



A framework for determining emergency readmission time window

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Outline

- What is an emergency readmission?
- The importance of emergency readmission for the National Health Service (NHS)
- Our initial method for determining an appropriate time window in defining readmission
- Generalisation of the developed framework
- Application of the methodology to the national dataset
- Conclusions



Emergency readmission (ER)

- High level of emergency (or unplanned) readmission is potentially associated with poor patient care
- Readmission is highly costly
- Readmission rate is a key element in the performance rating framework for NHS hospitals in the UK
- Currently the NHS defines readmission as an emergency or unplanned admission to the same hospital (department) within 28 days following discharge
- There is a lack of consensus in the literature on the appropriate choice of time interval in defining readmission.

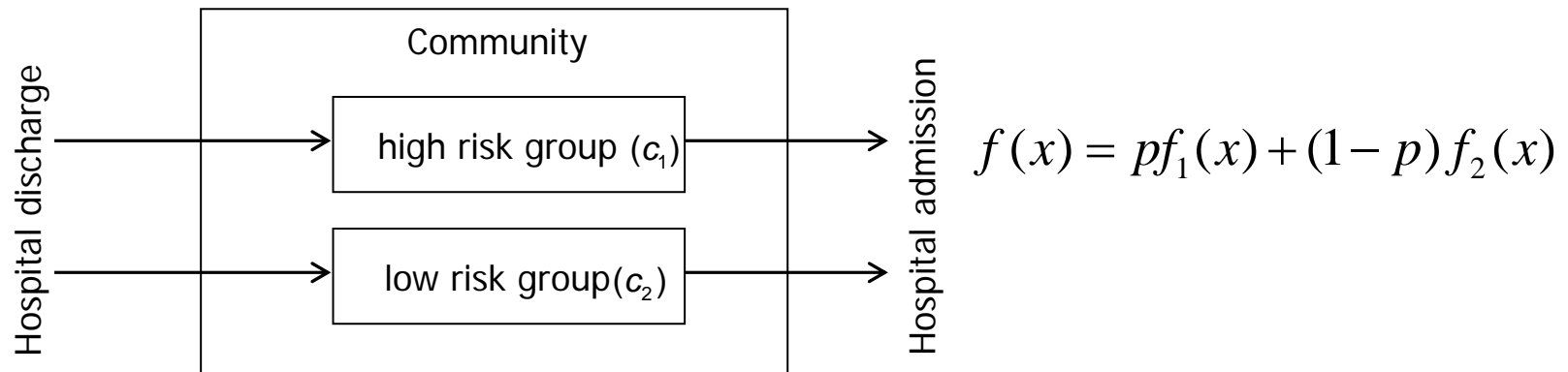
Why 28 days?

- Plot histogram of readmission
- Plots show lognormal or exponential shaped distribution
- 28 day interval was largely the result of visual inspection
- This could result in an inaccurate estimation
- As a result, the definition of readmission may be misleading



Modelling approach

- We conceptually model two groups
- We do not know which group the patient belongs to



- Probability of belonging to (c_1) and (c_2) can be determined from the posterior probability expressed via the Bayes' theorem as

$$p(c_1 | x) = \frac{pf_1(x)}{f(x)} \quad \text{and} \quad p(c_2 | x) = \frac{(1-p)f_2(x)}{f(x)}$$

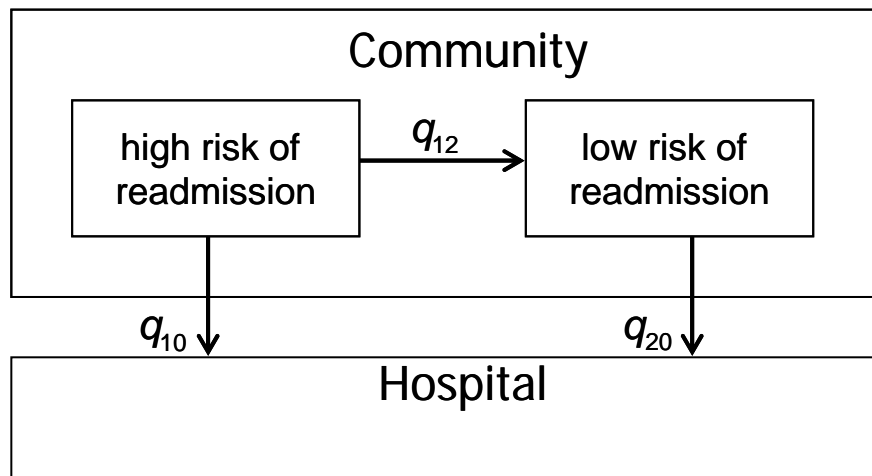


Identifying optimal time window

- Group membership of a patient with observed time to admission x : assign to c_1 if $p(c_1 | x) > p(c_2 | x)$; and c_2 otherwise.
- Optimal time window can be determined by solving $p(c_1 | x) = p(c_2 | x)$
- Or given by the time value where $pf_1(x) = (1 - p)f_2(x)$ that is, where the two corresponding curves intersect.

Conceptual movements of patients in the community

- Empirical evidence suggests that risk of readmission substantially changes over time
 - High soon after discharge
 - Low after a period of time in the community



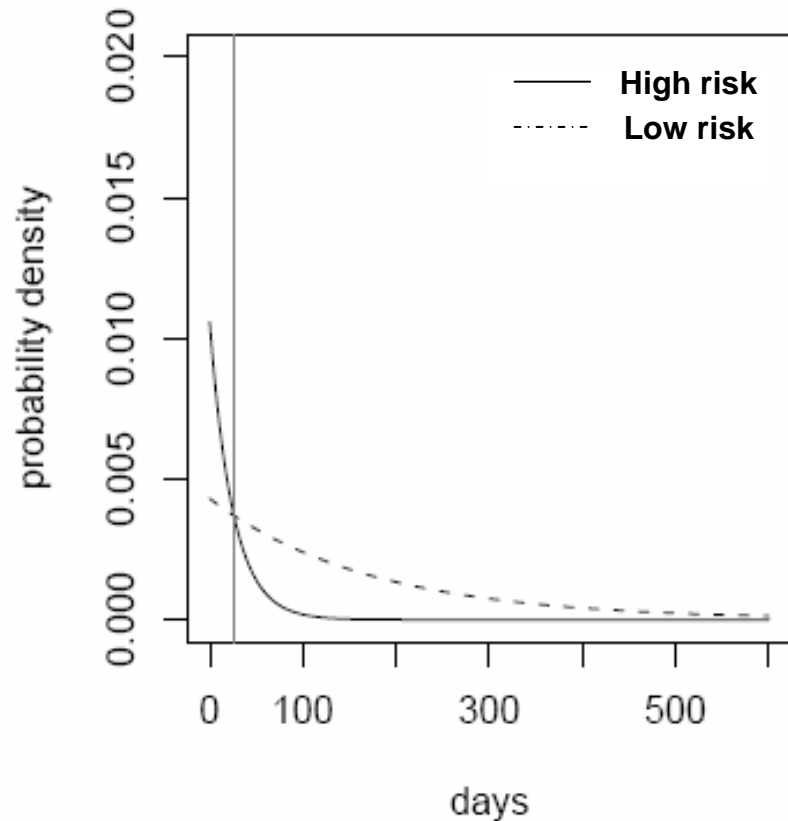
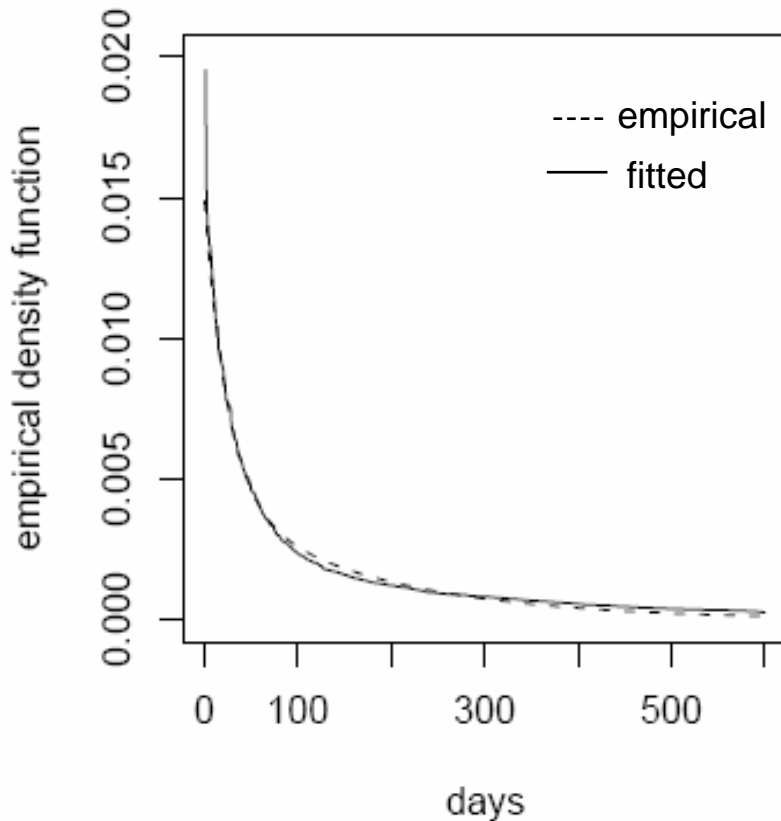
$$p = \frac{q_{10} - q_{20}}{q_{10} + q_{12} - q_{20}}$$

$$f(x) = pf_1(x) + (1 - p)f_2(x)$$

- Time to readmission follows a Coxian phase type distribution

Example: for COPD patients

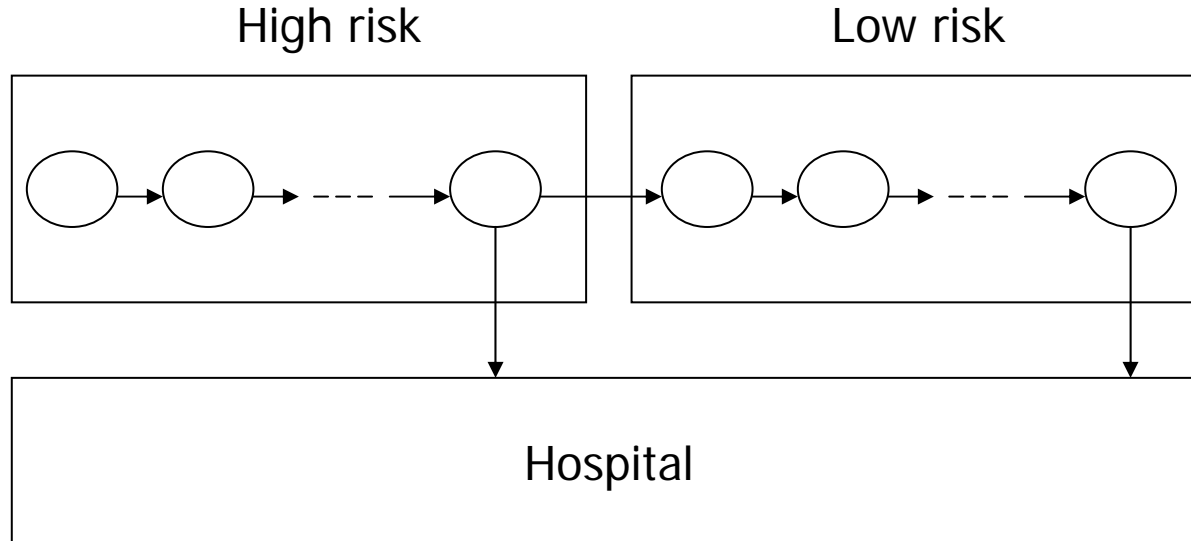
- The optimal time window is computed to be about 26 days



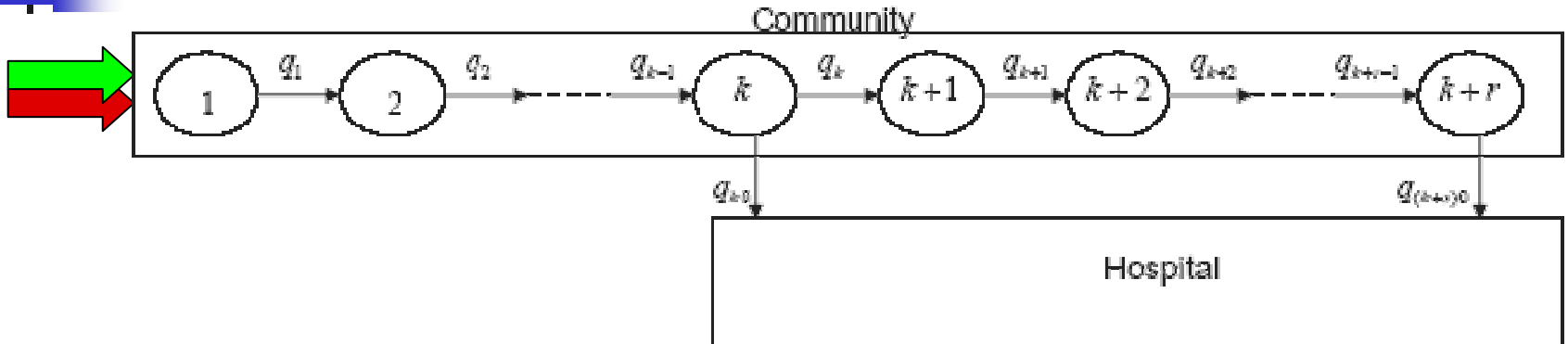
- Estimated probability of being in the high risk group is 0.26.

Generalisation of the framework

- The model assumes that there are only two phases and this can be restrictive
- What do we do when a two-phase Coxian do not fit?
- Modified approach is required.



Mixture of 2 generalised Erlang distribution

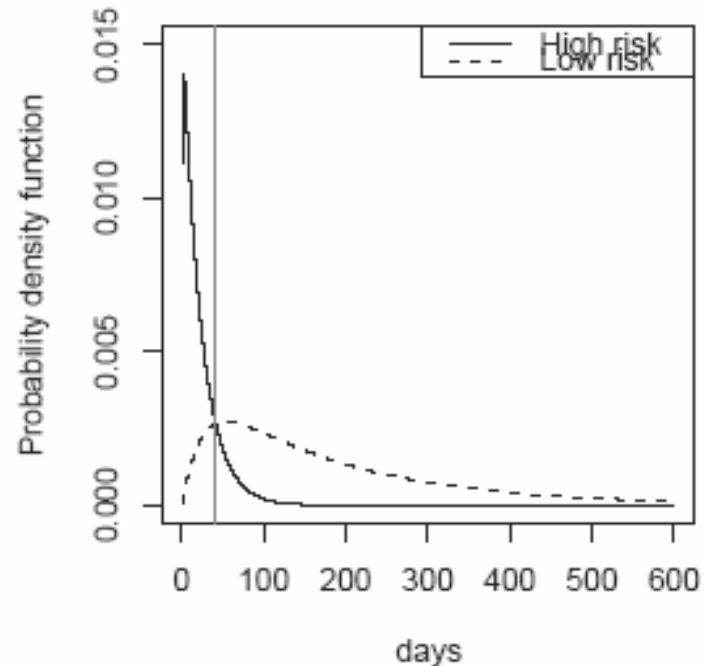
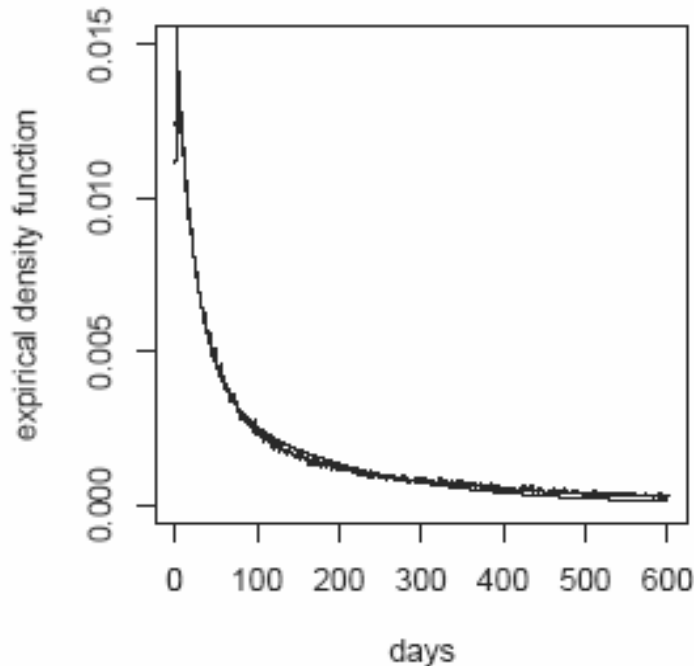


$$f(x) = p \underbrace{\sum_{i=1}^k C_{i,k} (q_i + q_{i0}) e^{-(q_i + q_{i0})x}}_{f_{GE_k}(x)} + (1-p) \underbrace{\sum_{i=1}^{k+r} C_{i,k+r} (q_i + q_{i0}) e^{-(q_i + q_{i0})x}}_{f_{GE_{k+r}}(x)}$$

$$p = \frac{q_{k0}}{q_{k0} + q_k}, \quad C_{i,k} = \prod_{j \neq i}^k \frac{q_i + q_{i0}}{q_i + q_{i0} - q_j - q_{j0}} \quad \text{and} \quad C_{i,k+r} = \prod_{j \neq i}^{k+r} \frac{q_i + q_{i0}}{q_i + q_{i0} - q_j - q_{j0}}$$

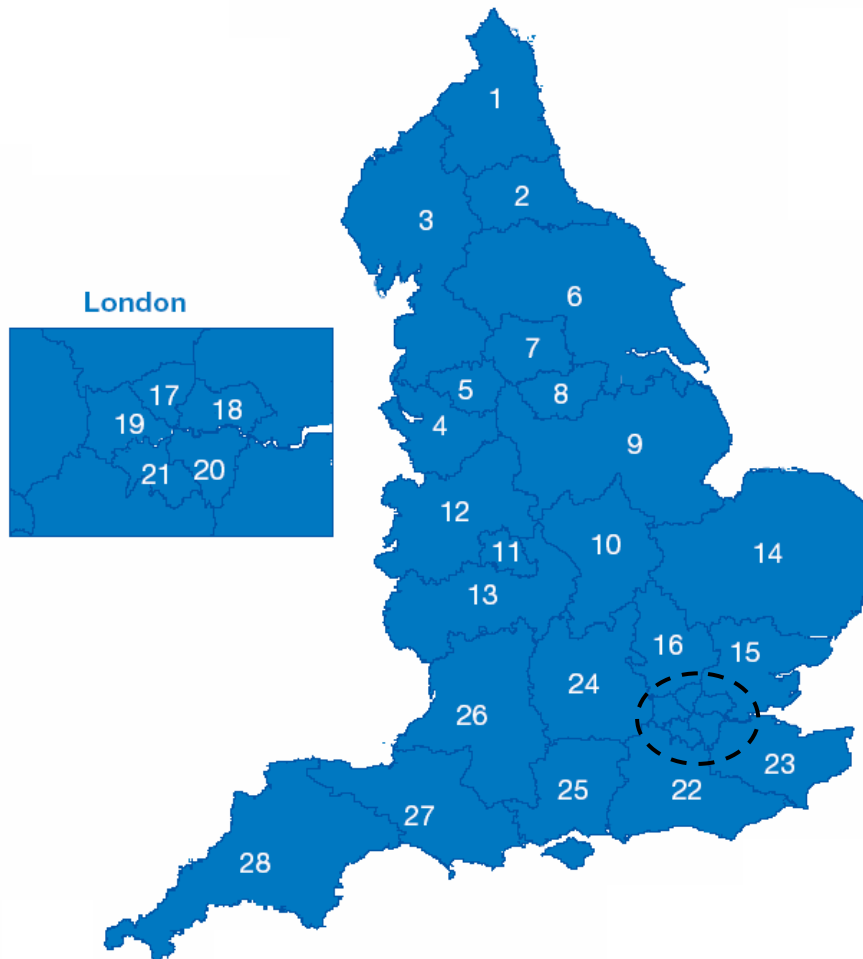
Application of the generalised model

$k+r = 3$ stages ($k=2, r=1$), judging by AIC and BIC



Estimated optimal time window is 36 days and probability of being in the high risk group is 0.36.

Strategic Health Authorities (SHAs) in England



17 = North Central London

18 = North East London

19 = North West London

20 = South East London

21 = South West London

28 = Southwest Peninsula

27 = Dorset and Somerset

25 = Hampshire and Isle of Wight

22 = Surrey and Sussex

23 = Kent and Medway



Readmission time window among SHA's

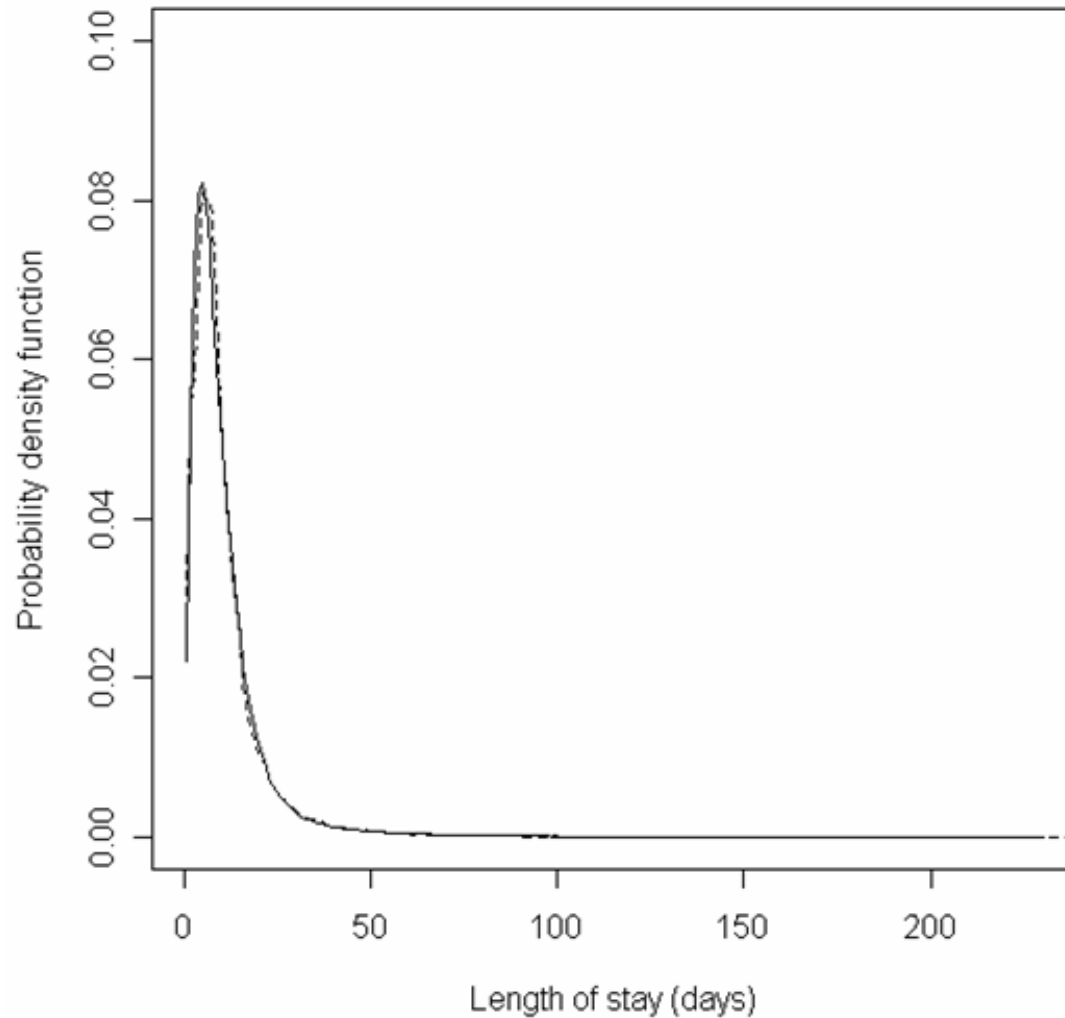
| SHA name | Prob. of being in high risk | Time window (days) |
|-----------------------------|-----------------------------|--------------------|
| North West London | 0.37 | 34 |
| North Central London | 0.39 | 39 |
| North East London | 0.39 | 40 |
| South East London | 0.37 | 39 |
| South West London | 0.29 | 29 |
| South West Peninsula | 0.30 | 29 |
| Surrey and Sussex | 0.27 | 30 |
| Dorset and Somerset | 0.33 | 34 |
| Kent and Medway | 0.32 | 30 |
| Hampshire and Isle of Wight | 0.27 | 25 |



Conclusion

- We developed a modelling approach in determining optimal time window to define readmission
- Single number defining a time window may not be appropriate across specialties
- Optimal time for SHAs suggests some hospitals may be disadvantaged in performance rating framework
- This model can be implemented as a software toolkit to estimate time windows for different diagnosis groups
- This approach can now support a broad class of distributions.

An illustration to admission dataset



$k+r = 4$ phases
($k=3, r=1$)

$\rho=0.90$

Time window = 16