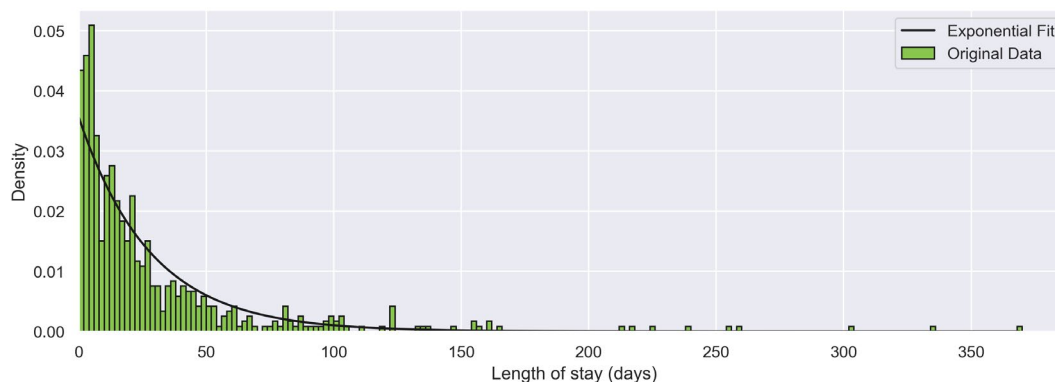
Within a PICU some common uncertainties include:

- Patient demographics, including age, sex, and ethnicity
- Patient diagnoses
- The frequency patients enter a ward
- The length of stay for each patient
- The level of care each patient requires

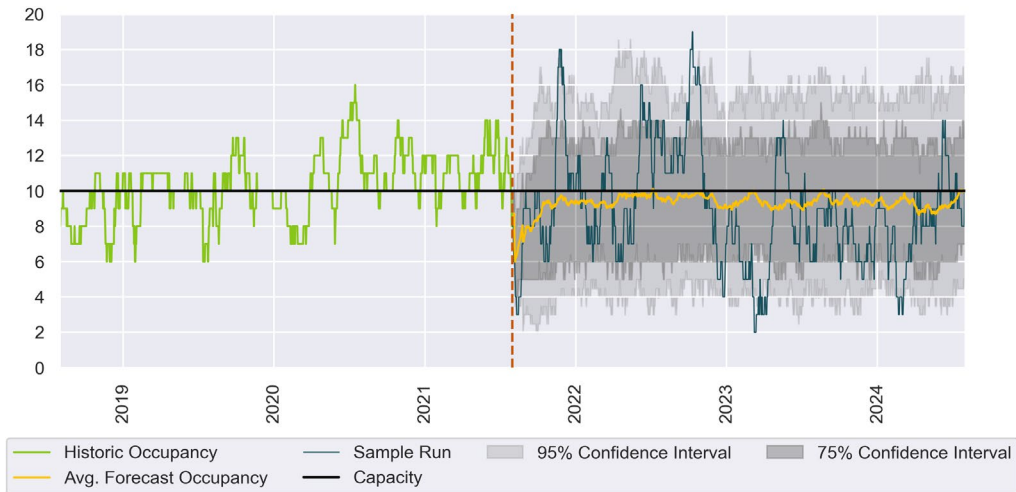
## How can we quantify their influence? And why is this so important?

The combination of the uncertainty within these factors causes difficulties when forecasting bed occupancies for the PICU. This section will outline how we find the relationship between these factors and the larger scale problem of the PICU’s occupancy and turnaway risk.

The first step we use is to calculate statistical properties for the uncertain factors in the system using historic data, which is often done by finding parameters for appropriate statistical distributions. In the figure below we fit an exponential distribution to the historic lengths of stay using a Maximum Likelihood Estimation (MLE). This gives statistical parameters which describe the distribution of historic lengths of stay, which can be used to predict the length of stay for future patients. The figure demonstrates good agreement between an exponential distribution and 286 patient stays in a PICU, where the mean length of stay on the PICU is 37.5 days.



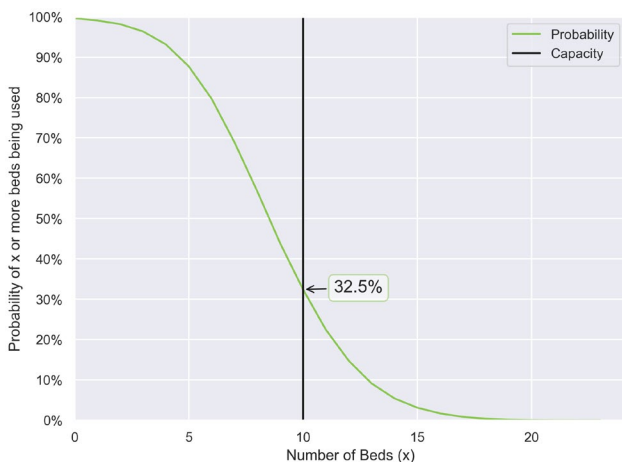
Similar methods can then be used to extract statistical parameters from the historic data for the patient start dates, gender split, ages, diagnoses, and usage of service types. Similarly, we should account for any population changes, which are forecast by the Office for National Statistics, by building these into the model. These parameters are then used to perform 100 simulations (also known as Monte Carlo simulations) which forecast the future activity of the PICU. The figure below uses these 100 simulations to find the average bed occupancy over the 5-year period (given in orange), along with the potential variation away from this average with a given certainty (represented using grey clouds). From the figure we see the forecast average occupancy is approximately 9.5 beds (which is 0.5 beds under the current bed capacity), where 75% confidence can be given that the occupancy remains between 6 and 13 and 95% confidence can be given that the occupancy remains between 3.5 and 15.5.



This kind of analysis is based on robust uncertainty quantification techniques and allows Niche to offer recommendations for maintaining the correct range of capacity and services available, whilst minimising the probability of overstaffing and using non-fixed cost staff.

### Deliverables produced by the model

Using the forecast occupancy for the PICU we can calculate the probability that no bed is available in the PICU despite being required on any given day during the 5-year forecast period, also known as the turnaway probability. For the 'do-nothing' baseline scenario we see the current capacity of 10 gives a turnaway risk of 32.5%, meaning approximately 1 in 3 patients will be turned away from the PICU due to insufficient capacity. However, if the capacity were to be increased to 17 or greater then the turnaway risk would be reduced to below 1%, thereby ensuring the PICU's bed capacity is sufficiently large to accommodate the service's forecast demand.



This form of analysis underpins a typical approach Niche would take when modelling and forecasting the capacity and demand for a PICU. We cannot eliminate uncertainty in planning capacity and demand, but we can forecast the most likely scenario and how confident we are of this prediction, which enables informed and evidence-based decisions to be made about future capacity requirements.