# Safe nurse staffing for A&E departments

## National Institute for Health and Care Excellence

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# Contents

# 1.0 Executive summary

An economic model of an A&E department has been developed using a system dynamics approach to support the development of the NICE safe staffing guideline for A&E departments. The model examines the trade-offs in various outputs based on adjustments to staff numbers, staff skill mix and patient volumes. The outputs measured in the model are:

- Average duration in the department
- Average time to assessment
- Average time to treatment
- Average patients per staff
- Average occupancy
- Percent of patients who leave without being seen
- Percent of patients who die in the department

Using data collected from a number of NHS Trusts, and applying a set of assumptions as agreed by an expert panel, the model was run and the analysis of the model results suggest the following key points:

- The outputs are most sensitive to low numbers of staff followed by high attendance volumes.

- The average time to assessment and treatment are only affected by the more extreme scenarios of low staff numbers, low staff skill mix and high attendance volumes.

- Increasing staff numbers above the average may allow a department to more easily accommodate increased volumes of patients as shown by the smaller variation in outputs. For example, at the lowest staff numbers modelled, average duration varied from 2.49 to 2.95 hours whereas with high staff numbers the average duration varied from 2.31 to 2.47 hours.

- Increasing staff numbers and/or staff skill mix above the average does not significantly improve outputs unless high patient volumes are also a factor.

- Reducing staff numbers has a detrimental impact across all model outputs and these differences become larger as the number of staff decreases.

- Long transfer times between A&E departments and inpatient wards can create blockages in the system whereby the assessment and treatment of other patients is delayed.

# 2.0 Introduction

In 2012, NHS England detailed their commitment to transforming the NHS to be a patient centred, customer focussed, efficient service, where safe and high quality urgent and emergency care is available 24 hours a day, seven days a week[1]. This pledge to transformation is the result of increasing demands on A&E and the need for financial austerity to ensure the long term viability of the service.

Attendance at A&E has increased steadily in recent years. In 2012/13 there were 21.7 million attendances at A&E departments, minor injury units and urgent care centres and 5.2 million emergency admissions to England's hospitals[2]. There were 6.8 million attendances at walk in centres and minor injury units in 2012/13 and activity at these facilities has increased by around 12 per cent annually since this data was first recorded in 2002/03. Recent estimates show that up to a quarter of A&E attendances could have been treated more appropriately in an alternate facility, and many admissions for long term conditions could be avoided through preventative interventions[3,4,5]. Each A&E attendance costs, on average, about £68, with a total of between £760m and £1.5bn spent on major A&E services in England[6].

One of the drivers for change has been the recent spate of patient safety reviews which have drawn attention to the need for reforms to improve patient safety outcomes. These include;

- The Francis report (2009) - Independent Inquiry into care provided by Mid Staffordshire NHS Foundation Trust January 2005 – March 2009[7];
- The Francis report (2013) - Public Inquiry into Mid Staffordshire NHS Foundation Trust[8];
- The Keogh Report (2013) - Review into the quality of care and treatment provided by 14 hospital trusts in England[9];
- The Berwick Report (2013) - Improving the safety of patients in England[10];
- Urgent and Emergency Care Review Team (2013) - The Evidence Base from the Urgent and Emergency Care Review[6];
- Department of Health (2013) - Hard Truths: the journey to putting patients first[11];
- National Quality board (2013) - Right people, Right skills, Right place, Right time[12].

One of the issues highlighted in these reports was the impact of low staffing levels on the provision of care. The link between patient-staff ratios has also been the subject of much research in the literature to explore the relationships between levels of nursing staff and patient outcomes and patient experience.

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1 NHS England. (2012). Everyone Counts: Planning for Patients 2013/14
2 NHS England A&E quarterly activity statistics, NHS and independent sector organisations in England 2012-13
3 Cooperative Pharmacy. (2011). Reducing needless A&E visits could save NHS millions
4 NHS Networks. (2011). New Choose Well Campaign
5 Self-Care Forum. (2012). Over 2 million unnecessary A&E visits "wasted"
6 Urgent and Emergency Care Review Team (2013). High quality care for all, now and for future generations: Transforming urgent and emergency care services in England: The Evidence Base from the Urgent and Emergency Care Review
7 The Mid Staffordshire NHS Foundation Trust Inquiry & Chaired by Robert Francis QC. (2010). Independent Inquiry into care provided by Mid Staffordshire NHS Foundation Trust January 2005 – March 2009, London, The Stationary Office
8 The Mid Staffordshire NHS Foundation Trust Public Inquiry Chaired by Robert Francis Qc 2013. Report of the Mid Staffordshire NHS Foundation Trust Public Inquiry (3 Vols). London: The Stationary Office
9 Keogh, B. (2013). Review into the quality of care and treatment provided by 14 hospital trusts in England: overview report.
10 Berwick, D. (2013). A promise to learn – a commitment to act: improving the safety of patients in England
11 Department Of Health. (2013). Hard truths. The journey to putting patients first; Department of health, England. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/270368/34658_Cm_8777_Vol_1_accessible.pdf
12 National Quality Board. (2013). How to ensure the right people, with the right skills, are in the right place. A guide to nursing midwifery and care staffing capacity and capability' http://www.england.nhs.uk/wp-content/uploads/2013/11/nqb-how-to-guid.pdf

# 3.0 Methods

## 3.1 Model overview

A system dynamics (SD) model of a type 1 (consultant led) A&E department that focuses on the flow of patients from arrival through to departure and the effect of staffing numbers and skill mix was developed. A range of parameters and processes have been incorporated into the model to help describe the patient population and the various pathways they follow during their stay in A&E. These include:

- Staff types and numbers
- Relative productivity across staff types
- Patient attendance distributions (how attendances vary throughout a day)
- Patient acuity levels
- Emergency attendances
- Admissions into hospital
- Discharges
- Initial assessments
- Treatment
- Deaths
- Patients that leave without being seen (LWBS)
- Early discharges

Various time stamps are used in the model to measure the average duration between specific points of the patient journey to create additional outputs on average time spent in the department, time to assessment and time to treatment.

## 3.2 Background to the model

SD is a technique used for modelling complex time based systems based on a concept of stocks and flows. A stock is the term for any entity that accumulates or depletes over time. A flow is the rate of change in a stock. The presence of feedback loops create reinforcing or balancing relationships between sequences of parameters. For example, one feedback loop in the model shows that as the volume of patients increase, the ratio of staff to patients decreases which causes an increase in treatment durations which in turn causes an increase in waiting times and an increase in the volume of patients again.

The differential equations that underpin an SD model mean that several calculation cycles are performed for each time interval. This allows the parameters to affect each other in a continuous process where subtle relationships can be observed.

Several software packages have been produced to support the development of SD models, most of which provide a graphical interface for building and running the model. A software package called iThink, developed by iseesystems[13] was used to create the model. The flow or process diagram view of the model helps non-technical people understand the structure without needing to comprehend the formal mathematics behind it. The software also allows rapid development of prototypes where model components can be created and linked together without needing to re-write functions and equations. This was an essential feature considering the limited time and resources available.

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[13] The model was built in version 9.1.3 of iThink. There may be compatibility issues with version 10 of the software available from http://www.iseesystems.com/.

## 3.3 Conceptual model

The conceptual model is a high level view of the model structure where the various patient flows, parameters and their direction of influence can be observed. The conceptual model was shared with topic experts and members of the National Institute for Health and Care Excellence's (NICE) Safe Staffing Advisory Committee (SSAC) to validate the approach that was being taken. The intention of the conceptual model is to present the model in a way that allows people to engage with it and provide feedback. Through an iterative development process, the conceptual model gets progressively more detailed and complicated as relationships are defined and more evidence and data is brought in. SD works very well in this way as the model can be viewed and designed in a graphical interface which hides the detailed relationships that underpin the detailed mathematical equations.

### 3.3.1 Structure

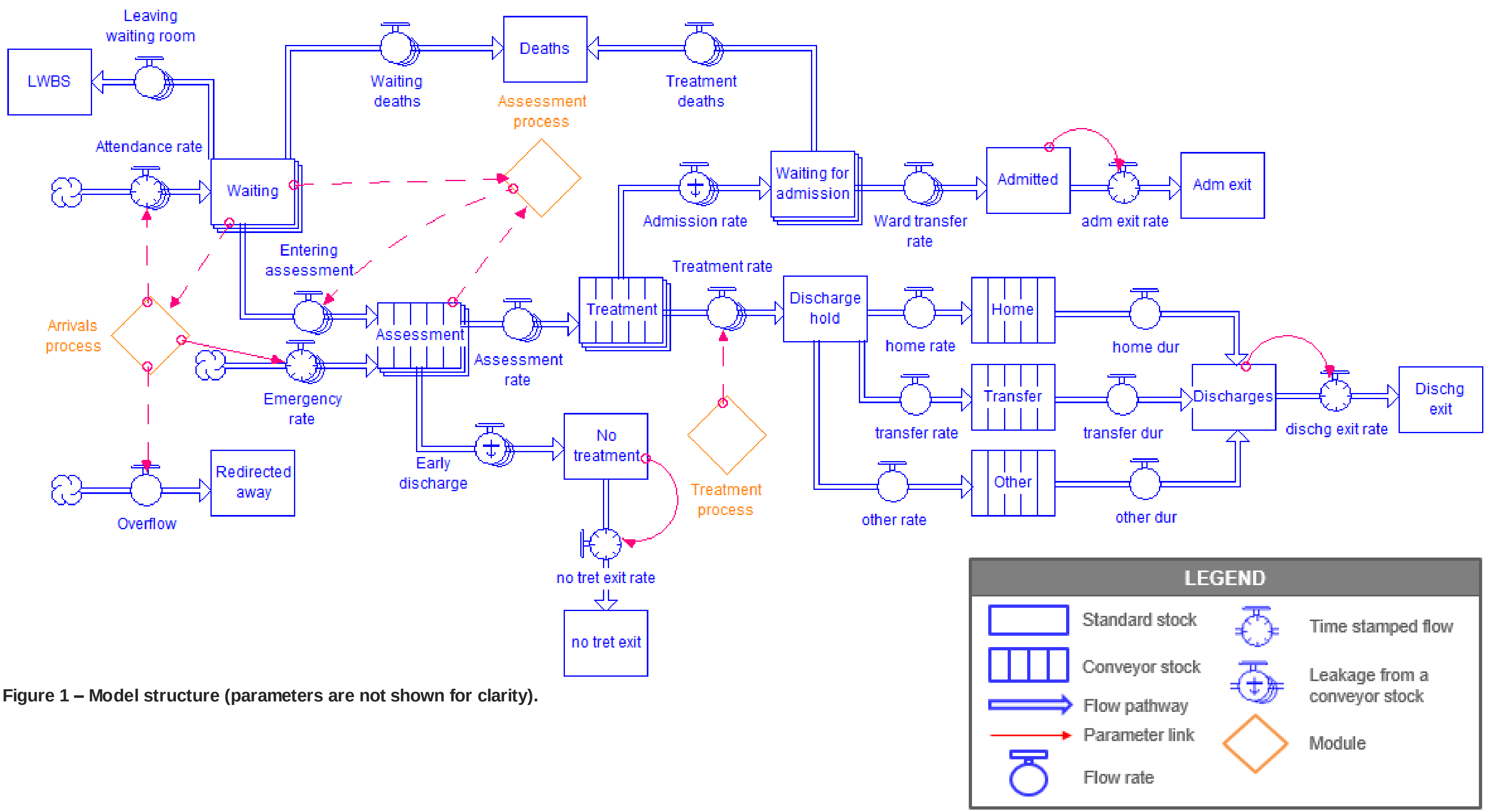


**Figure 1 – Model structure (parameters are not shown for clarity).**

Table 1 – Model component descriptions.

| Component | Description |
|---|---|
| Standard stock | A place in the model where entities accumulate and deplete over time. |
| Conveyor stock | Entities accumulate as in a standard stock, but they remain for a pre-defined period of time before moving in. |
| Flow pathway | The direction of travel between stocks. |
| Parameter link | Arrows indicate where a parameter is being fed into an equation. A dashed red arrow is a parameter link from or to a module. |
| Flow rate | The rate at which patients flow out of one stock and into another. |
| Time stamped flow | Determines the "starting line" for time based measurements. |
| Leakage from a conveyor stock | A secondary exit flow from a conveyor stock based on a probability. For example, when a patient reaches the end of treatment there is a probability of "leaking" into the admissions section. |
| Module | These are used to group a number of model components together to maintain visual clarity. These can be expanded to view the underlying structure. |

Patients flow from left to right, from arrival to discharge or admission. There are several additional exit points where patients leave without being seen, leave without receiving treatment (both self-discharge and do not require treatment) and deaths.

For more information about parameter inputs, see section 3.4.2

## Arrivals

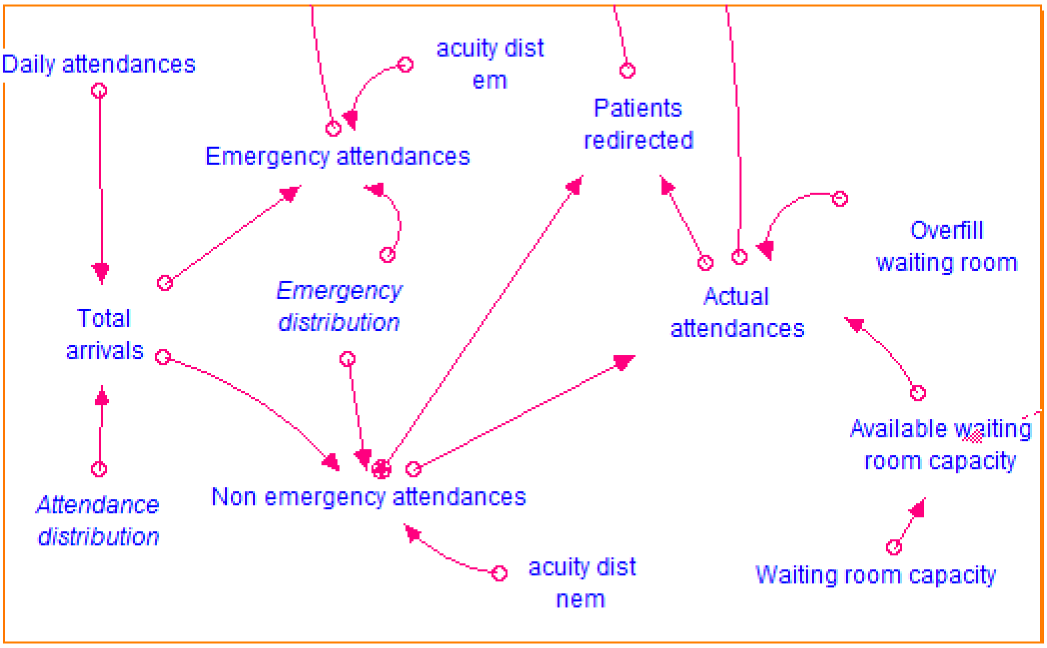


Figure 2 – Arrivals process module.

The rate at which patients arrive is based on an average hourly distribution observed in national Hospital Episode Statistics (HES) data. This is multiplied up by an adjustable daily attendance figure to allow modelling of different sized departments. A degree of randomisation is incorporated based on a Poisson distribution to create small variations.

Emergency arrivals are apportioned out based on the average hourly proportion observed in HES data. This creates a distribution whereby during the day approximately 20-30% of arrivals are via emergency services and overnight this increases to around 50% (see section 3.4 for more information).

A waiting room capacity is used to restrict the number of patients that arrive at the department. Expert opinion suggested that patients would not be redirected away from A&E so this process is disabled by default within the model. When activated, excess arrivals flow into the "Redirected away" stock rather than into the waiting room.

### Patients waiting

As patients arrive into the department, they are held in a waiting stock until there is capacity for assessment. Patients have a small probability of leaving the department without been assessed. This probability increases exponentially as the average waiting time increases. This is an assumption based on discussions with topic experts.

Arrivals via emergency services bypass the waiting room and go straight into assessment regardless of the department's current capacity.

### Assessment

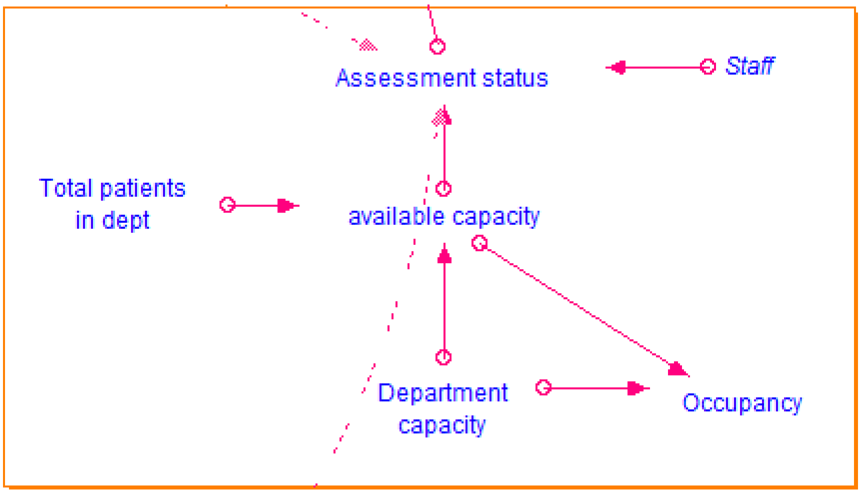


**Figure 3 – Assessment process module.**

The rate at which patients are assessed is based on the number of staff that are working in a triage role, the capacity of the department and an average assessment duration. The baseline assessment duration is adjusted based on the skill mix of the staff and then randomised across the average using a normal distribution.

Patients with high acuity are prioritised for assessment over those with low acuity. The assessment module checks if there are any patients at the highest acuity level and pushes those through first. Then it checks the next highest level and so on. This means that patients with lower acuity will have longer waiting times.

Some patients will be discharged after assessment as they do not require treatment, self-discharge or refuse treatment, or are diverted elsewhere. The probability of this occurring reduces as acuity increases. It is assumed that these patients do not receive treatment and exit immediately after assessment.

The average time taken for patients to move from arrival in the department to completing assessment is measured here. The result of this is fed into the probability of a patient leaving without being seen.

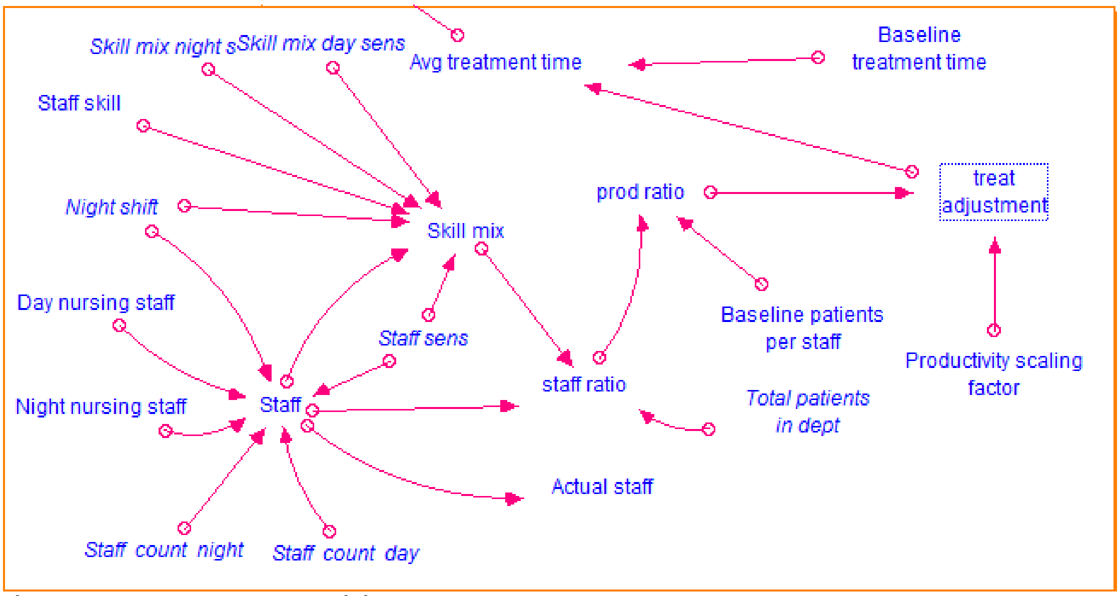


**Figure 4 – Treatment process module.**

## Treatment

The left hand side of the module contains parameters relating to staff numbers and skill mix. The model has been structured in a way that allows the user to define staff numbers in two ways. Firstly, the number of staff by nurse band can be defined and the model will calculate a weighted average skill mix. Secondly, a total number of staff can be set without affecting the skill mix. The latter allows independent adjustment of staff numbers and skill mix so that the observed effects of each can be separated.

An average treatment duration is used to define the length of time patients spent in treatment. This varies with acuity with higher acuities having longer treatment durations. The baseline treatment durations are adjusted based on the number of nursing staff in the department, the skill mix of the staff and the number of patients in the department (including those in assessment, waiting for admission and being discharged). They are then randomised using an exponential distribution so that a small number of patients have very long treatment durations, but the majority have short or average treatment durations. This relationship is based on observations of patient level activity data, see section 3.4.3 for more information.

## Staffing

The number of staff on duty changes according to a day/night shift pattern. By default, the day shift runs from 08:00 to 19:00. The number and type of staff in each shift can be defined in the model interface.

Skill mix is defined as the average skill of the nursing staff on duty, relative to band 5 nurses[14]. This is based on the number of staff in each band and does not factor in different levels of experience within a role. Skill mix is used to calculate the effective number of staff on duty. For example, 10 staff with a relative skill of 0.5 would produce an effective staff count of 5 band 5 nurses. It was necessary to use an index based skill mix to make the modelling exercise manageable. It is a simplification of reality, but it allows the definition of a baseline position from which the effect of increasing and decreasing skill mix can be analysed.

[14] Band 5 nurses are used as the baseline because they are the most common type of nurse in A&E departments.

The increase or reduction in treatment duration uses a productivity scaling factor. This is used in combination with a baseline patients per staff figure and the aforementioned skill mix to calculate the magnitude of the change. For more information on the parameters and methodology used, see section 3.4.2.

#### Admissions, transfers and discharges

Patients that are currently in treatment have a fixed probability of being admitted into hospital, varying by acuity level. This is based on the proportion of patients who receive treatment end up being admitted. At the end of the treatment duration, an admitted patient will flow into the admissions area of the model, otherwise they will flow into the discharge area.

Ward availability can either be permanently set to open, or to operate on a day/night cycle. If the latter is used, this causes a build-up of patients waiting for admission overnight. Since deaths are calculated here, the longer that patients spend in this area of the model the more deaths will occur.

The rate at which patients are transferred from the department to a ward is based on an average transfer time. This is only applied if the ward is flagged as being open.

The model structure has been designed to support different types of discharge from the department so that different destinations and methods can be modelled. For example, patients who require an ambulance to take them home, or require some form of social care support versus those who are able to make their own way home. At the time of building the model and conducting the analysis, the data to support these processes in terms of probabilities and time durations was not available so this section does not have any impact on the outputs presented here.

#### Deaths

Deaths are generally a rare occurrence in A&E departments, but they are an important factor when considering safe staffing. The model structure indicates that deaths can occur for patients stuck in the waiting room, or for patients waiting for admission. In reality, deaths can occur anywhere but a limitation in the software prevents more than 2 exit flows from conveyor stocks. Ideally the “In-treatment” stock would have a third exit flow also going to deaths to cover patients who die during treatment. To overcome this, the probability of admission also includes patients who die whilst in the department.

#### Other health outcomes

Since patients spend a relatively short time in A&E there isn’t much opportunity for other health outcomes to occur beyond successful treatment and discharge, admission into hospital or dying in the department. In other settings, a quality of life year (QALY) may be used to measure the improvement in a patient’s quality of life but the role of A&E departments is about getting patients well enough to be sent home rather than long term health gains. The duration spent in the department is one of the most important outputs that can be included in the model from both a quality and patient experience perspective.

### 3.3.2 Model settings

The following table lists the model settings (“Run specs”) used in the simulation.

**Table 2 – Model settings.**

| Setting | Description |
|---|---|
| Unit of time | Hours |
| Length of simulation | 336 hours (2 weeks) |
| Calculation period | 1/64 (64 calculation cycles per time period) |
| Run mode | Cycle-time[15] |
| Interaction mode | Normal |
| Integration method | Euler's Method[16] |
| Simulation speed | 0 real seconds |

A period of 2 weeks is simulated to let the model reach a steady state (assuming parameter settings aren't so extreme that a steady state is impossible). The model is not pre-populated with patients because this would require a more in depth analysis of activity data and wouldn't provide any benefit since the model would end up at the same stable state.

To align with binary computing formats, the calculation period is usually defined in multiples of 2 when using fractions (i.e. 1/2, 1/4, 1/8 etc.). The shorter the calculation period, the more accurate the results will be but at the consequence of real time required to run the model. The highest level of precision allowed for the required simulation length (1/64) was selected.

## 3.4 Model inputs

The model inputs were identified from a variety of sources, including:

- Evidence review conducted by The University of Southampton
- Several NHS trusts agreed to share their data
- Hospital Episode Statistics (HES)
- The Health and Social Care Information Centre (HSCIC)
- Royal College of Nurses (RCN)
- Personal Social Services Research Unit (PSSRU)
- Expert opinion

Four NHS trusts have provided data to support this version of the model and analysis. A summary of the information provided by these trusts is shown in Table 3. The data sharing agreement that was set up with these trusts means that they cannot be identified by name.

The difference in acuity distributions may be due to the location of the department. Studies have shown that attendance at A&E departments is linked to socio economic deprivation[17]. A report published by the HSCIC in 2013[18] highlights the disparity between the number of attendances by people living in the most deprived areas versus the least deprived areas. Since deprivation is also correlated with the prevalence of long term conditions (as shown in the national GP practice profiles[19]), this suggests that that type of population served by an A&E department can at least partially explain differences in the observed acuity distributions.

[15] Cycle time allows various time based durations to be measured within the model. For example, the average duration for patients to flow from the start of the model to the end.
[16] Euler's Method is mathematical procedure for solving differential equations. More information can be found at http://en.wikipedia.org/wiki/Euler_method
[17] Beattie, T F. (2001). The association between deprivation levels, attendance rate and triage category of children attending a children's accident and emergency department.
[18] HSCIC 2013. Accident & Emergency - http://www.hscic.gov.uk/catalogue/PUB13040/acci-emer-focu-on-2013-rep-V2.pdf
[19] National General Practice Profiles - http://fingertips.phe.org.uk/profile/general-practice

Trust D was unable to provide triage categories in their patient activity data and therefore it was not possible to calculate acuity distributions. It should be noted that Trust B and Site 1 in Trust C have slightly different acuity distributions to the other sites. Assuming that triage categories are used consistently, this suggests that they either serve different populations or their departments provide a different type of service.

The number of staff is based on an estimated average of the provided daily roster data (or planned staff levels where electronic data was not available) and does not include administrative roles, co-ordinators or emergency/advanced nurse practitioners.

**Table 3 – Summary of data provided by NHS trusts.**

| Trust | Trust A | | Trust B | Trust C | | | Trust D |
|---|---|---|---|---|---|---|---|
| **Region** | South East | | North West | Yorkshire & the Humber | | | South West |
| **Site** | Site 1 | Site 2 | Site 1 | Site 1 | Site 2 | Site 3 | Site 1 |
| **Size** | Small | Small | Large | Small | Large | Large | Medium |
| **Capacity** | 24 | 25 | 37 | 12 | 42 | 28 | 25 |
| **Total attendances** | 51,500 | 50,500 | 87,000 | 41,500 | 96,500 | 85,500 | 65,000 |
| **Daily attendances** | 141 | 138 | 238 | 114 | 265 | 234 | 178 |
| **Emergency acuity** | | | | | | | |
| **1 (least acute)** | 1.0% | 0.3% | 0.3% | 0.1% | 0.1% | 0.1% | n/a |
| **2** | 31.6% | 28.6% | 14.8% | 52.3% | 19.3% | 20.7% | n/a |
| **3** | 59.3% | 59.4% | 47.2% | 44.7% | 73.7% | 64.1% | n/a |
| **4** | 6.3% | 7.6% | 35.6% | 2.4% | 6.5% | 13.3% | n/a |
| **5 (most acute)** | 1.8% | 4.0% | 2.1% | 0.6% | 0.4% | 1.8% | n/a |
| **Non-emergency acuity** | | | | | | | |
| **1 (least acute)** | 2.9% | 1.7% | 0.8% | 0.0% | 0.2% | 0.4% | n/a |
| **2** | 59.6% | 74.3% | 47.6% | 66.7% | 50.9% | 58.9% | n/a |
| **3** | 34.2% | 22.3% | 39.5% | 30.4% | 46.3% | 36.2% | n/a |
| **4** | 2.7% | 1.4% | 11.8% | 2.9% | 2.6% | 4.3% | n/a |
| **5 (most acute)** | 0.6% | 0.3% | 0.2% | 0.0% | 0.0% | 0.1% | n/a |
| **Staff (day)** | 10 | 13 | 12 | 5 | 12 | 11 | 10 |
| **Staff (night)** | 8 | 10 | 10 | 2 | 11 | 7 | 8 |

### 3.4.1 Evidence review

The evidence review for this project was undertaken by the University of Southampton. A separate evidence review report has been produced describing the steps taken in producing the review. A final list of 25 studies was received for full text screening and data extraction to support the development of the economic model. 16 studies were extracted from the full text, apart from in the two cases where the full text was not available to purchase, and so the abstract was used. The data that was available for each paper is outlined in the table below.

**Table 4 – Overview of included papers from included studies in evidence review.**

| Study | Type of data |
|---|---|
| Greci et al 2011 | Nurse to patient ratio |
| Schull et al 2003 | Ambulance diversion |
| Chan et al 2010 | Nurse to patient ratio, Staff times based on acuity, Increase in time if out of ratio |
| Weichenthal et al 2011 | Waiting time values |
| Brown et al 2012 | Left without being seen |
| Hoxhaj et al 2004 | Left without being treated |
| Harris et al 2010 | Waiting times |
| Korn et al 2008 | Staff workload estimates |
| Hobgood 2005 | Nursing time fractions |
| Crouch et al 2006 | Patient dependency |
| Daniel 2012 | Skill mix and patient satisfaction |
| Chan et al 2009 | Time to treatment |

As this data had significant gaps, the team requested the excluded studies from the University of Southampton to examine whether there was usable background data within those studies.

38 studies were examined and 7 studies were found to have useful data. An overview of the data can be found in the below table.

**Table 5 – Overview of included papers from excluded studies in evidence review.**

| Study | Type of data |
|---|---|
| Fee et al 2011 | Timing of patient movement through A&E |
| Lyons et al 2007 | Triage related data, including time staff spend away from triage |
| O'Brian and Benger 2007 | Patient dependency |
| Steele and Kiss 2008 | Timing of patient movement through A&E and structure of A&E |
| Fullham 2002 | Time related to patient acuity |
| Paulson 2004 | Impact of using unqualified nursing staff |
| Pham et al 2011 | Association between temporary staff use and medication errors |

### 3.4.2 Parameters

All of the data used in the model can be edited within the CSV data template and imported into the software via the 'Edit > Manage persistent links' menu command. The tables below list all of the parameters used in the model, divided into fixed and adjustable parameters.

Some parameters are divided into acuity levels where acuity 1=minor patients and 5=most urgent patients (sometimes defined as resuscitation patients). These levels are based on triage categories from patient activity data. All patient activity data received from the NHS trusts indicates that they use a similar triage priority scale based on five categories, though it is recognised that these are subjective assessments and are unlikely to be perfectly consistent. It is understood that the Manchester Triage System (MTS) is widely used across the UK as the standard approach to triaging patients.

#### Fixed parameters

**Table 6 – Fixed parameters used in the model.**

| Parameter | Acuity | Value | Source | Time period | Notes |
|---|---|---|---|---|---|
| Attendance distribution | n/a | Varies | HES | 2012/13 | Average proportion of daily attendances in hourly intervals. |
| Ambulance distribution | n/a | Varies | HES | 2011/12 | The hourly proportion of attendances where the arrival method is ambulance or the Helicopter Emergency Medical Service (HEMS). Arrivals via an ambulance bypass the waiting room and go straight into assessment. |
| Probability of admission | 1<br>2<br>3<br>4<br>5 | 6.2%<br>13.4%<br>46.4%<br>74.5%<br>82.8% | Average of NHS Trusts | 2013/14 | The number of admitted patients as a proportion of those who died in the department, were admitted or discharged after treatment. |
| Average assessment duration | n/a | 0.17 hrs | Expert opinion | n/a | Patient activity data only contains the time when an assessment starts. Experts have suggested that 10 minutes is a reasonable estimate. |
| Baseline average treatment duration | 1<br>2<br>3<br>4<br>5 | 0.80 hrs<br>0.98 hrs<br>1.72 hrs<br>2.26 hrs<br>2.40 hrs | NHS Trusts | 2013/14 | This is measured as the time between treatment starting and departure. Patient activity data does not record the time at the end of treatment so this is the best measure available. |
| Band 2 skill | n/a | 0.64 | RCN | 2013/14 | Ratio of average pay rate in 2013/14 relative to band 5 nurse. |
| Band 3 skill | n/a | 0.73 | RCN | 2013/14 | Ratio of average pay rate in 2013/14 relative to band 5 nurse. |
| Band 4 skill | n/a | 0.84 | RCN | 2013/14 | Ratio of average pay rate in 2013/14 relative to band 5 nurse. |
| Band 5 skill | n/a | 1.0 | RCN | 2013/14 | Ratio of average pay rate in 2013/14 relative to band 5 nurse. |
| Band 6 skill | n/a | 1.22 | RCN | 2013/14 | Ratio of average pay rate in 2013/14 relative to band 5 nurse. |

| Parameter | Acuity | Value | Source | Time period | Notes |
|---|---|---|---|---|---|
| Band 7 skill | n/a | 1.45 | RCN | 2013/14 | Ratio of average pay rate in 2013/14 relative to band 5 nurse. |
| Probability of death | 1<br>2<br>3<br>4<br>5 | 0.00%<br>0.00%<br>0.01%<br>0.14%<br>12.96% | NHS Trusts | 2013/14 | These rates are applied to patients waiting for treatment and patients waiting for admission. Based on a random number generator, the longer that patients spend in the model, the more chances there are for death to occur.<br><br>Patients that are recorded as dead on arrival are not included in this rate. |
| Probability of departure without being seen | n/a | Varies from 0.5% - 50% | Expert opinion | n/a | Function that increases exponentially with average waiting time (from 0 up to 10 hours). The same distribution is applied to all acuity levels. |
| Probability of early discharge | 1<br>2<br>3<br>4<br>5 | 38.0%<br>25.9%<br>13.6%<br>10.0%<br>5.2% | NHS Trusts | 2013/14 | This includes patients that refuse treatment/self-discharges, referrals to other internal departments and deflections. |
| Baseline patients per staff | n/a | 1.5 | NHS Trusts | n/a | The average number of patients per staff that the baseline treatment duration is based on. |
| Productivity scaling factor | n/a | 1.35 | NHS Trusts<br>Evidence review | 2013/14<br>2010 | The increase or reduction in treatment duration associated with higher and lower staff to patient ratios. This is applied in such a way that treatment times are not reduced by a significant amount when adding more staff, but removing staff does have a significant impact. |
| Probability of home discharge | n/a | 98% | NHS Trusts | 2013/14 | Of the patients who are discharged, the probability of a patient being discharged back home. |
| Probability of transfer | n/a | 2% | NHS Trusts | 2013/14 | Of the patients who are discharged, the probability of a patient being transferred to another department or healthcare provider. |
| Probability of other discharge | n/a | 0% | n/a | n/a | Currently undefined |
| Duration of home discharge | n/a | 0 | n/a | n/a | The time required to discharge a patient back home after treatment. Data to support this parameter could not be acquired so it currently has no effect in the model. |
| Duration of transfer | n/a | 0 | n/a | n/a | The time required to transfer a patient to another department or healthcare provider after treatment. Data to support this parameter could not be acquired so it currently has no effect in the model. |
| Duration of other discharge | n/a | 0 | n/a | n/a | Currently undefined |

## Staff salaries

The following table shows the average salaries by nurse band that were used to calculate productivity relative to band 5, sourced from RCN[20]. Data from the PSSRU was reviewed as an additional source of staff salaries[21]. Although the estimated earnings are slightly higher, the effect on the calculated relative skill negligible.

**Table 7 – Average pay rates by band in 2013/14.**

| Band | Salary (RCN) | Relative skill (RCN) | Salary (PSSRU) | Relative skill (PSSRU) |
|---|---|---|---|---|
| 2 | £15,719 | 0.64 | £16,306 | 0.65 |
| 3 | £17,813 | 0.73 | £18,264 | 0.72 |
| 4 | £20,480 | 0.84 | £21,122 | 0.84 |
| 5 | £24,430 | 1.00 | £25,224 | 1.00 |
| 6 | £29,887 | 1.22 | £30,756 | 1.22 |
| 7 | £35,542 | 1.45 | £36,859 | 1.46 |

## Adjustable parameters

An adjustable parameter is one that has been included in the front end of the model as a control such as a switch, slider or an editable graph and can be changed whilst the model is running. These parameters were considered to be ones that would vary the most between different departments. The indicated ranges should cover most situations in a real department though they can be overridden in the model.

[20] http://www.rcn.org.uk/support/pay_and_conditions/pay_rates_201314
[21] Unit costs of Health and Social Care 2013, http://www.pssru.ac.uk/project-pages/unit-costs/2013/

**Table 8 – Adjustable parameters used in the model.**

| Parameter | Acuity | Initial value | Range | Notes |
|---|---|---|---|---|
| Daily attendances | No | n/a | 0-300 | The hourly arrivals distribution is multiplied up by this figure to produce the total number of arrivals at each hour. |
| Waiting room capacity | No | n/a | 0-50 | Puts a limit on the number of patients that can be in the waiting room. When at full capacity, additional patients are turned away. This process is disabled by default in the model. |
| Department capacity | No | n/a | 0-50 | The number of treatment/assessment units in the department (i.e. beds, trollies, cubicles). |
| Average transfer time | No | 0.25 hours | 0.00-1.00 | The average time in hours required to admit a patient provided wards are open. |
| Acuity distribution | Yes | n/a | 0-100% | The distribution of acuity amongst attendances. Level 1 = minor cases, level 5 = most urgent cases. This is split by emergency (ambulance/HEMS) and non-emergency arrivals. A value of 20% for emergency acuity level 2 would mean that 20% of emergency patients have an acuity level of 2.<br><br>Initial values are not provided since observed acuity distributions vary significantly based on the department. |
| Ward cycle | No | 11:00-03:00 = 1<br>04:00-10:00 = 0 | 0-1 | A time based flag that allows patients to be admitted. 1=admissions allowed, 0=admissions prevented. |
| Night shift | No | 20:00-07:00 = 1<br>08:00-19:00 = 0 | 0-1 | A time based flag that switches staff from day to night shift numbers. 1=night shift, 0=day shift. |
| Number of staff (day shift) | No | n/a | 0-20 | Number of staff on day shift by band (from 2 to 7). This used for testing scenarios of particular staff type combinations in the model. |
| Number of staff (night shift) | No | n/a | 0-20 | Number of staff on night shift by band (from 2 to 7). This used for testing scenarios of particular staff type combinations in the model. |
| Average skill mix (day/night) | No | 1.00 | 0.5-1.5 | When specified, this overrides the staff type combinations so that a consistent skill mix can be defined for testing sensitivities. |
| Average staff count (day/night) | No | n/a | 2-20 | When specified, this overrides the staff type combinations so that a consistent staff count can be defined for testing sensitivities. |

## Calculated parameters

**Table 9 – Calculated parameters used in the model.**

| Parameter | Acuity | Definition |
|---|---|---|
| Average skill mix[22] | No | Sum([Number of staff in band x] * [Band x skill]) / [Total number of staff] |
| Actual staff count[23] | No | Sum([Number of staff in band x]) |
| Adjusted assessment duration | Yes | [Baseline assessment duration] / [Average skill mix] |
| Effective staff count | No | [Average skill mix] * [Actual staff count] |
| Total patients in department | No | [In assessment] + [In treatment] + [Waiting for admission] |
| Staff ratio | No | [Effective staff count] / [Total patients in department] |
| Productivity ratio | No | (1 / [Baseline patients per staff]) / [Staff ratio] |
| Treatment adjustment factor | No | [Productivity scaling factor] ^ ([Productivity ratio] - 1) |
| Adjusted treatment duration | Yes | [Baseline treatment duration] * [Treatment adjustment factor] |
| Occupancy | No | ([Total patients in department] / [Capacity]) * 100 |

[22] This can be overridden by a user defined skill mix.
[23] This can be overridden by a user defined staff count.

### 3.4.3 Distributions

#### Parameter distributions

Some parameters in the model are defined as time based functions where the value of the parameter changes over the course of a day. These parameters include:

- the rate at which patients arrive in the department (sourced from HES);
- the proportion of patients that arrive via emergency services (sourced from HES);
- the day and night operating cycle of the department with respect to staff shifts and inpatient admissions (sourced from expert opinion).

All time based distributions are repeated for every 24 simulated hours. These are all adjustable within the model but the default distributions are shown below.

**Table 10 – Time based parameter distributions.**

| Hour | Attendances (% of daily total) | Emergency (% of hourly total) | Staff night shift (1=night) | Ward status (1=open) |
|---|---|---|---|---|
| 00:00 | 2.3 | 48 | 1 | 1 |
| 01:00 | 2.0 | 53 | 1 | 1 |
| 02:00 | 1.4 | 55 | 1 | 1 |
| 03:00 | 1.4 | 55 | 1 | 1 |
| 04:00 | 1.3 | 55 | 1 | 0 |
| 05:00 | 1.3 | 54 | 1 | 0 |
| 06:00 | 1.3 | 46 | 1 | 0 |
| 07:00 | 1.9 | 32 | 1 | 0 |
| 08:00 | 3.5 | 25 | 0 | 0 |
| 09:00 | 7.3 | 21 | 0 | 0 |
| 10:00 | 7.0 | 22 | 0 | 0 |
| 11:00 | 6.6 | 23 | 0 | 1 |
| 12:00 | 6.1 | 24 | 0 | 1 |
| 13:00 | 6.1 | 25 | 0 | 1 |
| 14:00 | 5.7 | 26 | 0 | 1 |
| 15:00 | 5.7 | 27 | 0 | 1 |
| 16:00 | 5.8 | 26 | 0 | 1 |
| 17:00 | 5.9 | 26 | 0 | 1 |
| 18:00 | 6.3 | 24 | 0 | 1 |
| 19:00 | 5.8 | 24 | 0 | 1 |
| 20:00 | 5.0 | 28 | 1 | 1 |
| 21:00 | 4.1 | 31 | 1 | 1 |
| 22:00 | 3.4 | 36 | 1 | 1 |
| 23:00 | 2.9 | 42 | 1 | 1 |

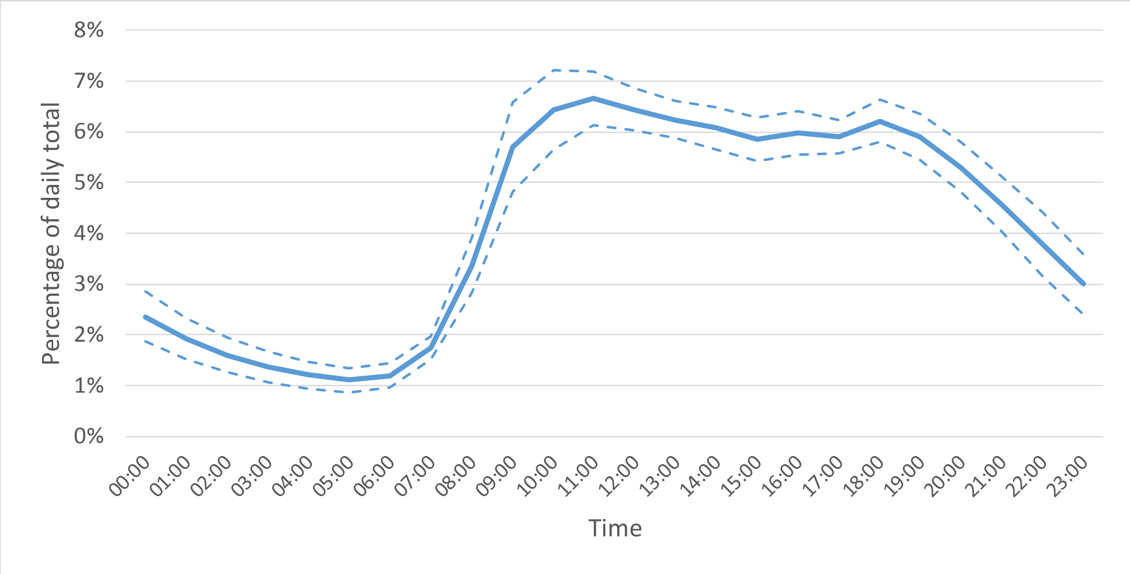


**Figure 5 – Hourly attendance distribution used in the model. The dashed lines represent one standard deviation from the mean. This analysis was based on 2011/12 data rather than 2012/13.**

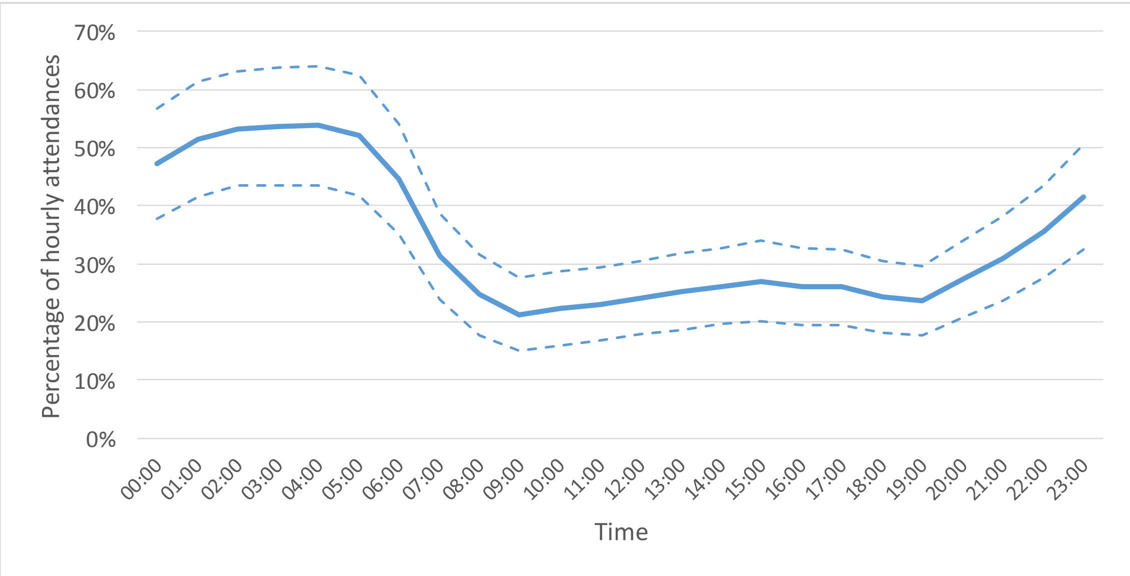


**Figure 6 – Proportion of attendances that are via emergency services (ambulance or HEMS). The dashed lines represent one standard deviation from the mean.**

A spike in attendances is observed in the morning and remains at a high level throughout the day. In the early evening the rate of attendances starts to drop off until around one or two o'clock where it levels out. This exact distribution may not be observed in all departments but the general trend will be similar.

Although the proportion varies from 55% down to 20%, the actual number of emergency attendances doesn't change much between night and day due to the overall number of attendances being much lower overnight. Once again, this exact pattern may not be observed across all departments but it shows the general trend.

## Randomised distributions

System dynamics modules are deterministic in nature, meaning that each time you run a simulation with the same parameters the outputs will be the same. To introduce a degree of randomisation that will better reflect reality, probability distributions are applied for several parameters.

**Table 11 – Random distributions used in the model.**

| Parameter | Distribution | Reason |
|---|---|---|
| Arrivals | Poisson | Poisson distributions are often used in healthcare modelling as they apply to discrete events (i.e. A&E attendances) over a fixed period of time. This generates attendance rates that will be slightly higher or lower than the average. The point in time that patients arrive will also be different in each simulation as a result of this distribution. |
| Assessment durations | Normal | Assessments are intended to be a specified duration and are not thought to be skewed in one direction or another. A standard deviation of 0.05 hours (3 minutes) is used. This does not take into account other factors such as translators or interpreters and uncooperative patients. |
| Treatment durations | Exponential | Observed treatment durations follow an exponential curve where the majority of patients have short treatment durations, but a minority have long treatment durations. The adjusted treatment duration for each acuity level is used as the lambda (λ) value. |

Figure 7 shows the probability density function of treatment durations, measured from treatment starting to departure, based on a random sample of HES data. Treatment durations were counted in 5 minute intervals to account for the tendency to record timestamps to the nearest 5th minute at the point of entry. The shape of the curve indicates an exponential relationship. It should be noted that this relationship may be skewed by the 4 hour waiting target, causing a larger number of patients to have shorter treatment durations. There are also known data quality issues with the timestamps recorded in patient activity data but in the absence of a better data source, it is assumed that these recording errors are averaged out amongst a large enough sample.

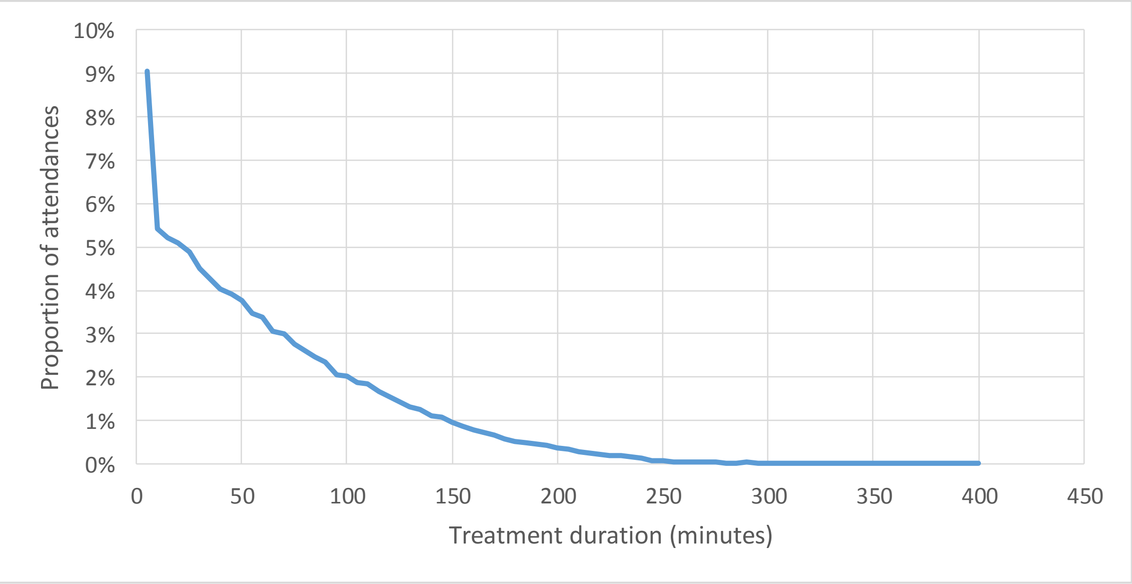


**Figure 7 – Probability density function of treatment durations in minutes (based on a random 1% sample of records from HES A&E 2011/12). Treatment durations of longer than 400 minutes are excluded.**

### 3.4.4 Key assumptions

There are various reasons why assumptions have been used in the A&E model. One of the key factors to consider is that A&E departments are incredibly complicated systems that are constantly changing. Unlike inpatient wards where capacity and staffing requirements can be planned, A&E departments are unpredictable by their very nature. Due to this and the lack of evidence and data on the subject of staffing in A&E departments, the following assumptions apply to the model.

**Table 12 – Conceptual assumptions used in the model.**

| Assumption | Reason |
|---|---|
| Staff are not restricted to individual roles. | In an A&E department you will likely find staff assigned to sub-roles such as resuscitation, majors and minors. Some staff may be responsible for triage only. Due to the possibility of staff moving between these roles to cope with the current demand, it was decided to model staff as a pooled resource that assess and treat all patients. This has a side of effect of blockages at the beginning of the system (such as patients not being triaged in a timely manner) not appearing in the model. |
| Capacity uniformity. | Similar to how staff are modelled, capacity is modelled as a uniform resource and is not defined by type of bed, trolley or cubicle. This effectively assumes that if there is spare capacity, it can be used regardless of what type of patient needs it. |
| Staff experience/skill does not vary within bands. | This would be too complicated to model. However, you could assume that highly experienced band 5 nurses were equivalent to band 6 nurses, for example. |
| Emergency arrivals are no different to non-emergency arrivals once split into acuity levels. | Arrivals by both methods are split by acuity (triage priority). It is assumed that it is the triage priority that defines the patient journey rather than how they arrive (beyond bypassing the waiting room). |
| Admission rates do not scale with duration in A&E. | Observed A&E durations follow a pattern whereby a very large number of patients are admitted into hospital shortly before the 4 hour mark. As individuals cannot be tracked through an SD model, it is assumed that admission rates are based on triage priority only. That said, the baseline admission rates are based on real data and thus it is impossible to isolate the effect of the 4 hour target. |
| Staff shifts only exist as day and night. | According to the data that was provided by NHS trusts, most staff work in a standard day or night shift cycle. There are other shifts that overlap but these were in the minority and would overly complicate the model without much benefit. |
| Patients waiting for admission are restricted based on a day/night cycle. | Modelling inpatient wards is outside of the scope of the analysis so a simple mechanism for restricting the flow of admitted patients was implemented. |

## 3.5 Quality assurance / validation

Optimity Matrix complies with ISO 9001. A set of quality standards informs our approach to project and resource management. Their effective implementation is monitored with improvements made where necessary.

Topic experts have been involved throughout the project, from developing the methodological approach to making content-specific recommendations. The analysis and this report have been checked for factual errors and omissions as well as making sure that the methodological approach is described in a transparent manner.

#### Quality assurance process

1) Agree deadline and structure of the analysis and report
2) Produce 1st draft of analysis
3) Methods/contents QA: The project manager and expert advisors review the analysis and provide feedback.

4) Produce revised draft: The team respond to all major comments and produce a revised version of the analysis.
5) Editorial QA: The revised draft is submitted for editorial QA.
6) Submit analysis: The project director signs off the report before submitting it to the client. The client reviews the report in accordance with the stipulations set out in the project specifications/contract. If the client is satisfied, the report is signed off by the client. Otherwise the cycle starts over with further revisions. The number of allowed revisions is stipulated in the proposal.

In addition to the QA steps laid out above, the basic model structure has been validated with the SSAC as well as topic experts who are experienced health system modellers. Feedback has been collected throughout the process from both parties and where possible the model has been modified and re-validated in an iterative development process.

Outputs from the model have been reviewed during development to ensure that they are broadly in line with what you would expect to see in a real department. Due to the model being a simplification of an A&E system, the outputs will never match exactly what is observed in reality but the relationships between the key parameters of staff numbers, staff skill mix and patient volumes should remain true. Due to the lack of data and evidence, the scale and direction of these relationships was considered to be more important than the absolute values.

A draft analysis of the findings and this report were presented to members of the SSAC on December 4th.

# 4.0 Results

The results of the analysis are presented as charts showing the trade-off between pairs of parameters and their effect on the modelled outputs. Tabular versions of the chart as well as inter-quartile ranges are included in the appendices. A series of sensitivity tests are also presented here where a number of baseline parameters and assumptions were varied and their effect on the outputs measured.

The parameter combinations selected for the main results were:

1) Staff numbers and staff skill mix
2) Attendance volume and staff skill mix
3) Attendance volume and staff numbers

A total of seven outputs are measured in the model:

1) Average duration in A&E – this is the average time spent by patients in the department, measured in hours.
2) Average time to assessment – this is the average time spent by patients in the waiting time, measured in hours. This does not include emergency arrivals who bypass the waiting room.
3) Average time to treatment – this is the average time spent by patients between arrival and treatment starting, measured in hours. This is a weighted average of standard and emergency arrivals.
4) Average number of patients per staff – this is the average at any one point in the department over the duration of the simulation. This does not include patients who are in the waiting room.
5) Average occupancy – a measure of the proportion of capacity that is taken up by patients expressed as an average over the duration of the simulation.
6) Patient deaths – the proportion of patients that arrive who die in the department, measured over the duration of the simulation. There is no distinction between expected and unexpected deaths in the model.
7) Patients who LWBS – the proportion of patients who leave the department without being seen by a member of staff, measured over the duration of the simulation.

As the model is initially empty when a simulation is started there is a burn in period during which there are various peaks and troughs in the outputs. To prevent this period from skewing the presented results, the first 50 hours of simulation are ignored when taking averages of the outputs.

## 4.1 Baseline settings

For each analysis, capacity and baseline staff levels were selected for a single trust that provided data to ensure the model was set up with realistic parameters. Unless specified, the model was run with default parameters and the following department specific parameters. For detailed definitions of parameters, please see section 3.4.2 and the glossary at the end of this report.

Daily attendances: 141
Capacity: 24
Day shift staff: 10
Night shift staff: 8
Day shift skill mix: 1.00
Night shift skill mix: 1.00

**Table 13 – Baseline acuity distributions used for analysis.**

| Acuity Level | Emergency | Non-emergency |
|---|---|---|

| | | |
|---|---|---|
| 1 | 1.0% | 2.9% |
| 2 | 31.6% | 59.6% |
| 3 | 59.3% | 34.2% |
| 4 | 6.3% | 2.7% |
| 5 | 1.8% | 0.6% |

## 4.2 Stochastic variation

The stochastic sensitivity was tested by running the model 100 times and it was found that the key outputs were stable. Combined with the large string of random numbers that are generated throughout a single simulation, this ensures that the results are not wholly dependent on the single random string. The results for each output were compared using basic descriptive statistics.

**Table 14 – Variation in outputs when the model is allowed to run stochastically.**

| Test | Avg duration | Avg time to assessment | Avg time to treatment | Avg patients per staff | Average occupancy % | LWBS % | Deaths % |
|---|---|---|---|---|---|---|---|
| n | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Min | 2.17 | 0.02 | 0.17 | 0.77 | 29.67 | 0.49 | 0.42 |
| 25th | 2.28 | 0.02 | 0.18 | 0.82 | 31.52 | 1.18 | 0.77 |
| 50th | 2.32 | 0.02 | 0.18 | 0.85 | 32.61 | 1.41 | 0.88 |
| 75th | 2.36 | 0.02 | 0.18 | 0.88 | 33.63 | 1.72 | 1.06 |
| Max | 2.46 | 0.02 | 0.18 | 0.95 | 36.57 | 3.28 | 1.69 |
| Mean | 2.32 | 0.02 | 0.18 | 0.85 | 32.64 | 1.51 | 0.94 |
| Stdev | 0.055 | 0.000 | 0.002 | 0.038 | 1.46 | 0.52 | 0.27 |
| Variance | 0.003 | 0.000 | 0.000 | 0.001 | 2.12 | 0.27 | 0.08 |
| 95% CI | 0.011 | 0.000 | 0.000 | 0.008 | 0.29 | 0.10 | 0.05 |

These results indicate that the average duration, average patients per staff and average occupancy outputs are very robust. However, there is a degree of uncertainty in the results for patients who leave without being seen and deaths which both have high standard deviations and confidence intervals in relation to the mean and are therefore viewed as unreliable. Due to the way that arrivals are modelled, the time to assessment and time to treatment are mostly static and unaffected by the randomness.

It would be expected that the observed variation would increase as the parameters deviate from the baseline.

When running simulations to produce results, the random distributions and number generators were set up with pre-defined seeds. A seed defines the starting point for the generation of a series of random numbers. By using the same seed for each simulation, the model is forced to produce the same set of random numbers each time, becoming deterministic rather than stochastic in the process. This allows the effect of each parameter change to be isolated.

## 4.3 Staff numbers and staff skill mix

Outputs from the model were measured across a range of staff skill mixes and staff numbers. To ensure consistency and to keep the quantity of output tables down to a reasonable number, skill mix changes were applied to both day and night staffing shifts. The range of skill mixes presented provides the maximum possible spread based on the assumption that salaries are an accurate measures of productivity.

The changes in staffing numbers were kept consistent between day and night shifts in absolute terms (i.e. a reduction of 2 day shift staff was mirrored by 2 night shift staff). Staff numbers are shown in the format of [Day shift staff] / [Night shift staff]. For example, 10 / 8 would mean 10 day shift staff and 8 night shift staff.

## Average duration in A&E (hours)

- Staff skill mix causes a wide variation in durations for each combination of staff numbers.
- With higher numbers of staff, the impact of average skill mix is lessened.
- There is not much difference between high skill levels.

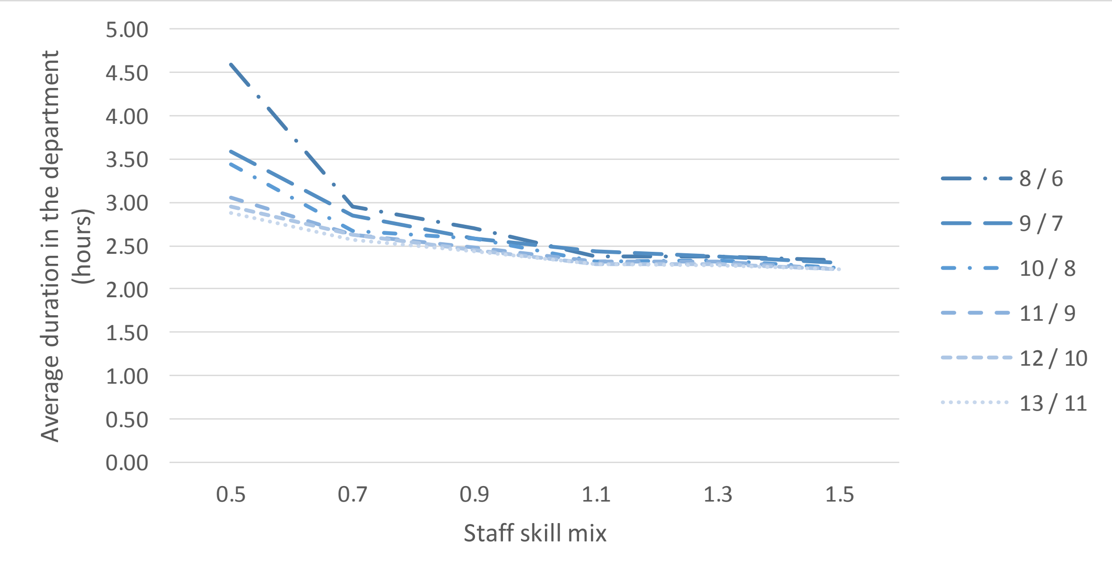


**Figure 8 – Average duration in A&E, by staff numbers and staff skill mix.**

## Average time to assessment (hours)

- There is minimal impact at high skill levels but a progressively large impact at low skill levels, based on the number of staff.

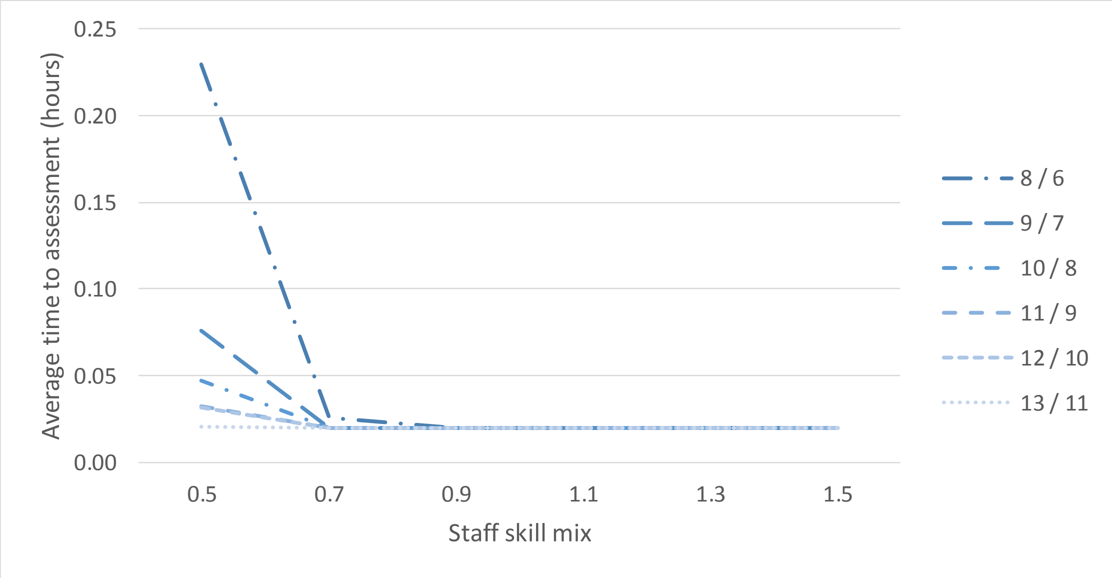


**Figure 9 – Average duration in A&E, by attendance volume and staff skill mix.**

## Average number of patients per staff

- Staff skill mix causes a wide variation in the average number of patients per staff for each combination of staff numbers.
- With higher numbers of staff, the impact of average skill mix is lessened.
- The average duration is closely linked to the average number of patients in the department so it's not surprising that a similar pattern is observed.

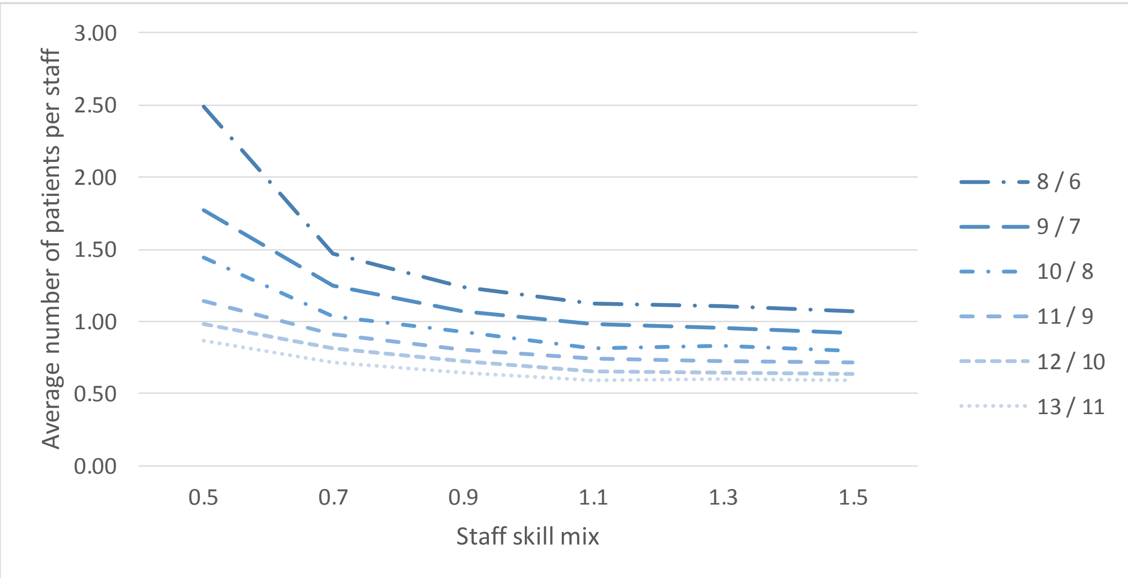


**Figure 10 – Average number of patients per staff, by staff numbers and skill mix.**

### Average occupancy

- There is a sharp increase in the average occupancy amongst lower staff skill mix, especially when staff numbers are low as well.
- At higher skill levels there is very little variation in occupancy across different staff numbers.

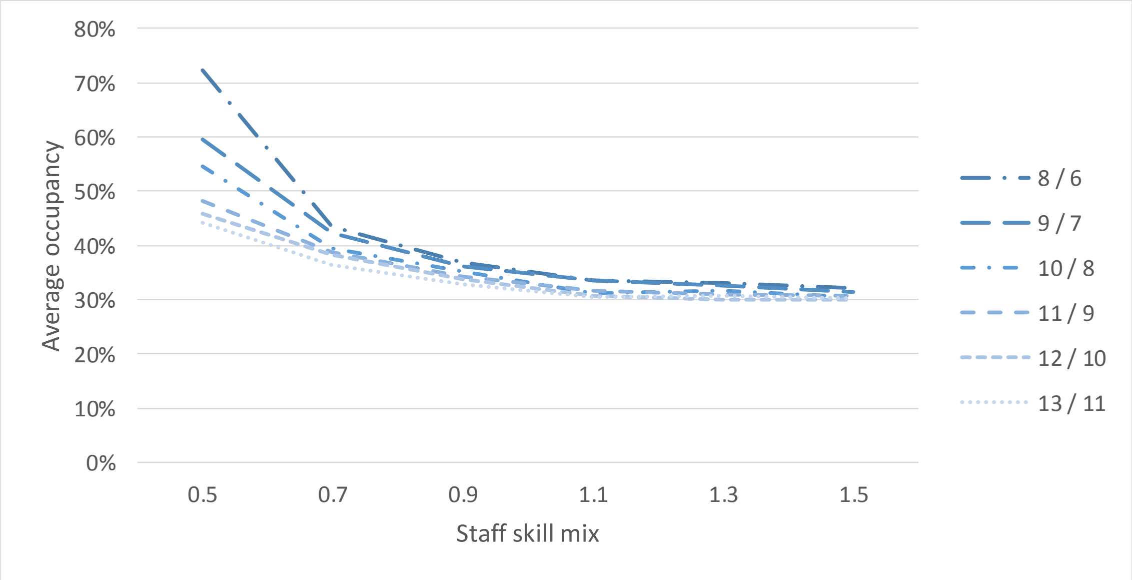


**Figure 11 – Average occupancy, by staff numbers and skill mix.**

### Patient deaths

- Death outputs are inconsistent and due to the very small numbers and probabilities associated with death causing discrepancies in the model they may not be clinically realistic.

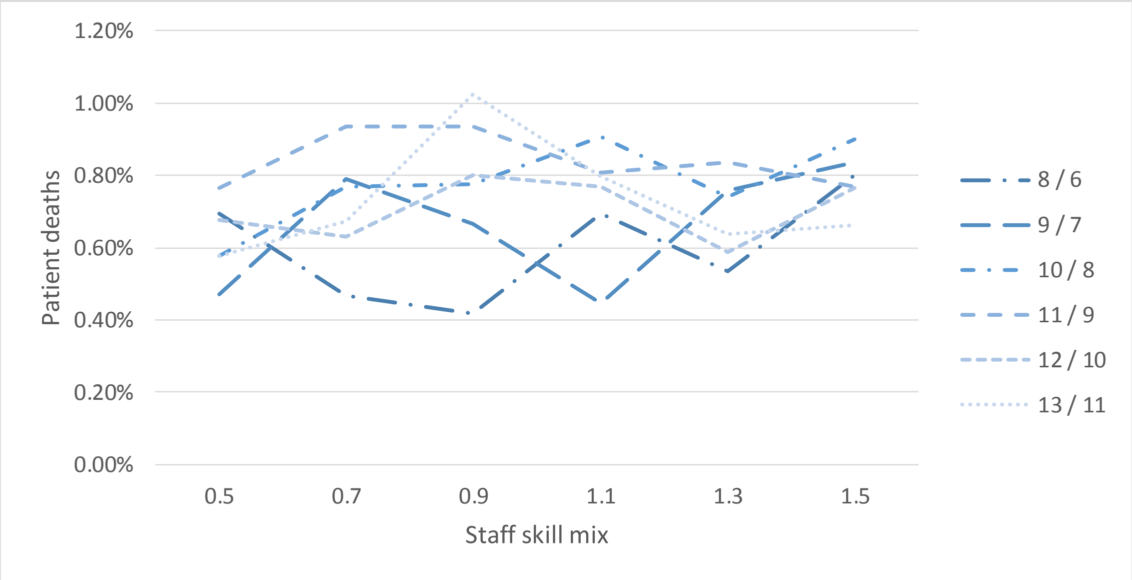


**Figure 12 – Patient deaths, by staff numbers and skill mix.**

### Patients who LWBS

- The data suggest that the staff skill mix is more important than staff numbers in preventing patients from leaving without being seen.

- At high skill levels, LWBS outputs are inconsistent. As with the deaths analysis, this could be due to the small numbers associated with this process in the model.

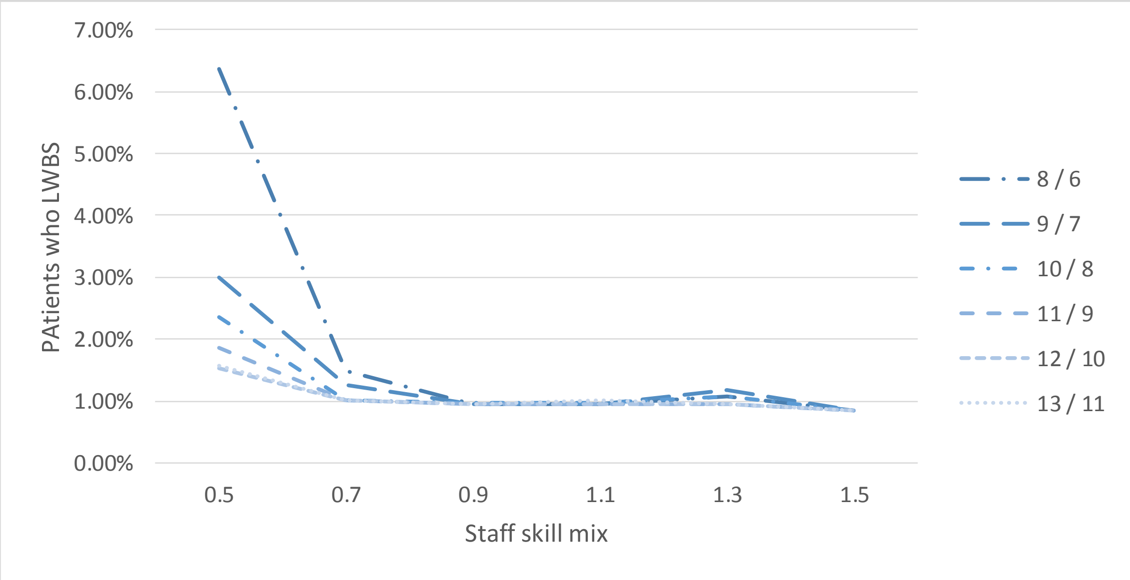


**Figure 13 – Patients who LWBS, by staff numbers and skill mix.**

## 4.5 Attendance volumes and staff skill mix

Outputs from the model were measured across a range of attendance volumes and staff skill mixes. To ensure consistency and to keep the quantity of output graphs down to a reasonable number, skill mix changes were applied to both day and night staffing shifts. The range of skill mixes presented provides the maximum possible spread based on the assumption that salaries are an accurate measure of productivity.

### Average duration in A&E (hours)

- The throughput of patients has the largest impact when the staff skill mix is low.
- The scale of the impact is greatest at the low staff skill end of the spectrum.

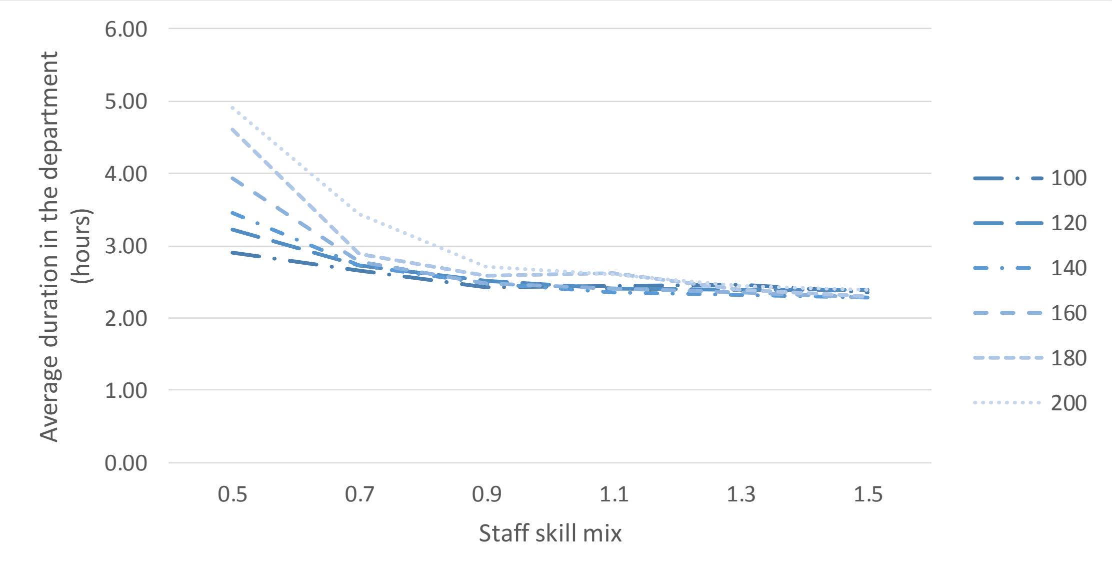


**Figure 14 – Average duration in A&E, by attendance volume and staff skill mix.**

## Average time to assessment (hours)

- The time to assessment is only affected with higher than average attendance volumes.
- There is minimal impact at high skill levels but a large impact at low skill levels.

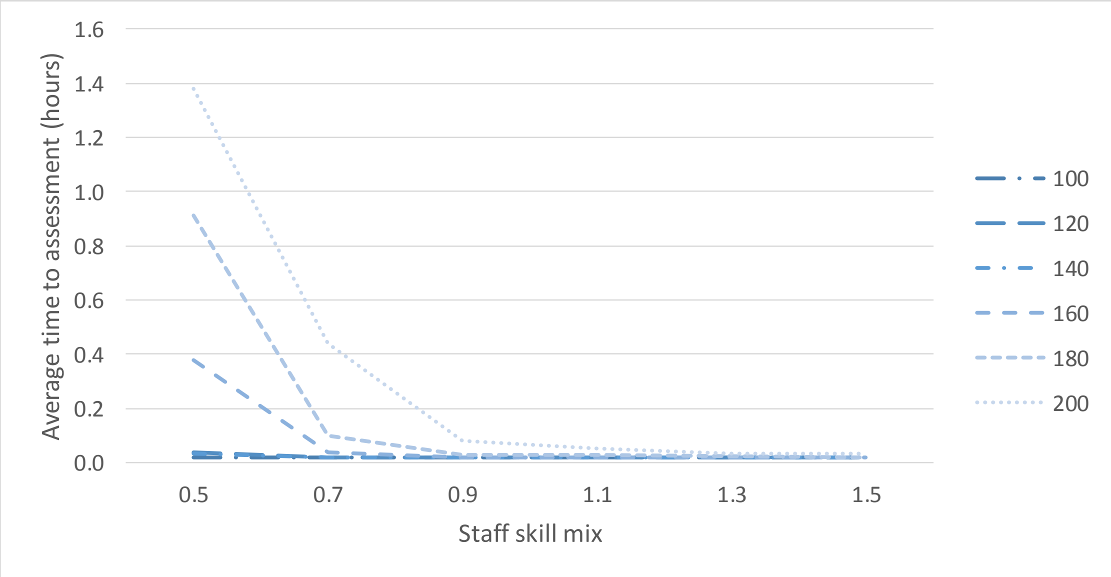


**Figure 15 – Average duration in A&E, by attendance volume and staff skill mix.**

## Average time to treatment (hours)

- There is a consistent high to low trend across skill mixes.
- There is very little difference at average or lower attendance volumes.

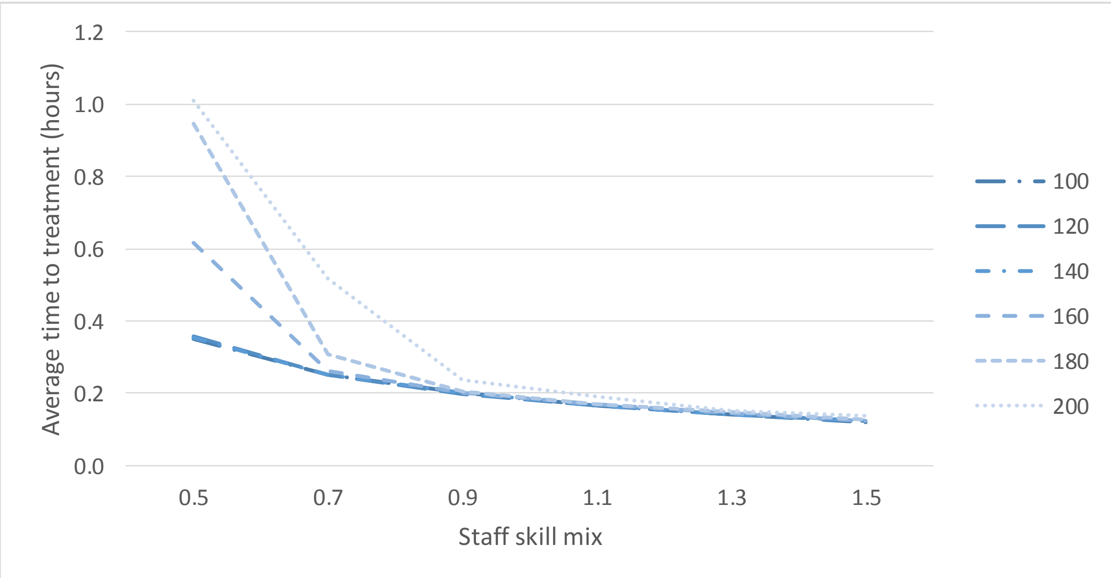


**Figure 16 – Average duration in A&E, by attendance volume and staff skill mix.**

## Average patients per staff

- At low attendance volumes, the average number of patients per staff stays below 1 with the exception of the lowest skill mix.

- At high attendance volumes, the average number of patients per staff almost doubles between the highest and lowest staff skill mixes.

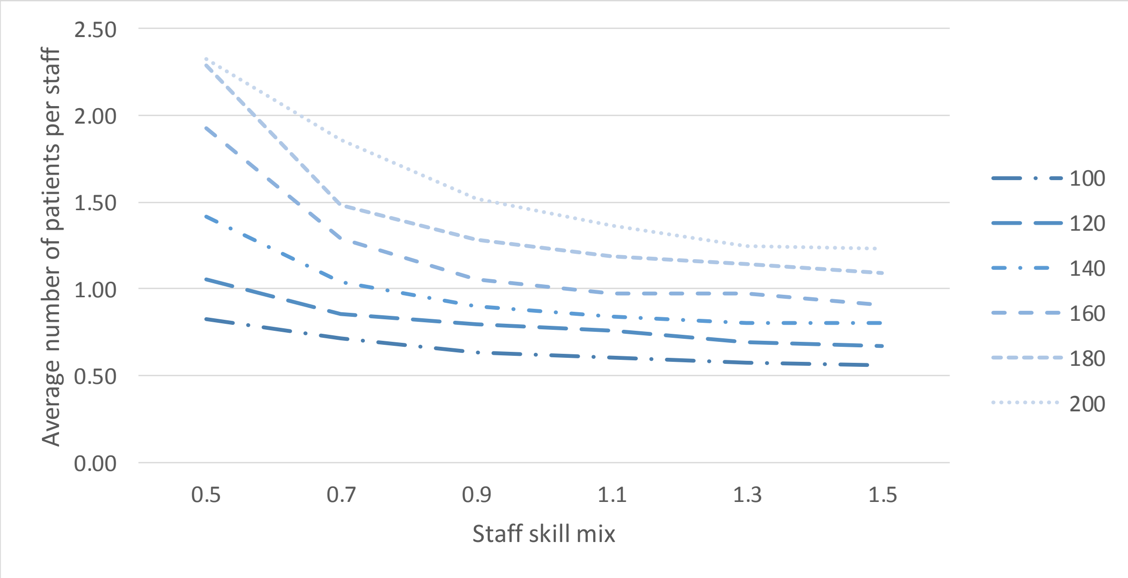


**Figure 17 – Average number of patients per staff, by attendance volume and staff skill mix.**

## Average occupancy

- At low attendance volumes, average occupancy does not rise above 50%.
- At higher attendance volumes and with lower skilled staff, average occupancy stays above 85%.

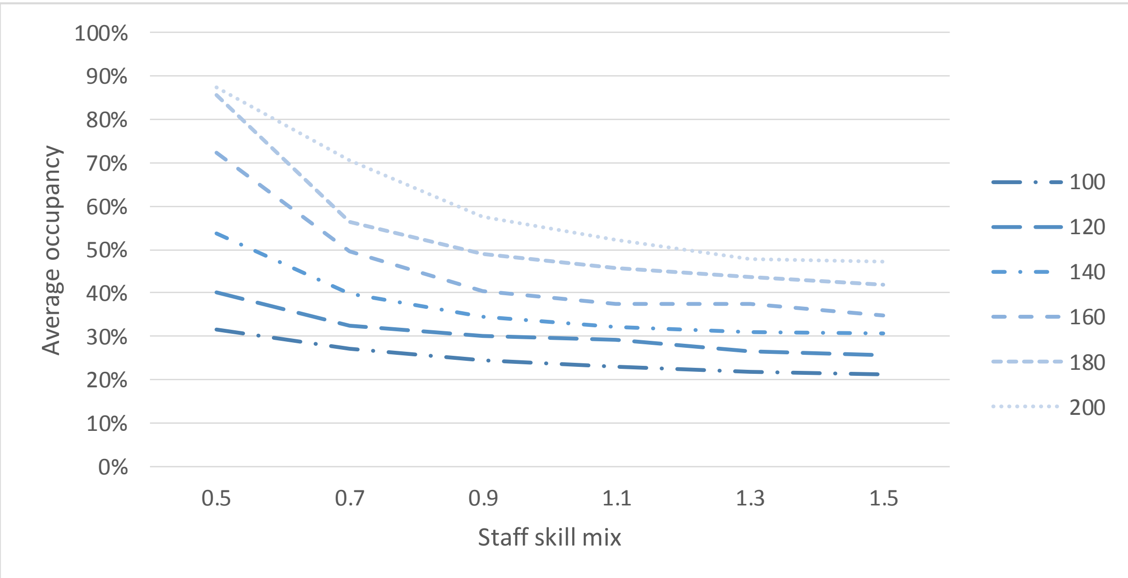


**Figure 18 – Average occupancy, by attendance volume and staff skill mix.**

## Patient deaths

- Death outputs are inconsistent and due to the very small numbers and probabilities associated with death causing discrepancies in the model they may not be clinically realistic.

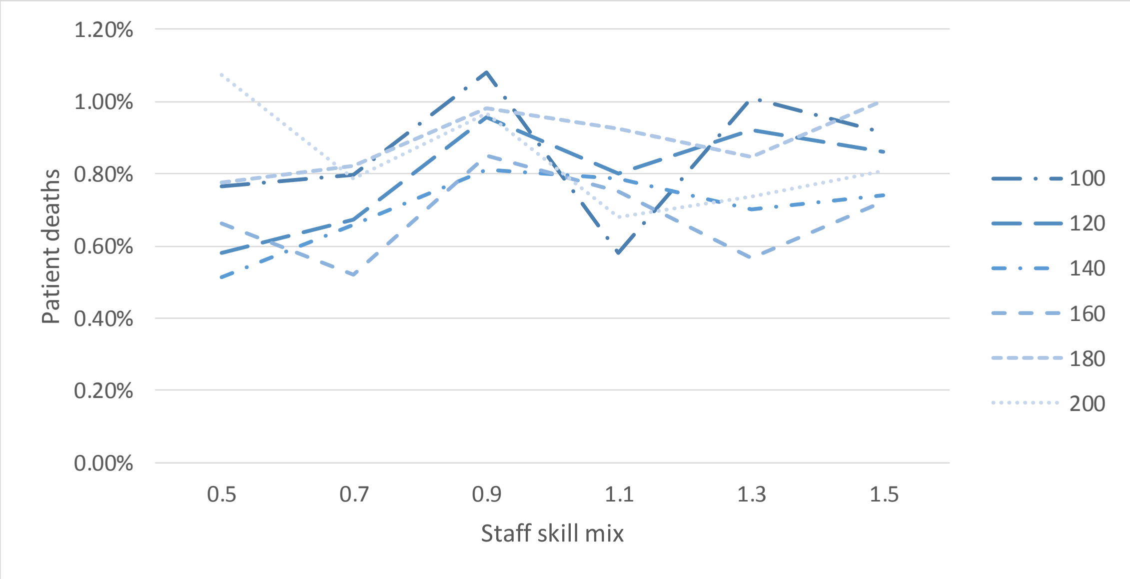


**Figure 19 – Patient deaths, by attendance volume and staff skill mix.**

Patients who LWBS

- Patient volumes have a large effect across all skill mix variations.
- The longer assessment and treatment durations associated with lower skilled staff is highlighted by the large variation in results on the left hand side where staff skill is low.

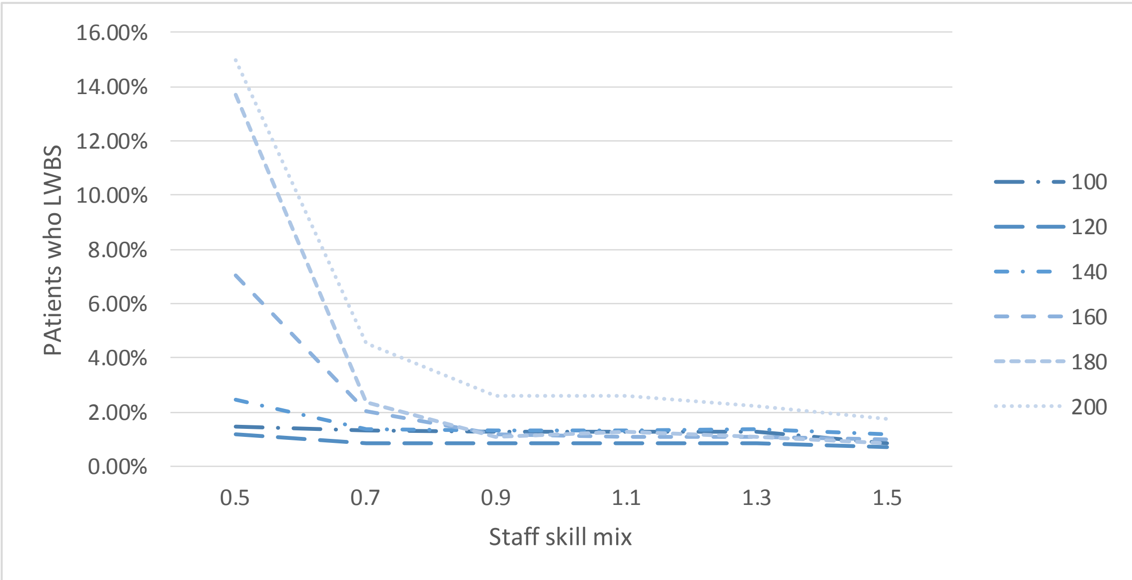


**Figure 20 – Patients who LWBS, by attendance volume and staff skill mix.**

## 4.6 Attendance volumes and staff numbers

Outputs from the model were measured across a range of patient volumes and staff numbers. To ensure consistency and to keep the quantity of output tables down to a reasonable number, the changes in staffing numbers were kept consistent between day and night shifts in absolute terms (i.e. a reduction of 2 day shift staff was mirrored by 2 night shift staff). Staff numbers are shown in the format of [Day shift staff] / [Night shift staff]. For example, 10 / 8 means 10 day shift staff and 8 night shift staff.

### Average duration in A&E (hours)

- With higher than average staff numbers there is a very gradual increase in average durations as attendance volumes rise.
- Lower staff numbers have much larger increases.

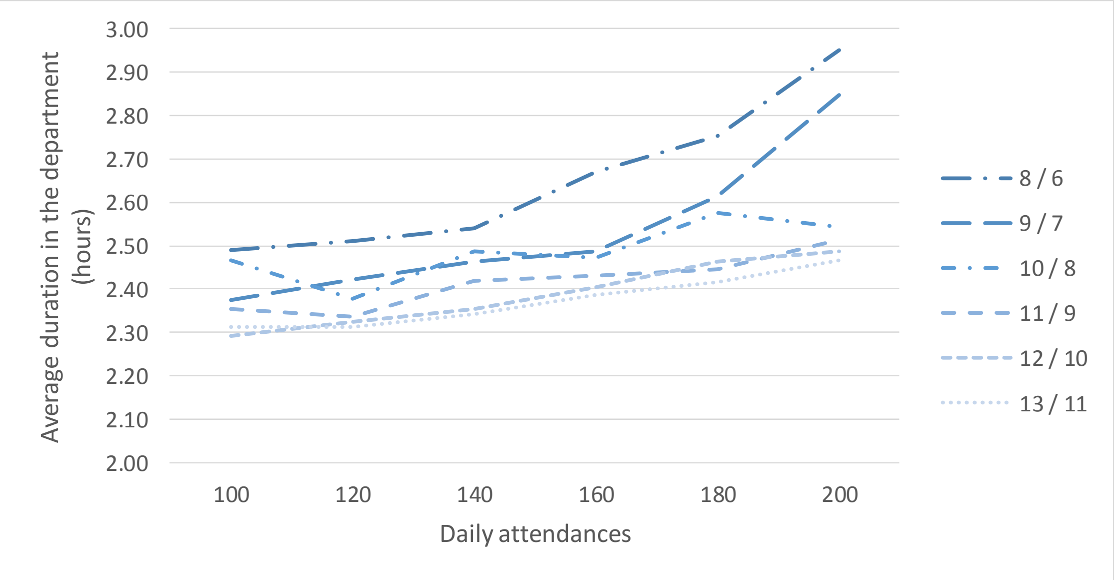


**Figure 21 – Average duration in A&E, by attendance volume and staff numbers.**

### Average time to assessment (hours)

- The lowest staff number scenario is the only one too see an increase in time to assessment at 160 daily attendances.
- At 200 daily attendances, all staff number scenarios see an increase in average time to assessment.

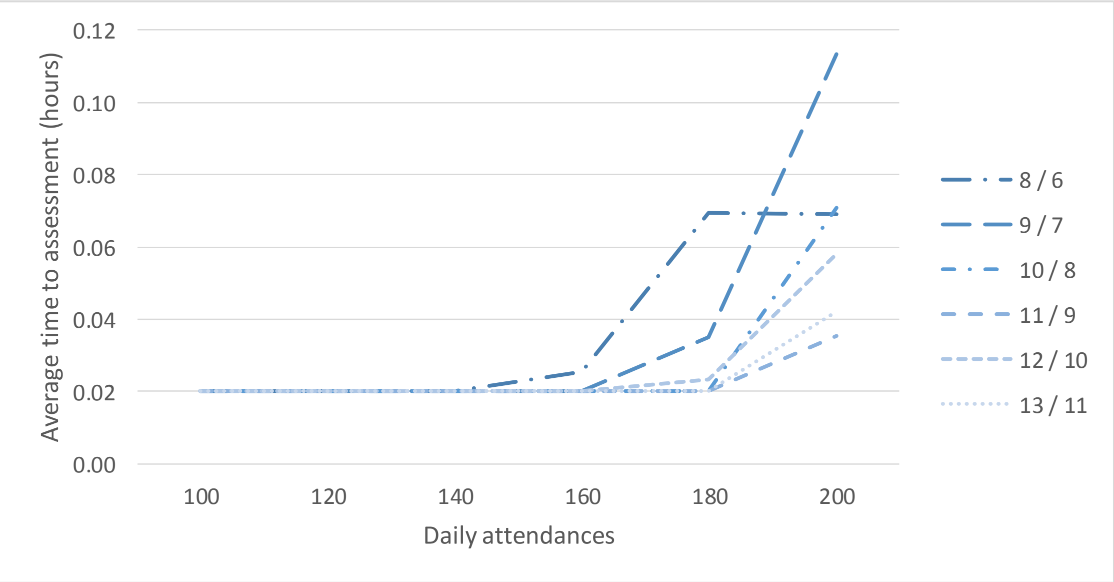


**Figure 22 – Average duration in A&E, by attendance volume and staff numbers.**

### Average time to treatment (hours)

- There is very little variation in average time to treatment, though the pattern is almost identical to the average time to assessment.

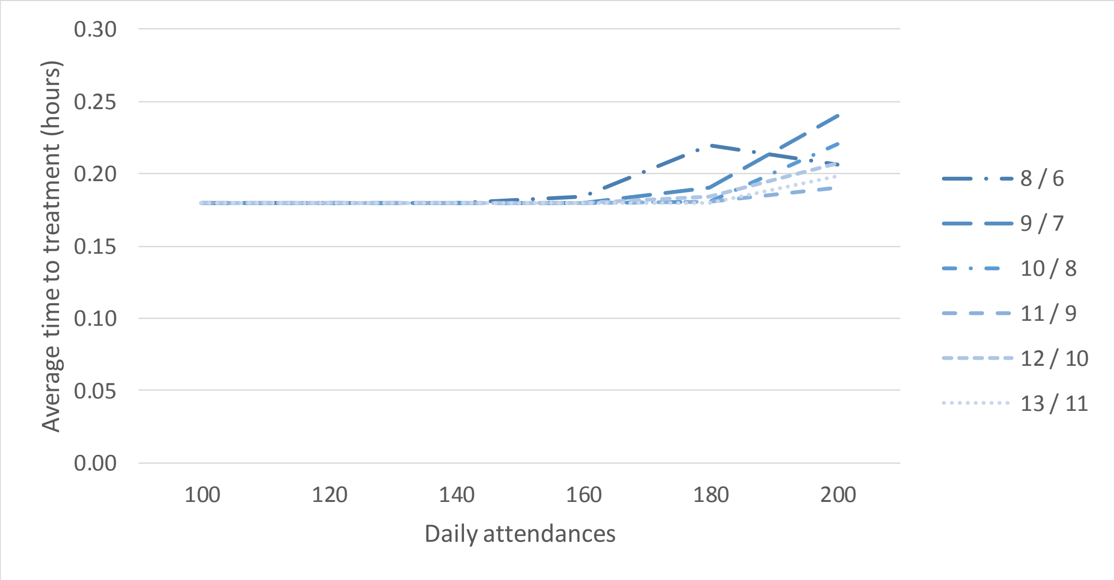


**Figure 23 – Average duration in A&E, by attendance volume and staff numbers.**

### Average patients per staff

- At the highest attendance volume, the average number of patients per staff doubles between the highest and lowest staff number configuration.
- The difference between 100 and 200 attendances more than doubles the average number of patients per staff across all staff number scenarios, indicating that there is a snowballing effect.

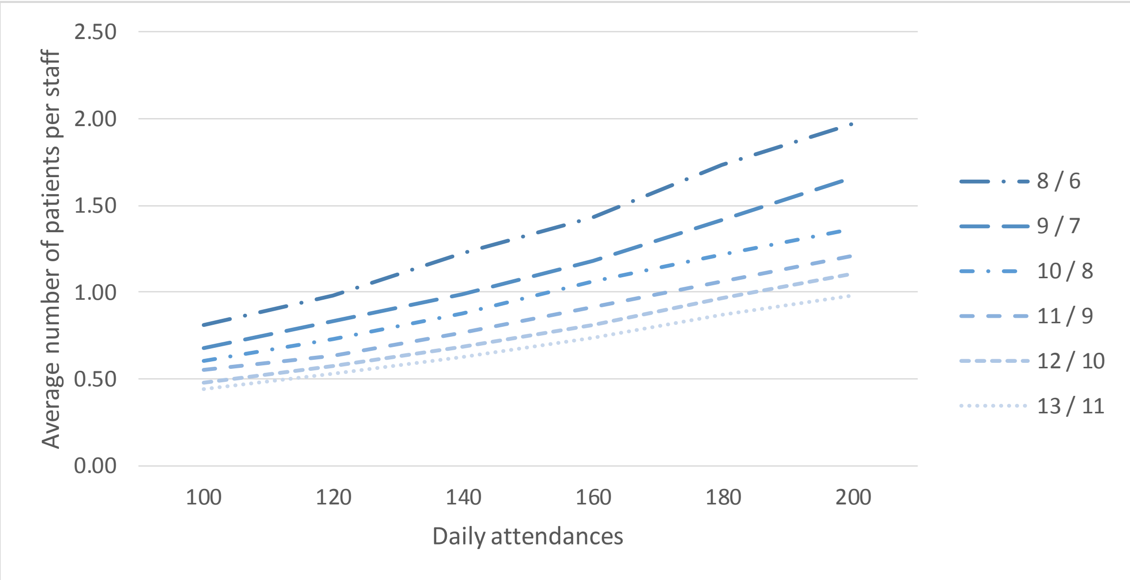


**Figure 24 – Average number of patients per staff, by attendance volume and staff numbers.**

## Average occupancy

- With high attendance volumes the department stays at or above 50% occupancy for the entire simulation regardless of staff counts.
- Variation in attendance volumes has a fairly consistent impact on average occupancy across different staffing numbers.

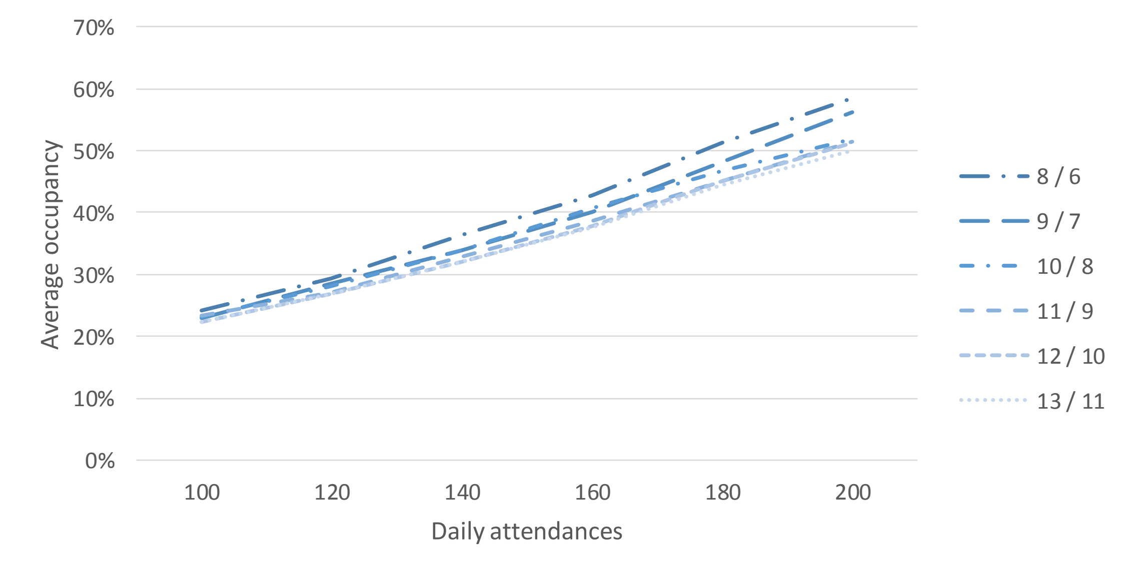


**Figure 25 – Average occupancy, by attendance volume and staff numbers.**

## Patient deaths

- Death outputs are inconsistent and due to the very small numbers and probabilities associated with death causing discrepancies in the model they may not be clinically realistic.

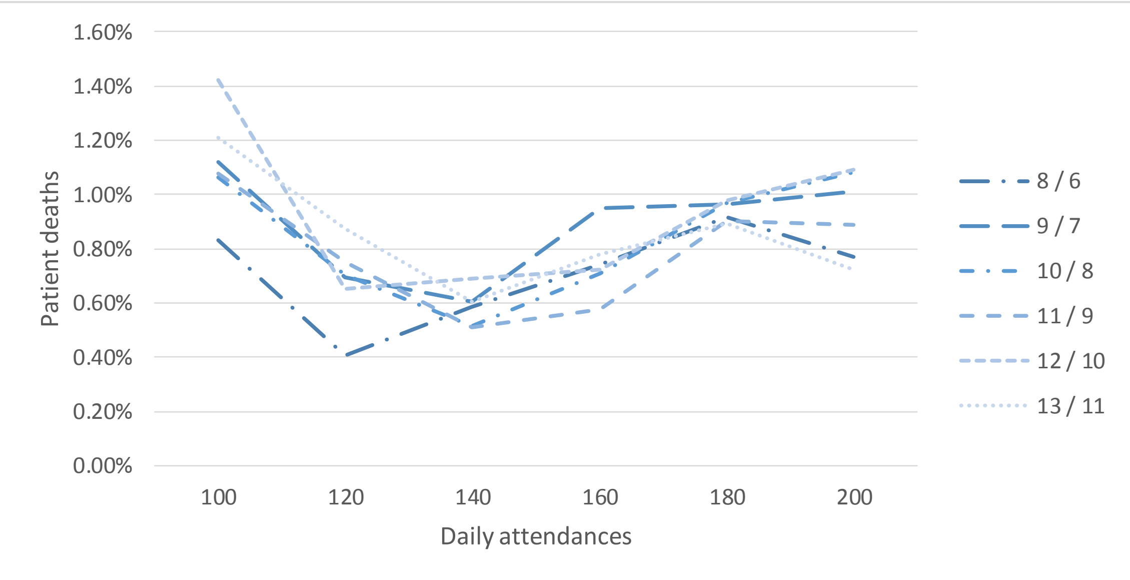


**Figure 26 – Patients deaths, by attendance volume and staff numbers.**

## Patients who LWBS

- At low attendance volumes the proportion of patients who leave without being seen is consistently low.
- There is a clear trend towards increasing LWBS rates as attendance volumes rise but there is some inconsistency between staff number scenarios.

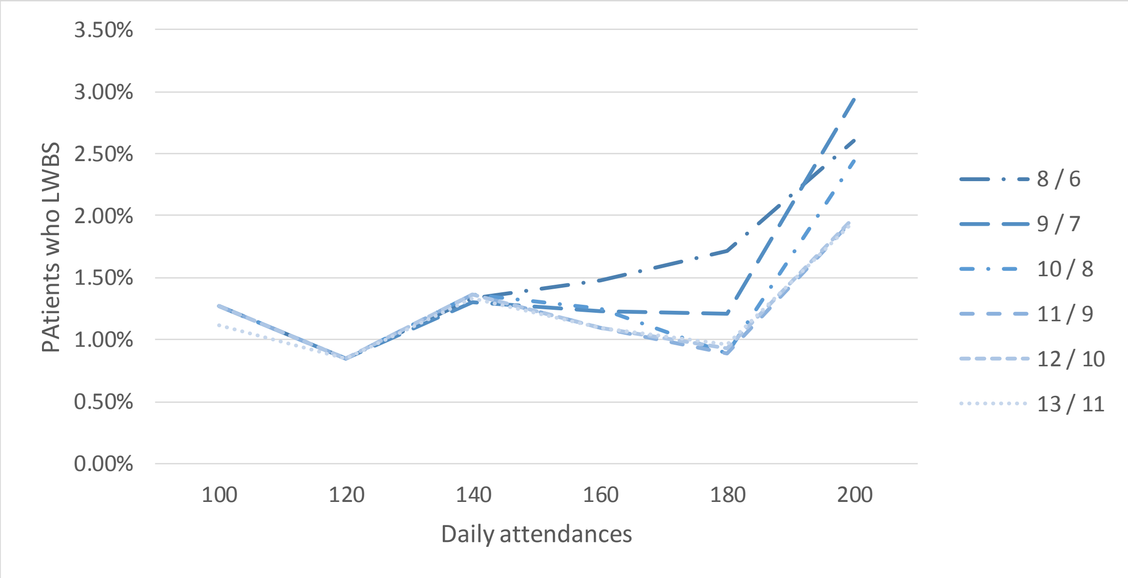


**Figure 27 – Patients who LWBS, by attendance volume and staff numbers.**

## 4.7 Sensitivity analysis

This sections contains tables of 1 way sensitivity analyses across most parameters in the model. For some analyses, specific combinations of parameters have been used as it was not practical to exhaustively test large ranges. For example, testing acuity distributions would require adjusting 5 parameters with each one ranging between 0 and 100%.

Unless specified, the model was run with default parameters and the following department specific parameters:

Daily attendances: 141
Capacity: 24
Day shift staff: 10
Night shift staff: 8
Day shift skill mix: 1.00
Night shift skill mix: 1.00

**Table 15 – Acuity distributions used in the sensitivity analysis**

| Acuity Level | Emergency | Non-emergency |
|---|---|---|
| 1 | 1.0% | 2.9% |
| 2 | 31.6% | 59.6% |
| 3 | 59.3% | 34.2% |
| 4 | 6.3% | 2.7% |
| 5 | 1.8% | 0.6% |

### Staff numbers, skill mix and cost

Average salaries by nurse band as listed on the website of the RCN[24] were combined with various numbers and types of staff. Salaries are based on 2013/14 and have not been uplifted. This assumes that all adjustments are for full time staff rather than bringing in temporary staff. The first table shows the various distributions of staff that were used in the model (from band 2 through to band 7). The incremental outputs shown in Table 18 are compared against the previous row in the table and

[24] Pay rates 2013/14: http://www.rcn.org.uk/support/pay_and_conditions/pay_rates_201314

sorted by total annual cost. This is based on the baseline productivity assumption where the possible skill mixes can range from 0.64 (100% band 2 nurses) to 1.45 (100% band 7 nurses).

- These results suggest that having an appropriate number of staff is a key factor.
- With an appropriate number of staff, there are some subtle relationships between number and skill mix. Scenarios 9 and 2 show that an increase in staff from 9 to 10 with a reduction in skill mix from 1.13 to 1.02 improves the ratio of patients to staff, but average durations and occupancy increase.

**Table 16 – Distribution of staff numbers and types in each scenario.**

| Scenario | Staff types (day) | | | | | | Staff types (night) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | B2 | B3 | B4 | B5 | B6 | B7 | B2 | B3 | B4 | B5 | B6 | B7 |
| 5 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 7 | 0 | 3 | 0 | 3 | 1 | 1 | 0 | 1 | 0 | 3 | 1 | 1 |
| 8 | 0 | 8 | 0 | 0 | 1 | 1 | 0 | 6 | 0 | 0 | 1 | 1 |
| 4 | 0 | 3 | 0 | 4 | 1 | 1 | 0 | 1 | 0 | 4 | 1 | 1 |
| 2 | 0 | 3 | 0 | 5 | 1 | 1 | 0 | 1 | 0 | 5 | 1 | 1 |
| 1 | 0 | 2 | 0 | 4 | 2 | 2 | 0 | 0 | 0 | 4 | 2 | 2 |
| 9 | 0 | 3 | 0 | 6 | 1 | 1 | 0 | 1 | 0 | 6 | 1 | 1 |
| 3 | 0 | 3 | 0 | 7 | 1 | 1 | 0 | 1 | 0 | 7 | 1 | 1 |
| 6 | 0 | 0 | 0 | 20 | 1 | 1 | 0 | 0 | 0 | 20 | 1 | 1 |

**Table 17 - Sensitivity analysis on staff numbers, skill mix and cost. The table is ordered by the total annual cost of staff.**

| Scenario | Avg staff | Avg skill mix | Staff cost (annual) | Capacity per staff | Avg duration | Avg patients per staff (excl. waiting) | Avg occupancy | Deaths | LWBS |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 1.34 | £130,858 | 12.00 | 7.07 | 11.47 | 96% | 1.01% | 28.24% |
| 2 | 7 | 1.03 | £348,688 | 3.43 | 2.53 | 1.24 | 37% | 0.64% | 0.86% |
| 3 | 9 | 0.86 | £380,242 | 2.67 | 2.52 | 0.91 | 35% | 0.68% | 0.86% |
| 4 | 8 | 1.02 | £397,547 | 3.00 | 2.44 | 1.05 | 36% | 0.78% | 0.86% |
| 5 | 9 | 1.02 | £446,407 | 2.67 | 2.38 | 0.88 | 34% | 0.74% | 0.86% |
| 6 | 9 | 1.13 | £492,779 | 2.67 | 2.37 | 0.84 | 32% | 0.65% | 0.86% |
| 7 | 10 | 1.02 | £495,266 | 2.40 | 2.40 | 0.80 | 34% | 0.84% | 0.86% |
| 8 | 11 | 1.02 | £544,125 | 2.18 | 2.35 | 0.71 | 33% | 0.84% | 0.86% |
| 9 | 22 | 1.03 | £1,108,043 | 1.09 | 2.27 | 0.33 | 30% | 0.55% | 0.91% |

**Table 18 – Incremental outputs of staff numbers and cost sensitivity analysis, compared against the previous row. The table is ordered by the total annual cost of staff.**

| Scenario | Avg staff | Avg skill mix | Staff cost (annual) | Capacity per staff | Avg duration | Avg patients per staff (excl. waiting) | Avg occupancy | Deaths | LWBS |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 1.34 | £0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 7 | 1.025 | £217,830 | -8.57 | -4.54 | -10.23 | -59% | -0.37% | -27.38% |
| 3 | 9 | 0.865 | £31,554 | -0.76 | -0.01 | -0.32 | -2% | 0.04% | 0.00% |
| 4 | 8 | 1.02 | £17,306 | 0.33 | -0.08 | 0.13 | 1% | 0.10% | 0.00% |
| 5 | 9 | 1.02 | £48,859 | -0.33 | -0.05 | -0.16 | -2% | -0.05% | 0.00% |
| 6 | 9 | 1.125 | £46,372 | 0.00 | -0.01 | -0.04 | -2% | -0.09% | 0.00% |
| 7 | 10 | 1.015 | £2,487 | -0.27 | 0.03 | -0.04 | 2% | 0.19% | 0.00% |
| 8 | 11 | 1.015 | £48,859 | -0.22 | -0.05 | -0.10 | -1% | 0.01% | 0.00% |
| 9 | 22 | 1.03 | £563,918 | -1.09 | -0.09 | -0.37 | -3% | -0.30% | 0.05% |

## Staff skill mix (day shift)

The skill mix of day shift staff was varied from 0.5 to 1.5 (relative to band 5 nurses).

- The lowest skill mixes cause a large change in outputs.
- Time to assessment does not change at all until a skill mix of 0.6 is used.

**Table 19 – Sensitivity analysis on day shift skill mix.**

| Scenario | Skill mix (day) | Skill mix (night) | Avg duration | Avg time to assessment | Avg time to treatment | Avg patients per staff (excl. waiting) | Avg occupancy | Deaths | LWBS |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.50 | 1.00 | 3.12 | 0.05 | 0.32 | 1.25 | 48% | 0.48% | 1.56% |
| 2 | 0.60 | 1.00 | 2.82 | 0.03 | 0.27 | 1.08 | 42% | 0.56% | 1.31% |
| 3 | 0.70 | 1.00 | 2.70 | 0.02 | 0.23 | 1.02 | 39% | 0.68% | 1.06% |
| 4 | 0.80 | 1.00 | 2.55 | 0.02 | 0.21 | 0.97 | 37% | 0.67% | 0.86% |
| 5 | 0.90 | 1.00 | 2.55 | 0.02 | 0.19 | 0.94 | 36% | 0.64% | 0.86% |
| 6 | 1.00 | 1.00 | 2.47 | 0.02 | 0.18 | 0.88 | 34% | 0.74% | 0.86% |
| 7 | 1.10 | 1.00 | 2.43 | 0.02 | 0.17 | 0.85 | 33% | 0.63% | 0.96% |
| 8 | 1.20 | 1.00 | 2.46 | 0.02 | 0.16 | 0.85 | 33% | 0.66% | 0.86% |
| 9 | 1.30 | 1.00 | 2.35 | 0.02 | 0.15 | 0.82 | 31% | 0.68% | 0.86% |
| 10 | 1.40 | 1.00 | 2.30 | 0.02 | 0.15 | 0.80 | 31% | 0.76% | 0.86% |

| Scenario | Skill mix (day) | Skill mix (night) | Avg duration | Avg time to assessment | Avg time to treatment | Avg patients per staff (excl. waiting) | Avg occupancy | Deaths | LWBS |
|---|---|---|---|---|---|---|---|---|---|
| 11 | 1.50 | 1.00 | 2.42 | 0.02 | 0.14 | 0.84 | 32% | 0.66% | 0.86% |

## Staff skill mix (night shift)

The skill mix of night shift staff was varied from 0.5 to 1.5 (relative to band 5 nurses).

- The pattern of outputs is the same as the day shift skill mix analysis, but the scale of the differences are smaller due to their being less activity overnight.

**Table 20 – Sensitivity analysis on night shift skill mix.**

| Scenario | Skill mix (day) | Skill mix (night) | Avg duration | Avg time to assessment | Avg time to treatment | Avg patients per staff (excl. waiting) | Avg occupancy | Deaths | LWBS |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.00 | 0.50 | 2.65 | 0.02 | 0.23 | 0.96 | 36% | 0.59% | 0.91% |
| 2 | 1.00 | 0.60 | 2.51 | 0.02 | 0.27 | 0.90 | 35% | 0.61% | 0.86% |
| 3 | 1.00 | 0.70 | 2.53 | 0.02 | 0.23 | 0.89 | 34% | 0.51% | 0.86% |
| 4 | 1.00 | 0.80 | 2.51 | 0.02 | 0.21 | 0.88 | 34% | 0.49% | 0.86% |
| 5 | 1.00 | 0.90 | 2.55 | 0.02 | 0.19 | 0.86 | 33% | 0.63% | 0.86% |
| 6 | 1.00 | 1.00 | 2.47 | 0.02 | 0.18 | 0.88 | 34% | 0.74% | 0.86% |
| 7 | 1.00 | 1.10 | 2.39 | 0.02 | 0.17 | 0.86 | 33% | 0.61% | 0.86% |
| 8 | 1.00 | 1.20 | 2.40 | 0.02 | 0.16 | 0.87 | 33% | 0.72% | 0.86% |
| 9 | 1.00 | 1.30 | 2.36 | 0.02 | 0.15 | 0.83 | 32% | 0.77% | 0.86% |
| 10 | 1.00 | 1.40 | 2.36 | 0.02 | 0.15 | 0.85 | 32% | 0.69% | 0.86% |
| 11 | 1.00 | 1.50 | 2.37 | 0.02 | 0.14 | 0.85 | 33% | 0.57% | 0.86% |

## Staff numbers (day shift)

The number of staff on the day shift was varied from 2 to 20. The model produced errors when simulating with a staff count of 1 so this was excluded from the sensitivity analysis.

- With low numbers of day time staff, there is a much larger change in the outputs compared with high numbers of staff.
- There seems to be a threshold at 6 staff at which point lower numbers of staff cause the differences in outputs to become more significant.

**Table 21 – Sensitivity analysis on day shift staff numbers.**

| Scenario | Skill count (day) | Skill count (night) | Avg duration | Avg time to assessment | Avg time to treatment | Avg patients per staff (excl. waiting) | Avg occupancy | Deaths | LWBS |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 8 | 9.37 | 1.88 | 1.33 | 7.54 | 100% | 1.12% | 37.62% |
| 2 | 3 | 8 | 4.08 | 0.42 | 0.46 | 3.96 | 67% | 0.55% | 6.15% |
| 3 | 4 | 8 | 4.45 | 0.11 | 0.23 | 2.50 | 52% | 0.81% | 1.82% |
| 4 | 5 | 8 | 2.79 | 0.02 | 0.18 | 1.73 | 41% | 0.66% | 1.11% |
| 5 | 6 | 8 | 2.64 | 0.02 | 0.18 | 1.40 | 38% | 0.73% | 1.01% |
| 6 | 7 | 8 | 2.53 | 0.02 | 0.18 | 1.20 | 36% | 0.61% | 0.91% |
| 7 | 8 | 8 | 2.50 | 0.02 | 0.18 | 1.03 | 34% | 0.52% | 0.91% |
| 8 | 9 | 8 | 2.42 | 0.02 | 0.18 | 0.94 | 34% | 0.73% | 0.91% |
| 9 | 10 | 8 | 2.47 | 0.02 | 0.18 | 0.88 | 34% | 0.74% | 0.86% |
| 10 | 11 | 8 | 2.48 | 0.02 | 0.18 | 0.82 | 33% | 0.62% | 0.86% |
| 11 | 12 | 8 | 2.47 | 0.02 | 0.18 | 0.77 | 33% | 0.68% | 0.86% |
| 12 | 13 | 8 | 2.43 | 0.02 | 0.18 | 0.73 | 33% | 0.73% | 0.86% |
| 13 | 14 | 8 | 2.36 | 0.02 | 0.18 | 0.69 | 32% | 0.75% | 0.86% |
| 14 | 15 | 8 | 2.38 | 0.02 | 0.18 | 0.66 | 32% | 0.70% | 0.86% |
| 15 | 16 | 8 | 2.39 | 0.02 | 0.18 | 0.63 | 31% | 0.60% | 0.86% |
| 16 | 17 | 8 | 2.36 | 0.02 | 0.18 | 0.61 | 31% | 0.68% | 0.86% |
| 17 | 18 | 8 | 2.37 | 0.02 | 0.18 | 0.59 | 31% | 0.66% | 0.86% |
| 18 | 19 | 8 | 2.33 | 0.02 | 0.18 | 0.58 | 31% | 0.60% | 0.86% |
| 19 | 20 | 8 | 2.35 | 0.02 | 0.18 | 0.56 | 31% | 0.59% | 0.86% |

Staff numbers (night shift)

The number of staff on the night shift was varied from 2 to 20. The model produced errors when simulating with a staff count of 1 so this was excluded from the sensitivity analysis.

- This analysis indicates that the number of night shift staff have a smaller effect on the outputs compared with the day shift staff numbers.

**Table 22 – Sensitivity analysis on night shift staff numbers.**

| Scenario | Skill count (day) | Skill count (night) | Avg duration | Avg time to assessment | Avg time to treatment | Avg patients per staff (excl. waiting) | Avg occupancy | Deaths | LWBS |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 10 | 2 | 4.04 | 0.06 | 0.22 | 3.25 | 50% | 0.71% | 2.22% |
| 2 | 10 | 3 | 2.64 | 0.02 | 0.18 | 1.75 | 39% | 0.59% | 1.51% |
| 3 | 10 | 4 | 2.89 | 0.02 | 0.18 | 1.35 | 36% | 0.55% | 0.96% |
| 4 | 10 | 5 | 2.49 | 0.02 | 0.18 | 1.12 | 35% | 0.52% | 0.86% |
| 5 | 10 | 6 | 2.45 | 0.02 | 0.18 | 0.99 | 33% | 0.70% | 0.86% |
| 6 | 10 | 7 | 2.44 | 0.02 | 0.18 | 0.92 | 34% | 0.69% | 0.86% |
| 7 | 10 | 8 | 2.47 | 0.02 | 0.18 | 0.88 | 34% | 0.74% | 0.86% |
| 8 | 10 | 9 | 2.39 | 0.02 | 0.18 | 0.81 | 33% | 0.69% | 0.91% |
| 9 | 10 | 10 | 2.38 | 0.02 | 0.18 | 0.79 | 33% | 0.70% | 0.91% |
| 10 | 10 | 11 | 2.39 | 0.02 | 0.18 | 0.76 | 33% | 0.74% | 0.86% |
| 11 | 10 | 12 | 2.36 | 0.02 | 0.18 | 0.73 | 32% | 0.67% | 0.86% |
| 12 | 10 | 13 | 2.38 | 0.02 | 0.18 | 0.73 | 33% | 0.80% | 0.86% |
| 13 | 10 | 14 | 2.39 | 0.02 | 0.18 | 0.71 | 33% | 0.77% | 0.86% |
| 14 | 10 | 15 | 2.35 | 0.02 | 0.18 | 0.70 | 33% | 0.84% | 0.86% |
| 15 | 10 | 16 | 2.35 | 0.02 | 0.18 | 0.69 | 33% | 0.86% | 0.86% |
| 16 | 10 | 17 | 2.36 | 0.02 | 0.18 | 0.68 | 32% | 0.81% | 0.86% |
| 17 | 10 | 18 | 2.35 | 0.02 | 0.18 | 0.66 | 32% | 0.73% | 0.86% |
| 18 | 10 | 19 | 2.34 | 0.02 | 0.18 | 0.66 | 32% | 0.77% | 0.86% |
| 19 | 10 | 20 | 2.33 | 0.02 | 0.18 | 0.65 | 32% | 0.73% | 0.86% |

## Ward status

The ward status was varied between a day/night cycle and accepting admissions at any time of day.

- Allowing patients to be admitted into hospital at any time causes a reduction in average duration, occupancy and patients per staff.

**Table 23 – Sensitivity analysis on ward status.**

| Scenario | Ward status | Avg duration | Avg time to assessment | Avg time to treatment | Avg patients per staff (excl. waiting) | Avg occupancy | LWBS | Deaths |
|---|---|---|---|---|---|---|---|---|
| 1 | Cycle | 2.47 | 0.02 | 0.18 | 0.88 | 34% | 0.86% | 0.74% |
| 2 | Open | 2.37 | 0.02 | 0.18 | 0.80 | 30% | 0.86% | 0.56% |

## Assessment durations

The average duration of an assessment was varied from 6 to 30 minutes.

- The average assessment duration seems to have a linear relationship with the outputs with no significant changes between one scenario and the next. This does not take the quality of the assessment into account.

**Table 24 – Sensitivity analysis on assessment durations.**

| Scenario | Assessment duration | Avg duration | Avg time to assessment | Avg time to treatment | Avg patients per staff (excl. waiting) | Avg occupancy | LWBS | Deaths |
|---|---|---|---|---|---|---|---|---|
| 1 | 6m | 2.43 | 0.02 | 0.11 | 0.85 | 33% | 0.63% | 0.81% |
| 2 | 9m | 2.38 | 0.02 | 0.16 | 0.87 | 33% | 0.68% | 0.86% |
| 3 | 12m | 2.49 | 0.02 | 0.22 | 0.90 | 35% | 0.47% | 0.86% |
| 4 | 15m | 2.59 | 0.02 | 0.27 | 0.96 | 37% | 0.67% | 0.96% |
| 5 | 18m | 2.69 | 0.02 | 0.32 | 1.00 | 39% | 0.73% | 1.06% |
| 6 | 21m | 2.97 | 0.02 | 0.37 | 1.01 | 39% | 0.68% | 1.16% |
| 7 | 24m | 2.95 | 0.02 | 0.42 | 1.06 | 41% | 0.71% | 1.46% |
| 8 | 27m | 2.89 | 0.02 | 0.47 | 1.09 | 42% | 0.71% | 1.82% |
| 9 | 30m | 3.22 | 0.02 | 0.52 | 1.09 | 42% | 0.80% | 1.87% |

## Ward transfer durations

The average duration of transferring a patient from the A&E department to a ward was varied from 5 to 60 minutes.

- All outputs increase as the ward transfer duration increases.
- At around 40 minutes there is a significant jump in outputs.

**Table 25 – Sensitivity analysis on ward transfer durations.**

| Scenario | Ward transfer duration | Avg duration | Avg time to assessment | Avg time to treatment | Avg patients per staff (excl. waiting) | Avg occupancy | LWBS | Deaths |
|---|---|---|---|---|---|---|---|---|
| 1 | 6m | 2.44 | 0.02 | 0.18 | 0.84 | 32% | 0.55% | 0.86% |
| 2 | 12m | 2.46 | 0.02 | 0.18 | 0.87 | 33% | 0.66% | 0.86% |
| 3 | 18m | 2.50 | 0.02 | 0.18 | 0.87 | 33% | 0.63% | 0.91% |
| 4 | 24m | 2.52 | 0.02 | 0.18 | 0.90 | 35% | 0.73% | 0.91% |
| 5 | 30m | 2.67 | 0.02 | 0.18 | 0.99 | 38% | 0.73% | 0.96% |
| 6 | 36m | 2.77 | 0.02 | 0.18 | 1.12 | 43% | 0.79% | 1.06% |
| 7 | 42m | 3.44 | 0.21 | 0.33 | 1.36 | 52% | 0.92% | 2.47% |
| 8 | 48m | 5.40 | 0.96 | 0.79 | 2.59 | 97% | 0.90% | 17.65% |
| 9 | 54m | 5.28 | 0.82 | 0.74 | 2.75 | 102% | 1.01% | 18.96% |
| 10 | 60m | 7.09 | 1.65 | 1.05 | 2.84 | 106% | 1.32% | 29.15% |

## Non-emergency acuity

The non-emergency acuity distribution was varied such that the average acuity was increased and decreased. The first table shows the acuity distributions that were used. Realistic acuity distributions were defined with a focus on small increases or reductions rather than testing extreme scenarios of all patients at the highest or lowest acuity.

- As the average non-emergency acuity distribution increases, the measured outputs also increase.
- There does not seem to be a significant threshold, although deaths and LWBS outputs rise above the seemingly random fluctuations at the highest average acuity levels.

Table 26 – Non-emergency acuity distributions.

| Scenario | AL 1 | AL 2 | AL 3 | AL 4 | AL 5 | Average AL |
|---|---|---|---|---|---|---|
| 1 | 50.0% | 30.0% | 17.0% | 2.4% | 0.6% | 1.74 |
| 2 | 40.0% | 40.0% | 17.0% | 2.4% | 0.6% | 1.84 |
| 3 | 30.0% | 45.0% | 22.0% | 2.4% | 0.6% | 1.99 |
| 4 | 20.0% | 50.0% | 27.0% | 2.4% | 0.6% | 2.14 |
| 5 | 10.0% | 55.0% | 32.0% | 2.4% | 0.6% | 2.29 |
| 6 | 2.9% | 59.6% | 34.2% | 2.7% | 0.6% | 2.39 |
| 7 | 2.0% | 50.0% | 40.0% | 7.0% | 1.0% | 2.55 |
| 8 | 2.0% | 40.0% | 50.0% | 7.0% | 1.0% | 2.65 |
| 9 | 2.0% | 40.0% | 45.0% | 10.0% | 3.0% | 2.72 |
| 10 | 2.0% | 40.0% | 40.0% | 13.0% | 5.0% | 2.79 |

Table 27 – Sensitivity analysis on non-emergency acuity.

| Scenario | Avg non-emergency acuity | Avg duration | Avg time to assesment | Avg time to treatment | Avg patients per staff (excl. waiting) | Avg occupancy | Deaths | LWBS |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.74 | 2.20 | 0.02 | 0.18 | 0.73 | 28% | 0.53% | 0.84% |
| 2 | 1.84 | 2.41 | 0.02 | 0.18 | 0.74 | 28% | 0.75% | 1.36% |
| 3 | 1.99 | 2.35 | 0.02 | 0.18 | 0.80 | 31% | 0.57% | 1.29% |
| 4 | 2.14 | 2.39 | 0.02 | 0.18 | 0.84 | 32% | 0.51% | 0.84% |
| 5 | 2.29 | 2.53 | 0.02 | 0.18 | 0.87 | 33% | 0.50% | 1.16% |
| 6 | 2.39 | 2.47 | 0.02 | 0.18 | 0.88 | 34% | 0.74% | 0.86% |
| 7 | 2.55 | 2.60 | 0.02 | 0.18 | 0.96 | 37% | 0.57% | 0.97% |
| 8 | 2.65 | 2.59 | 0.02 | 0.18 | 0.98 | 37% | 0.77% | 0.97% |
| 9 | 2.72 | 2.65 | 0.02 | 0.18 | 1.00 | 38% | 1.81% | 1.67% |
| 10 | 2.79 | 2.72 | 0.03 | 0.19 | 1.03 | 40% | 2.97% | 1.78% |

## Emergency acuity

The non-emergency acuity distribution was varied such that the average acuity was increased and decreased. The first table shows the acuity distributions that were used. Realistic acuity distributions were defined with a focus on small increases or reductions rather than testing extreme scenarios of all patients at the highest or lowest acuity.

- A similar trend to the non-emergency acuity distribution is observed, but the overall effect is smaller due to the relatively small number of patients that arrive via emergency services.

**Table 28 – Emergency acuity distributions.**

| Scenario | AL 1 | AL 2 | AL 3 | AL 4 | AL 5 | Average AL |
|---|---|---|---|---|---|---|
| 1 | 13.0% | 43.0% | 37.0% | 5.2% | 1.8% | 2.40 |
| 2 | 8.0% | 45.0% | 40.0% | 5.2% | 1.8% | 2.48 |
| 3 | 3.0% | 45.0% | 45.0% | 5.2% | 1.8% | 2.58 |
| 4 | 3.0% | 40.0% | 50.0% | 5.2% | 1.8% | 2.63 |
| 5 | 3.0% | 35.0% | 55.0% | 5.2% | 1.8% | 2.68 |
| 6 | 1.0% | 31.6% | 59.3% | 6.3% | 1.8% | 2.76 |
| 7 | 1.0% | 30.0% | 55.0% | 10.0% | 4.0% | 2.86 |
| 8 | 1.0% | 30.0% | 50.0% | 15.0% | 4.0% | 2.91 |
| 9 | 1.0% | 27.0% | 45.0% | 20.0% | 7.0% | 3.05 |
| 10 | 1.0% | 24.0% | 40.0% | 25.0% | 10.0% | 3.19 |

**Table 29 – Sensitivity analysis on emergency acuity.**

| Scenario | Avg emergency acuity | Avg duration | Avg time to assesment | Avg time to treatment | Avg patients per staff (excl. waiting) | Avg occupancy | Deaths | LWBS |
|---|---|---|---|---|---|---|---|---|
| 1 | 2.40 | 2.32 | 0.02 | 0.18 | 0.83 | 32% | 0.57% | 0.90% |
| 2 | 2.48 | 2.30 | 0.02 | 0.18 | 0.82 | 31% | 0.56% | 0.86% |
| 3 | 2.58 | 2.50 | 0.02 | 0.18 | 0.87 | 33% | 0.58% | 0.86% |
| 4 | 2.63 | 2.36 | 0.02 | 0.18 | 0.86 | 33% | 0.59% | 0.86% |
| 5 | 2.68 | 2.32 | 0.02 | 0.18 | 0.85 | 33% | 0.63% | 0.85% |
| 6 | 2.76 | 2.47 | 0.02 | 0.18 | 0.88 | 34% | 0.74% | 0.86% |
| 7 | 2.86 | 2.39 | 0.02 | 0.18 | 0.89 | 34% | 1.08% | 0.85% |
| 8 | 2.91 | 2.54 | 0.02 | 0.18 | 0.89 | 34% | 1.18% | 0.85% |

| Scenario | Avg emergency acuity | Avg duration | Avg time to assesment | Avg time to treatment | Avg patients per staff (excl. waiting) | Avg occupancy | Deaths | LWBS |
|---|---|---|---|---|---|---|---|---|
| 9 | 3.05 | 2.42 | 0.02 | 0.18 | 0.89 | 34% | 1.42% | 0.90% |
| 10 | 3.19 | 2.52 | 0.02 | 0.18 | 0.94 | 36% | 2.10% | 1.00% |

### Daily attendance counts

The average number of daily attendances was varied above and below the baseline position.

- The number of daily attendances has a significant impact on average occupancy and the patients per staff.
- There is an inconclusive effect on durations, deaths and LWBS.

**Table 30 – Sensitivity analysis on daily attendance counts.**

| Scenario | Daily attendance count | Avg duration | Avg time to assesment | Avg time to treatment | Avg patients per staff (excl. waiting) | Avg occupancy | Deaths | LWBS |
|---|---|---|---|---|---|---|---|---|
| 1 | 100 | 2.47 | 0.02 | 0.18 | 0.61 | 23% | 0.90% | 1.05% |
| 2 | 110 | 2.39 | 0.02 | 0.18 | 0.66 | 25% | 0.82% | 1.08% |
| 3 | 120 | 2.38 | 0.02 | 0.18 | 0.73 | 28% | 0.62% | 0.71% |
| 4 | 130 | 2.39 | 0.02 | 0.18 | 0.79 | 30% | 0.70% | 1.42% |
| 5 | 140 | 2.49 | 0.02 | 0.18 | 0.88 | 34% | 0.56% | 1.42% |
| 6 | 150 | 2.42 | 0.02 | 0.18 | 0.95 | 37% | 0.39% | 0.94% |
| 7 | 160 | 2.47 | 0.02 | 0.18 | 1.06 | 41% | 0.68% | 1.04% |
| 8 | 170 | 2.62 | 0.02 | 0.18 | 1.14 | 44% | 0.74% | 1.07% |
| 9 | 180 | 2.58 | 0.02 | 0.18 | 1.22 | 47% | 0.77% | 1.15% |
| 10 | 190 | 2.58 | 0.05 | 0.20 | 1.33 | 51% | 0.91% | 1.38% |
| 11 | 200 | 2.54 | 0.07 | 0.22 | 1.36 | 52% | 0.92% | 1.87% |

## Average treatment durations

These tables show how treatment durations in the model vary with patients, staff numbers and skill mix. See Table 9 for calculation methodologies used in these tables. The final column contains the treatment adjustment which is multiplied by the baseline treatment duration to produce the actual treatment duration. If you assume the baseline treatment duration is 1 hour, the treatment adjustment column shows the actual duration in hours.

- The number of patients currently in the department has a fairly small impact on treatment durations.
- When the department is full, the effect on treatment duration is smaller than when it's nearly empty.
- Low skill mixes have a larger effect than high skill mixes.
- Low numbers of staff have an increasingly detrimental impact on treatment durations.
- High numbers of staff have a relatively small impact on treatment durations.

**Table 31 – Treatment duration adjustments for varying numbers of patients.**

| Patients | Skill mix | Actual Staff | Effective staff | Baseline patient to staff ratio | Staff to patient ratio | Productivity ratio | Scaling factor | Treatment adjustment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.00 | 10 | 10 | 1.5 | 10.00 | 0.07 | 1.35 | 0.76 |
| 2 | 1.00 | 10 | 10 | 1.5 | 5.00 | 0.13 | 1.35 | 0.77 |
| 3 | 1.00 | 10 | 10 | 1.5 | 3.33 | 0.20 | 1.35 | 0.79 |
| 4 | 1.00 | 10 | 10 | 1.5 | 2.50 | 0.27 | 1.35 | 0.80 |
| 5 | 1.00 | 10 | 10 | 1.5 | 2.00 | 0.33 | 1.35 | 0.82 |
| 6 | 1.00 | 10 | 10 | 1.5 | 1.67 | 0.40 | 1.35 | 0.84 |
| 7 | 1.00 | 10 | 10 | 1.5 | 1.43 | 0.47 | 1.35 | 0.85 |
| 8 | 1.00 | 10 | 10 | 1.5 | 1.25 | 0.53 | 1.35 | 0.87 |
| 9 | 1.00 | 10 | 10 | 1.5 | 1.11 | 0.60 | 1.35 | 0.89 |
| 10 | 1.00 | 10 | 10 | 1.5 | 1.00 | 0.67 | 1.35 | 0.90 |
| 11 | 1.00 | 10 | 10 | 1.5 | 0.91 | 0.73 | 1.35 | 0.92 |
| 12 | 1.00 | 10 | 10 | 1.5 | 0.83 | 0.80 | 1.35 | 0.94 |
| 13 | 1.00 | 10 | 10 | 1.5 | 0.77 | 0.87 | 1.35 | 0.96 |
| 14 | 1.00 | 10 | 10 | 1.5 | 0.71 | 0.93 | 1.35 | 0.98 |
| 15 | 1.00 | 10 | 10 | 1.5 | 0.67 | 1.00 | 1.35 | 1.00 |
| 16 | 1.00 | 10 | 10 | 1.5 | 0.63 | 1.07 | 1.35 | 1.02 |
| 17 | 1.00 | 10 | 10 | 1.5 | 0.59 | 1.13 | 1.35 | 1.04 |
| 18 | 1.00 | 10 | 10 | 1.5 | 0.56 | 1.20 | 1.35 | 1.06 |

| Patients | Skill mix | Actual Staff | Effective staff | Baseline patient to staff ratio | Staff to patient ratio | Productivity ratio | Scaling factor | Treatment adjustment |
|---|---|---|---|---|---|---|---|---|
| 19 | 1.00 | 10 | 10 | 1.5 | 0.53 | 1.27 | 1.35 | 1.08 |
| 20 | 1.00 | 10 | 10 | 1.5 | 0.50 | 1.33 | 1.35 | 1.11 |
| 21 | 1.00 | 10 | 10 | 1.5 | 0.48 | 1.40 | 1.35 | 1.13 |
| 22 | 1.00 | 10 | 10 | 1.5 | 0.45 | 1.47 | 1.35 | 1.15 |
| 23 | 1.00 | 10 | 10 | 1.5 | 0.43 | 1.53 | 1.35 | 1.17 |
| 24 | 1.00 | 10 | 10 | 1.5 | 0.42 | 1.60 | 1.35 | 1.20 |

**Table 32 – Treatment duration adjustments for varying skill mix of staff.**

| Patients | Skill mix | Actual Staff | Effective staff | Baseline patient to staff ratio | Staff to patient ratio | Productivity ratio | Scaling factor | Treatment adjustment |
|---|---|---|---|---|---|---|---|---|
| 15 | 0.50 | 10 | 5 | 1.5 | 0.33 | 2.00 | 1.35 | 1.35 |
| 15 | 0.60 | 10 | 6 | 1.5 | 0.40 | 1.67 | 1.35 | 1.22 |
| 15 | 0.70 | 10 | 7 | 1.5 | 0.47 | 1.43 | 1.35 | 1.14 |
| 15 | 0.80 | 10 | 8 | 1.5 | 0.53 | 1.25 | 1.35 | 1.08 |
| 15 | 0.90 | 10 | 9 | 1.5 | 0.60 | 1.11 | 1.35 | 1.03 |
| 15 | 1.00 | 10 | 10 | 1.5 | 0.67 | 1.00 | 1.35 | 1.00 |
| 15 | 1.10 | 10 | 11 | 1.5 | 0.73 | 0.91 | 1.35 | 0.97 |
| 15 | 1.20 | 10 | 12 | 1.5 | 0.80 | 0.83 | 1.35 | 0.95 |
| 15 | 1.30 | 10 | 13 | 1.5 | 0.87 | 0.77 | 1.35 | 0.93 |
| 15 | 1.40 | 10 | 14 | 1.5 | 0.93 | 0.71 | 1.35 | 0.92 |
| 15 | 1.50 | 10 | 15 | 1.5 | 1.00 | 0.67 | 1.35 | 0.90 |

**Table 33 – Treatment duration adjustments for varying numbers of staff.**

| Patients | Skill mix | Actual Staff | Effective staff | Baseline patient to staff ratio | Staff to patient ratio | Productivity ratio | Scaling factor | Treatment adjustment |
|---|---|---|---|---|---|---|---|---|
| 15 | 1.00 | 2 | 2 | 1.5 | 0.13 | 5.00 | 1.35 | 3.32 |
| 15 | 1.00 | 3 | 3 | 1.5 | 0.20 | 3.33 | 1.35 | 2.01 |
| 15 | 1.00 | 4 | 4 | 1.5 | 0.27 | 2.50 | 1.35 | 1.57 |
| 15 | 1.00 | 5 | 5 | 1.5 | 0.33 | 2.00 | 1.35 | 1.35 |
| 15 | 1.00 | 6 | 6 | 1.5 | 0.40 | 1.67 | 1.35 | 1.22 |

| Patients | Skill mix | Actual Staff | Effective staff | Baseline patient to staff ratio | Staff to patient ratio | Productivity ratio | Scaling factor | Treatment adjustment |
|---|---|---|---|---|---|---|---|---|
| 15 | 1.00 | 7 | 7 | 1.5 | 0.47 | 1.43 | 1.35 | 1.14 |
| 15 | 1.00 | 8 | 8 | 1.5 | 0.53 | 1.25 | 1.35 | 1.08 |
| 15 | 1.00 | 9 | 9 | 1.5 | 0.60 | 1.11 | 1.35 | 1.03 |
| 15 | 1.00 | 10 | 10 | 1.5 | 0.67 | 1.00 | 1.35 | 1.00 |
| 15 | 1.00 | 11 | 11 | 1.5 | 0.73 | 0.91 | 1.35 | 0.97 |
| 15 | 1.00 | 12 | 12 | 1.5 | 0.80 | 0.83 | 1.35 | 0.95 |
| 15 | 1.00 | 13 | 13 | 1.5 | 0.87 | 0.77 | 1.35 | 0.93 |
| 15 | 1.00 | 14 | 14 | 1.5 | 0.93 | 0.71 | 1.35 | 0.92 |
| 15 | 1.00 | 15 | 15 | 1.5 | 1.00 | 0.67 | 1.35 | 0.90 |
| 15 | 1.00 | 16 | 16 | 1.5 | 1.07 | 0.63 | 1.35 | 0.89 |
| 15 | 1.00 | 17 | 17 | 1.5 | 1.13 | 0.59 | 1.35 | 0.88 |
| 15 | 1.00 | 18 | 18 | 1.5 | 1.20 | 0.56 | 1.35 | 0.88 |
| 15 | 1.00 | 19 | 19 | 1.5 | 1.27 | 0.53 | 1.35 | 0.87 |
| 15 | 1.00 | 20 | 20 | 1.5 | 1.33 | 0.50 | 1.35 | 0.86 |

# 5.0 Interpretation

It should be noted that the results presented in this report are based on a single sequence of random distributions and numbers that represent one possible combination of stochastic parameters. Although the model is allowed to run for a sufficient duration to reach stability, it is possible that the particular sequence of random numbers can create isolated discrepancies for particular combinations of parameters which would disappear when averaged out over the course of a larger number of simulations.

It is thought that this is the main reason why there are some results that do not appear to make sense such as an average duration increasing despite staff skill mix or staff numbers increasing, and the apparent random nature of deaths and, to a lesser degree, LWBS. It is also possible that the necessity of keeping the model simple has meant that some relationships have not been defined in sufficient detail to reflect the real world.

## 5.1 Average skill mix

The interpretation of skill mix is important in understanding what the results mean. The analyses that show a variation in skill mix are presented as the maximum possible range given the baseline assumption of salaries being an accurate reflection of productivity. When the relative ratios of staff salaries compared with a band 5 nurse were calculated, the result was a skill mix ranging from 0.64 to 1.45 (with band 5s being the baseline at 1.0) which is covered in the results that show a range from 0.5 to 1.5.

Although the use of wages is a standard approach to measuring relative productivity in economic analysis, it is understood that this can imply a larger difference than actually exists and does not reflect the different roles and tasks that the staff carry out. To understand the effect of narrowing the productivity assumption, the leading and trailing results can simply be ignored. For example, you might look at a skill mix range of 0.75 to 1.25 if the skill gap between bands isn't considered to be as high as the salaries would indicate.

## 5.2 Insufficient nursing staff

Our model shows that when there are insufficient staff to cope with the number of arrivals, this has a detrimental effect on the patients in terms of duration spent in A&E, patients who leave without being seen, occupancy and the number of deaths occurring.

The smooth running of a department and maintaining the flow of patients coming in and departing are extremely important factors in relation to safety and the results from our model reflect this. Table 21 and Table 22 show that with low numbers of staff, the average duration that patients spend in A&E increases significantly from a baseline of 2.47 hours up to just under 10 hours for day shift and 4 hours for night shift. A large backlog of patients waiting causes a significant increase in the percentage of patients who LWBS. These patients exit the system and the resulting effect on them is not modelled.

The effect that staff numbers and skill have on the time taken to treat and discharge or admit patients also has to be considered. Table 34 shows that low staff numbers have the largest impact by far on treatment durations with an increase of 232%. Low staff skill increases treatment durations by 35% and high patient volumes by 11%. It is important to note that these effects are not additive so a high patient volume and a low staff skill mix will not necessarily produce a treatment adjustment of +46%.

In the reverse scenarios, low patient volumes have the greatest effect on reducing treatment durations at 24%. High staff counts reduce treatment durations by 14% and high staff skill by 10%.

Although these are extreme scenarios which are unlikely to play out in reality, the scale of the difference between them is important. It is also important to note that the psychological impacts of these scenarios are not incorporated into the model. For example, the lack of a senior band 6 or band 7 nurse on a shift may well have an additional impact beyond there being a lower skill mix or a lower number of staff.

**Table 34 – Key treatment adjustment outputs.**

| Scenario | Treatment duration change |
|---|---|
| High patient volume | +11% |
| Low staff count | +232% |
| Low staff skill | +35% |
| Low patient volume | -24% |
| High staff count | -14% |
| High staff skill | -10% |

## 5.3 Unexpected attendance volumes

Typical practice in A&E departments is to roster staff to cope with demand that is higher than the predicted average. This provides some slack that allows the department to cope with higher than average attendance numbers, although there will still be some occasions where even this is not sufficient. Our analysis shows that attendance volumes can have a significant impact across all of the outputs that were included. Table 34 shows that treatment durations do not vary considerably with patient volume which indicates that the issue is more likely related to patients waiting for admission or insufficient capacity to handle the required throughput, causing patients to wait for longer.

The analysis of patient volumes and staff numbers shows that when staffing numbers are increased, high sustained levels of patient attendances can be maintained without seeing a significant decline in the rate at which they flow through the department.

# 6.0 Conclusion

The results from an SD model of an A&E department have been presented results across a variety of process measures. The model was designed in collaboration with topic experts and validated with members of the SSAC. The model was populated with parameters and relationships based on patient activity and staffing data from 3 NHS trusts, national datasets, a systematic evidence review and topic experts.

The stochastic nature of the model was tested to ensure that the key outputs were robust

Based on the baseline parameters and assumptions described in section 3.4, the key findings from the analysis are:

- The modelled outputs are most sensitive to low numbers of staff followed by high attendance volumes.
- Reducing staff numbers and/or skill mix has a detrimental impact across all model outputs and these differences become larger as the staff numbers and/or skill mix decrease.
- Day shift staff numbers and skill mix has a greater impact than night shift staff numbers and skill mix.
- The average time to assessment and treatment are only affected by the more extreme scenarios of low staff numbers, low staff skill mix and high attendance volumes.
- As patient volumes increase there is a consistent decrease in the rate at which patients flow through the model and larger numbers exit via the non-discharge and non-admission pathways. When combined with low staff numbers or low skill mix, these observations are increased even further.
- Increasing staff numbers above the average may allow a department to more easily accommodate increased volumes of patients as shown by the smaller variation in outputs. For example, at the lowest staff numbers modelled, average duration varied from 2.49 to 2.95 hours whereas with high staff numbers the average duration varied from 2.31 to 2.47 hours.
- Increasing staff numbers and/or staff skill mix above the average does not significantly improve outputs unless high patient volumes are also a factor.
- Long transfer times between A&E departments and inpatient wards can create blockages in the system whereby the assessment and treatment of other patients is delayed.

The intention of this report is not to present what the optimal or most cost effective staffing levels are. That was not the scope of this analysis. Instead, the goal was to explore the trade-offs between staff numbers, staff skill mix and patient volumes and the impact they have on the modelled outputs.

This analysis is just one piece of evidence amongst a wider set of quantitative and qualitative evidence, from literature, personal professional experience, views from patients etc. that needs to inform the development of safe staffing guidelines.

# 7.0 Discussion

A&E departments are incredibly complicated environments due to the nature of the service that they provide. This economic model, as all models are, is a simplification of a real world system based on the data and information that was available.

Simulation modelling is not a new or innovative technique (especially in health systems), but there is clearly a lack of evidence and data to support such an exercise. It is hoped that this helps to highlight some of the key relationships and factors that are important when considering the question of what constitutes a safe level of staffing. It is also hoped that this creates an opportunity to collect more data to help resolve some of the limitations.

## 7.1 Limitations

The main obstacle that was encountered whilst the model was developed was the lack of data sources that help describe the relationship between patients and staff and their effects one another. There are numerous data sources that provide information on patient activity in A&E departments including HES patient level data, sit reps and annual reports published by the HSCIC[25]. Even with this patient level data, it was not possible to find any information on patient acuity without relying on some broad assumptions around diagnosis and HRG codes. During early discussions and research into possible data sources, triage categories were identified as being a good proxy for acuity but these are not included in HES data.

For staffing levels there is no national source of electronic staff rosters. This was essential to help inform the relationship between the patient's journey through A&E and the number and type of staff that are on duty. This was a vital piece of information as without it there would be a large part of the model that would be purely reliant on assumptions. Members of the SSAC were approached several were able to respond and provide us with some of their own data.

Several other limitations of the model are already mentioned in the assumptions but there are 3 main ones that will be discussed here:

1) Not all of the processes and intricacies of an A&E department have been included
2) Only a small subset of outputs are included
3) The model and the results presented have a potential bias towards urban settings

### 7.1.1 Model simplification

#### Investigation and diagnostics

One of the most significant processes that is not present in the model is investigation and diagnostics. It has been assumed that these are included within the treatment durations which is reasonable if the length of time a patient spends in A&E is the primary output. However, the implications on staffing extend beyond just the time required as a nurse or support staff that is required to take the patient to and from other departments won't be available to care for other patients during this time.

#### Discharges

[25] A request was submitted in January 2014 for the 2012/13 HES data but due to the large backlog of requests, it could not be completed in time for the analysis.

If a patient is discharged there is no distinction in the model between different methods of discharge. There is functionality built into the model to support this but data to help describe these relationships and the durations could not be acquired. The main limitation was the data that is recorded at patient level. The length of time between treatment starting and the patient departing can be measured, but ideally the point at which treatment ended and the patient was ready to be discharged or admitted needs to be measured. This is especially important for patients that require an ambulance to take them home, or patients who require some form of social care support.

#### Dependency

Dependency is a parameter that was planned to be included as a measure of how much of patient's time in A&E actually requires a nurse to be with them. Elderly patients, for example, will more likely need help caring for themselves. Based on discussions on data requirements with NHS trusts, dependency is something that is not often measured at the time of assessment and is not recorded electronically.

### 7.1.2 Outputs

The scope for the guideline listed a large range of indicators and outcomes that were of interest. Most of these do not have data to support them, or the concept of the indicator was too complicated to be included in the model. The evidence review also highlighted the issue of there being very little data, and not a single economic study was identified.

There are also limitations of the modelling approach that prevent some outputs from being measured. For example, in a SD model individual patients cannot be tracked so although the average duration in the department can be measured, the proportion of patients that were in the department for 4 hours or less cannot be calculated.

### 7.1.3 Model bias

The baseline parameters used in the model are based on a small selection of NHS trusts and so may not be an average representation of the country. Several of the NHS trusts that provided data are based in urban settings and so there is a risk that some parameters used in the model will have a bias towards this. It would be expected that departments in more rural settings would have lower average acuity levels, higher dependency (due to more elderly populations) and perhaps have lower proportions of arrivals via emergency services. Rural departments may also be serving a different type of population with different needs which, as discussed in section 3.4, would likely create a different acuity and attendance pattern.

## 7.2 Future research

As previously mentioned, there are gaps in the evidence that have meant only a limited selection of outputs can be modelled. This is particularly true around clinical and cost outputs of which there is very little data collected in an A&E environment.

Developing a monitoring framework for the recommendations where the impact can be assessed by specifying data collections to ensure that where departments have changed their staffing patterns, the patients are experiencing the same or a better quality of care.

The model has been built in a way that would allow individual departments to enter data and run a simulation. If more data and evidence were to become available then the model could be developed further to provide more robust and detailed findings as well as covering more outputs. The complexity of A&E departments means that there are large number of factors that are linked with safe staffing. Undertaking a project to review all of these parameters and understanding their effect on staffing would be a significant task, requiring a longer period of time than was available for this analysis.

It has also been made clear that there are a large number of external factors that can affect the running of an A&E department such as the availability of surrounding healthcare services (especially primary care), the lifestyles of the population being served, increased demand for services, restricted budgets, service redesigns

# 8.0 Glossary

**Admission**
A patient who has been admitted into hospital from the A&E department after receiving treatment.

**Discharge**
A patient who has been discharged from the A&E department after receiving treatment.

**Early discharge**
A patient who is discharged without receiving treatment. This could be due to refusal of treatment, being deflected to another service or referral to another internal department.

**HEMS**
The Helicopter Emergency Medical Service, providing air ambulance services across the UK.

**HES**
Hospital Episode Statistics. Patient level data describing activity in A&E, inpatient and outpatient settings.

**IQR**
Inter-quartile range. The range between the $25^{th}$ and $75^{th}$ percentile values. Can either be expressed as the calculated difference or as the lower and upper bounds of the range (e.g. 4.1 – 5.7).

**LWBS**
Left without being seen. Patients who leave the A&E department without being seen by a member of staff.

**Occupancy**
The amount of a department's capacity that is taken up by current patients, expressed as a percentage. This does not include patients who are in the waiting room.

**Occupancy (average)**
The average occupancy of the department over the duration of the simulation, sampled at hourly intervals.

**Patients per staff**
The number of patients who are currently in the department divided by the number of nursing staff. This does not include patients who are in the waiting room.

**Patients per staff (average)**
The average number of patients per staff over the duration of the simulation, sampled at hourly intervals.

**Productivity scaling factor**
The proportional increase or decrease in treatment durations when the patient to staff ratio is twice as large or small as the baseline patient to staff ratio.

**PSSRU**

The Personal Social Services Research Unit who conduct research on needs, resources and outcomes in social and health care.

**Skill mix**

The average skill of nursing staff in the department relative to band 5 nurses.

**Transfer**

A patient who is transferred to a different department or healthcare provider.

**Treatment adjustment**

The factor by which the baseline treatment durations are multiplied by to calculate the actual treatment duration. An adjustment of 0.76 means that the actual treatment duration is 24% shorter than the baseline.