Healthier Together

Improving health and care in Bristol, North Somerset and South Gloucestershire

Appendix 10 – BNSSG Stroke Programme - Model for assessing sufficiency of allocated flex capacity

Date: Feb 2021

Appendix 10 - Model for assessing sufficiency of allocated flex capacity

1. Introduction

“Patient flow” refers to the movement of patients along the patient pathway – from attendance of the paramedic, presentation at hospital, through to admission to the HASU, step down to the ASU and discharge to SSARU or home based rehabilitation care and “life after stroke”. Patient flow is important to understand because any blockages in the progression of care will lead to queues forming further “upstream”. In an acute clinical service, such as stroke, queues can lead to congestion at the beginning of the patient pathway and risk the most acutely unwell patients being unable to access the specialist care that they need.

Good capacity planning underpins patient flow and having the right capacity at each stage of the pathway helps to avoid queues. The capacity planning work for the proposed changes to stroke care in BNSSG has been done in close liaison with all service providers, including SWASFT, and using recognised, validated, data sources. The detailed capacity analysis is presented in Chapter 11 of the PCBC and, to support this, a simulation model has been developed to evaluate the variation (peaks and troughs) that the service is likely to experience and what this will mean for patient flow across the course of a year.

2. Conclusion

The findings from this ‘stochastic’ modelling work demonstrate that blockages are more likely to occur with a high number of small units, unless additional flexibility (more beds) are provided at peak times. For example, when 3 smaller SSARUs are included, 15 beds of flexibility are required to achieve the same patient flow as 10 beds of flexibility within the 2 SSARU model. As community beds continue to be a pressure within the BNSSG health system, consideration of a smaller number of units is important.

Section One: Summary

Title: **Modelling for assessing sufficiency of allocated and flex capacity**
Author: **Rich Wood, Ben Murch, Simon Moss (BI Modelling and Analytics)**
Date: **15 December 2020**

1. Background

BNSSG CCG Modelling and Analytics have supported the Stroke Programme Board since December 2016, mainly through the demand and capacity model we have developed specifically for this project. This model has been peer reviewed and published.

The motivation for developing this model is the established fact that 'averages-based' approaches can considerably under-estimate capacity requirements. Indeed, one recently published study – modelling a stroke service – finds that averages-based methods under-estimate required acute beds by at least 30-40%. This is because such methods fail to appreciate variability in arrivals, length of stay, and delayed transfers of care.

The purpose of this paper is to outline the degree of 'flex' that would be required at certain times were services planned upon the currently considered bed numbers. This would require the ability to readily use additional or alternative (clinically appropriate) beds at times of peak demand and bed occupancy.

Four separate scenarios were investigated, comprising different combinations of Hyper Acute Stroke Unit (HASU), Acute Stroke Units (ASUs), and Sub-acute Rehabilitation Units (SARUs). Each option was analysed under two different sets of assumptions: In the first, it was assumed that in times of high demand all units could "flex" to an additional number of beds beyond their nominal "normal" capacity. In the second, it was assumed that this was only possible for HAUS and ASU, with the given capacities for SARUs being a hard limit.

Option	Configuration
1a	1 HASU, 1 ASU, 3 SARUs
1b	1 HASU, 1 ASU, 2 SARUs
2a	1 HASU, 2 ASUs, 3 SARUs
2b	1 HASU, 2 ASUs, 2 SARUs

Based on a variety of considerations, including an assessment of the results from this modelling, the Healthier Together BNSSG Stroke Programme is proceeding with public consultation on options 1b and 2b only.

2. Key findings

The first scenario, with no 'flex capacity' available at the sub-acute rehab units (SARUs), sees HASU and ASU at their flex capacity limit 13% and 24% of the time for Option 1a. Each SARU is full between 15% and 35% of the time for Options 1a and 2a without this additional flex.

For the latter two scenarios (options 1b and 2b, additional flex capacity at each sub-acute rehab unit and a reduction from three sub-acute rehab units to two), no unit reaches its flex capacity limit more than 2.4% of the time. HASU occupancy and time spent at or below nominal capacity (22 beds) is consistent at 70% across these scenarios, for both Option 1b and 2b.

Each option and scenario would also require a relatively consistent number of 'flex beds' (i.e. additional, clinically appropriate and available beds) on average when at full occupancy. However, the number of additional 'flex beds' required at HASU and ASU would increase with no flex available at any of the SARUs.

The summary results in terms of time spent at or below nominal capacity, time spent at flex capacity limit and flex requirements at full occupancy are shown in Appendix 1.

3. Appendix: Table of Results

Option	Flex permitted	Unit	Beds	Time spent below or at nominal capacity (%)	Time spent at flex capacity limit (%)	Mean Occupancy	Mean 'flex beds' required at full occupancy
1a	Yes	HASU	22 (32)	57.6	13	22.1	5.6
1a	Yes	ASU	22 (32)	41.3	23.7	24.3	6.6
1a	No	SARU (Bristol)	18	84.9	N/A	14.4	N/A
1a	No	SARU (North Somerset)	12	78	N/A	10	N/A
1a	No	SARU (South Glos)	12	71.2	N/A	9.4	N/A
2a	Yes	HASU	22 (32)	68.7	1.6	20.4	3.7
2a	Yes	NBT ASU	15 (32)	64.3	1.6	14.4	4.8
2a	Yes	UHBW ASU	9 (20)	60.6	1.7	9	3.3
2a	No	SARU (Bristol)	18	79.9	N/A	10	N/A
2a	No	SARU (North Somerset)	12	74	N/A	9.4	N/A
2a	No	SARU (South Glos)	12	65	N/A	14.5	N/A
1a	Yes	HASU	22 (32)	69.8	1.1	20.3	3.6
1a	Yes	ASU	22 (32)	80.2	0.5	18.8	3.2
1a	Yes	SARU (Bristol)	18 (23)	85.4	1.2	14.5	2.4
1a	Yes	SARU (North Somerset)	12 (17)	83.3	1.4	9.5	2.3
1a	Yes	SARU (South Glos)	12 (17)	76.1	2.4	10.3	2.5
2a	Yes	HASU	22 (32)	69.6	1.1	20.3	3.6
2a	Yes	NBT ASU	15 (32)	89.4	0	11.2	2.4
2a	Yes	UHBW ASU	9 (20)	76	0	7.6	2.4
2a	Yes	SARU (Bristol)	18 (23)	83.7	1.4	14.7	2.4
2a	Yes	SARU (North Somerset)	12 (17)	83.6	1.4	9.5	2.3
2a	Yes	SARU (South Glos)	12 (17)	77.2	2.1	10.1	2.4

1b	Yes	HASU	22 (32)	69.6	1.1	20.3	3.6
1b	Yes	ASU	22 (32)	79.9	0.5	18.9	3.3
1b	Yes	SARU 1	30 (35)	88.2	0.9	24.4	2.5
1b	Yes	SARU 2	12 (17)	79.1	2.1	9.9	2.4
2b	Yes	HASU	22 (32)	69.5	1.1	20.3	3.4
2b	Yes	NBT ASU	15 (32)	89.2	0	11.2	2.5
2b	Yes	UHBW ASU	9 (20)	75.9	0	7.6	2.4
2b	Yes	SARU 1	30 (35)	87.9	0.9	24.5	2.5
2b	Yes	SARU 2	12 (17)	79.8	1.8	9.9	2.4

Section Two: Options 1a and 2a with subacute "flex" (three sub-acute units)

Author: Simon Moss, Ben Murch, Rich Wood (BI Modelling and Analytics)
Date: 11 December 2020

1. Background

CCG Modelling and Analytics have supported the Stroke Programme Board since December 2016, mainly through the demand and capacity model we have developed specifically for this project. This model has been peer reviewed and published.

The motivation for developing this model is the inadequacy of commonly-used 'averages-based' approaches in appreciating realistic variability in arrivals, length of stay, and delays to transfers of care. Indeed, one recently published study – modelling a stroke service – finds that averages-based methods under-estimate required acute beds by at least 30-40%. Conversely, naïve interpretation of the appropriate 'stochastic' models can yield *over-estimation*, if used without consideration to the wider bed base, and how this can be 'flexed'.

The purpose of this paper is to outline the degree of 'flex' that would be required at certain times were services planned upon the currently considered bed numbers. Note that for this analysis, the same pathway specification is used as per that derivation.

2. Key findings

Having sufficient 'flex' capacity in the system means that additional or alternative (clinically appropriate) beds can be utilised at times of peak demand and bed occupancy. Under Option 1a, HASU would be at the 'upper flex capacity limit' of 32 beds 1.1% of the time. ASU would reach its limit of 32 beds 0.5% of the time. For Option 2a, HASU would reach its 'upper flex' limit 1.4% of the time, while NBT ASU (32 beds) and UHBW ASU (20 beds) would never reach their upper limits of 'flex capacity'.

In addition to the acute elements of the pathway, the latest iteration of modelling inputs account for the inclusion of three Sub-Acute Rehabilitation Units (SARU). Each of these units is allocated to one local authority area in Bristol, North Somerset and South Gloucestershire. With additional flex capacity at HASU and ASU, the Bristol SARU, South Glos SARU and North Somerset SARU would be full 1.2%, 2.4% and 1.4% of the time under Option 1a. For Option 2a, these same units would also be at full capacity 1.4%, 2.1% and 1.4% of the time.

Appendix: Methodology and full results (allocated beds plus additional 'flex' capacity)

A.1. Summary

Two options for the reconfigured BNSSG Stroke Pathway have been proposed – both with a single Hyper Acute Stroke Unit (HASU), and with either one or two Acute Stroke Units (ASUs). Fixed bed capacities for these two options have been proposed using averages-based estimates of usage. Because arrivals and lengths of stay are subject to random variation, these estimates may not be robust.

Computer simulation has therefore been used to assess the extent to which the proposed bed numbers may underestimate the required capacity (in terms of proportions of time the units are full, and whether unacceptable volumes of patients have to queue).

Additional 'upper limits of flex capacity' have also been proposed by the team responsible for the BNSSG Stroke Reconfiguration Programme, in order to provide full consideration to the wider bed base available at times of peak demand and bed occupancy.

A.2. Method

Flow through the proposed Stroke Pathway configurations were simulated using a computerised mathematical model.[1]

A.3. Results

For each of the two options, patient flow was simulated under the assumption of an allocated bed capacity proposed by the team responsible for the BNSSG Stroke Reconfiguration Programme, in addition to a set number of 'flex capacity' beds which could be utilised if required.

The summary results in terms of occupancy, queue size, and proportion of time at full occupancy, are shown in Table A.1. More detailed results and a full specification of the options follow in Sections A.3.1 and A.3.2.

[1] Discrete event simulation using *PathSimR* https://github.com/nhs-bnssg-analytics/PathSimR

Option	Flex permitted	Unit	Beds	Time at or above proposed capacity (%)	Mean Occupancy	Mean Queue
1a	Yes	HASU	32	1.1	20.3	N/A
1a	Yes	ASU	32	0.5	18.8	N/A
1a	Yes	SARU (Bristol)	23	1.2	14.5	N/A
1a	Yes	SARU (North Somerset)	17	1.4	9.5	N/A
1a	Yes	SARU (South Glos)	17	2.4	10.3	N/A
2a	Yes	HASU	32	1.1	20.3	N/A
2a	Yes	NBT ASU	32	0	11.2	N/A
2a	Yes	UHBW ASU	20	0	7.6	N/A
2a	Yes	SARU (Bristol)	23	1.4	14.7	N/A
2a	Yes	SARU (North Somerset)	17	1.4	9.5	N/A
2a	Yes	SARU (South Glos)	17	2.1	10.1	N/A

Table A.1. Summary results of simulated scenarios

A.3.1 Option 1a

This option – detailed in Figure A.1 - includes a single HASU and a single ASU (assumed to be on the same site, at NBT). There are prescribed delays to some discharge destinations but not between HASU and ASU. Bed numbers are given as per business case estimates.

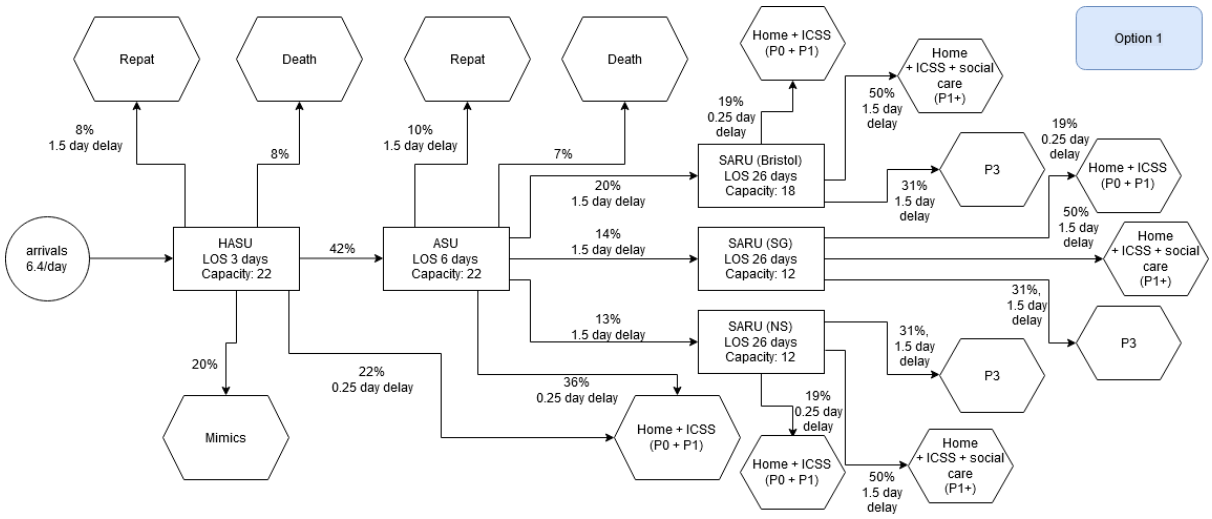


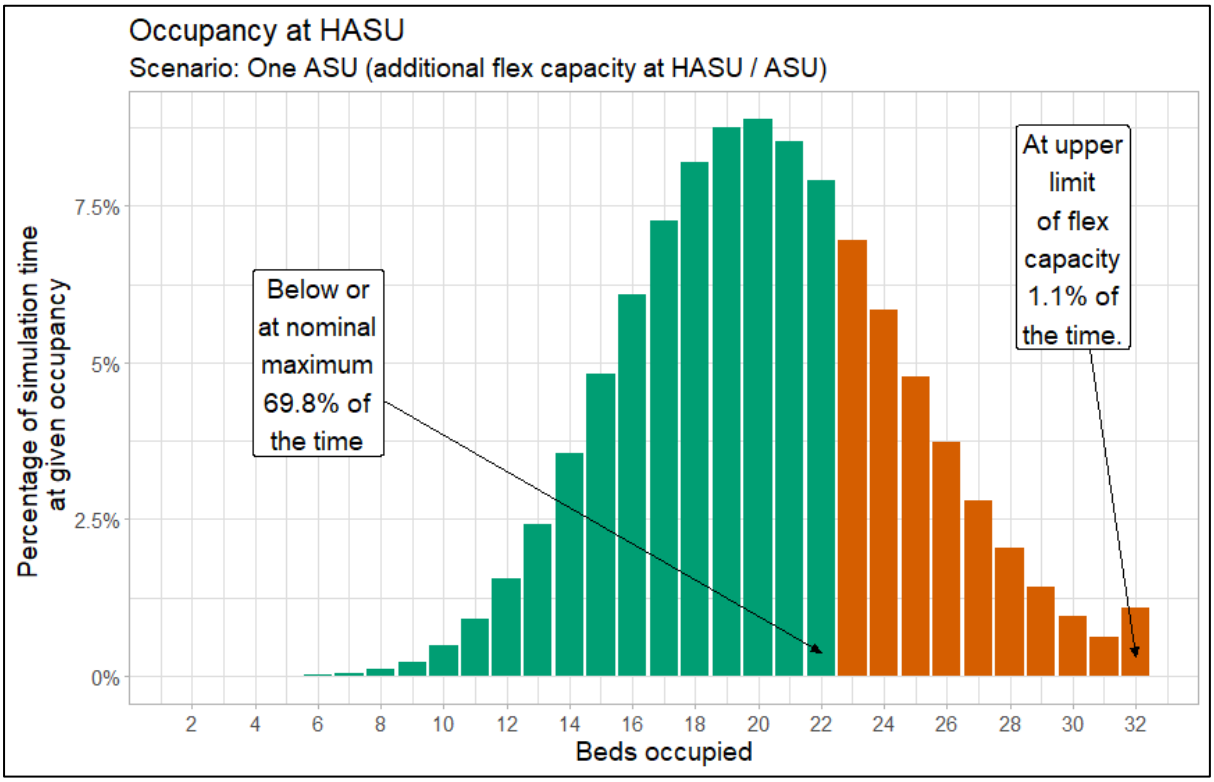
Figure A.1. Configuration of Stroke Pathway Option 1a (including SARU extension)

Simulating flow through the pathways using allocated bed constraints can often fail to provide appropriate consideration to the wider bed base, and how this can be 'flexed'. This would require the ability to readily use additional or alternative (clinically appropriate) beds at times of peak demand and bed occupancy.

Figure A.2 uses agreed 'upper flex capacity limits' to outline the degree of 'flex' that would be required at certain times were services planned upon the currently considered bed numbers.

In the event of additional flex capacity being available at both HASU and ASU, HASU would be at this upper limit of flex capacity 1.1% of the time. Likewise, ASU would be at its upper limit 0.5% of the time. Both units would be below or at their nominal capacities 70% and 80% of the time respectively. With additional flex capacity available at HASU, ASU and the three Sub-Acute Units, SARU Bristol, SARU North Somerset and SARU South Gloucestershire reach their upper capacity limit 1.2%, 1.4% and 2.4% of the time respectively.

Without this flex capacity at each of the SARU units, SARU Bristol would be full 15% of the time. SARU North Somerset and SARU South Gloucestershire would be full 22% and 30% of the time respectively. Patients would also spend an average of 2.1 days at ASU waiting for capacity to be freed up at one of these units.



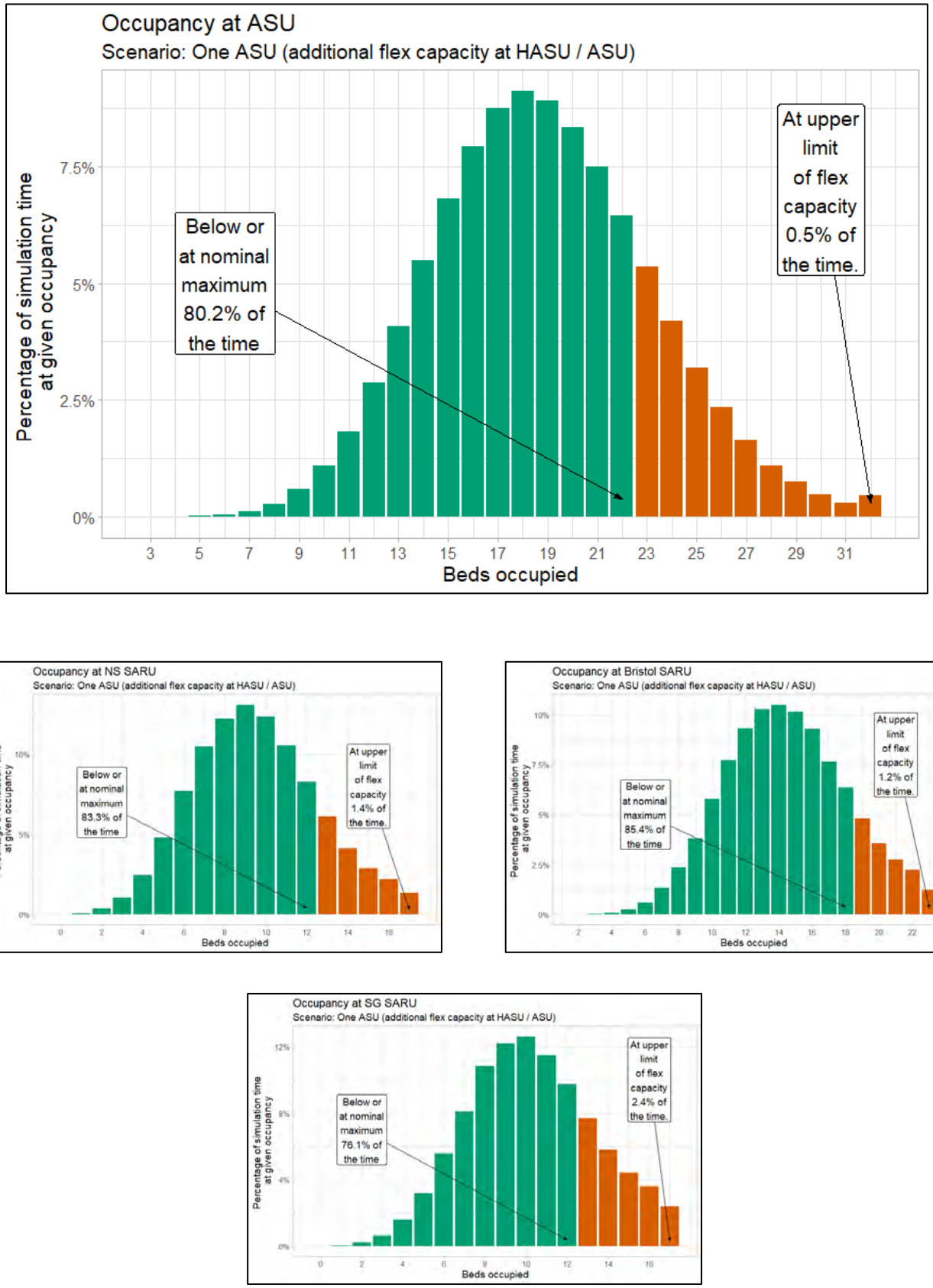


Figure A.2. Option 1a: Occupancy assuming additional pre-determined flex capacity

A.3.2 Option 2a

This option – detailed in Figure A.3 – is very similar to Option 1a, except that ASU capacity is now split between two sites, with an assumed prescribed delay to transfer to the ASU (UHBW ASU) which is not in the same hospital as the HASU. This, along with the consequences of splitting ASU capacity between two different units (which increases the chance of either one of them being full at any given time) leads to greater capacity pressures.

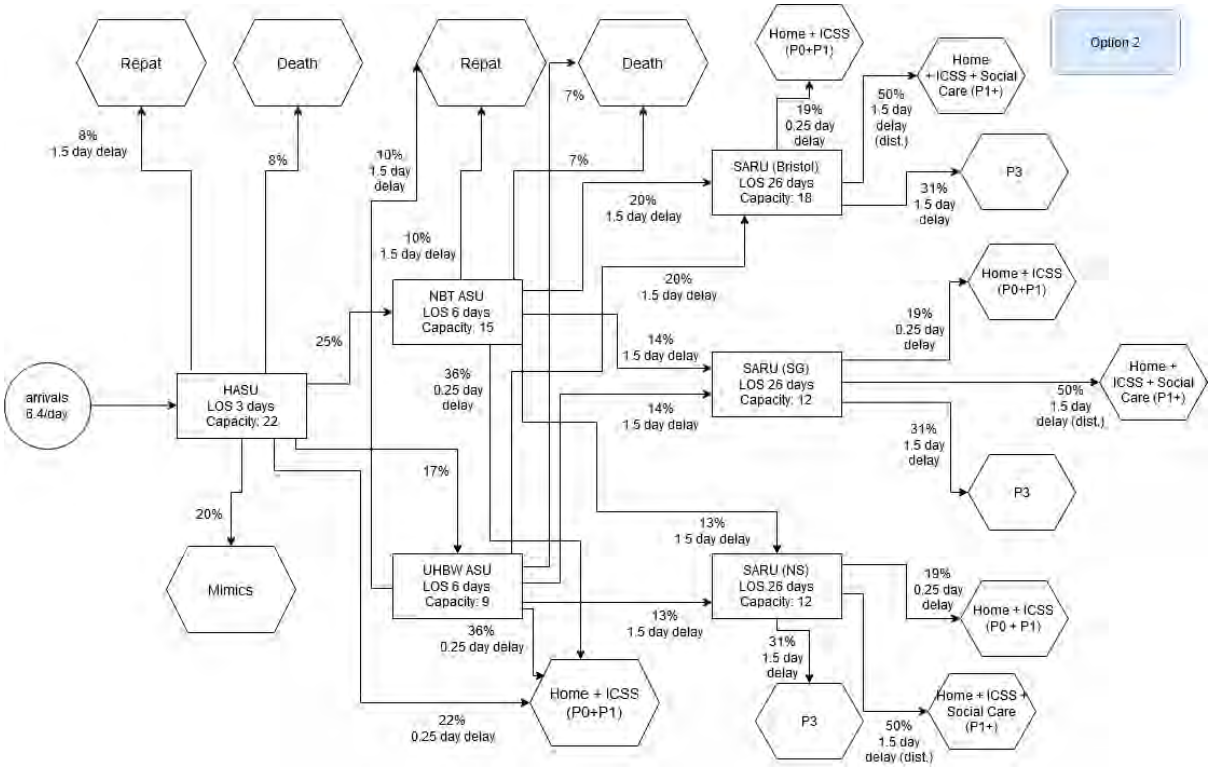
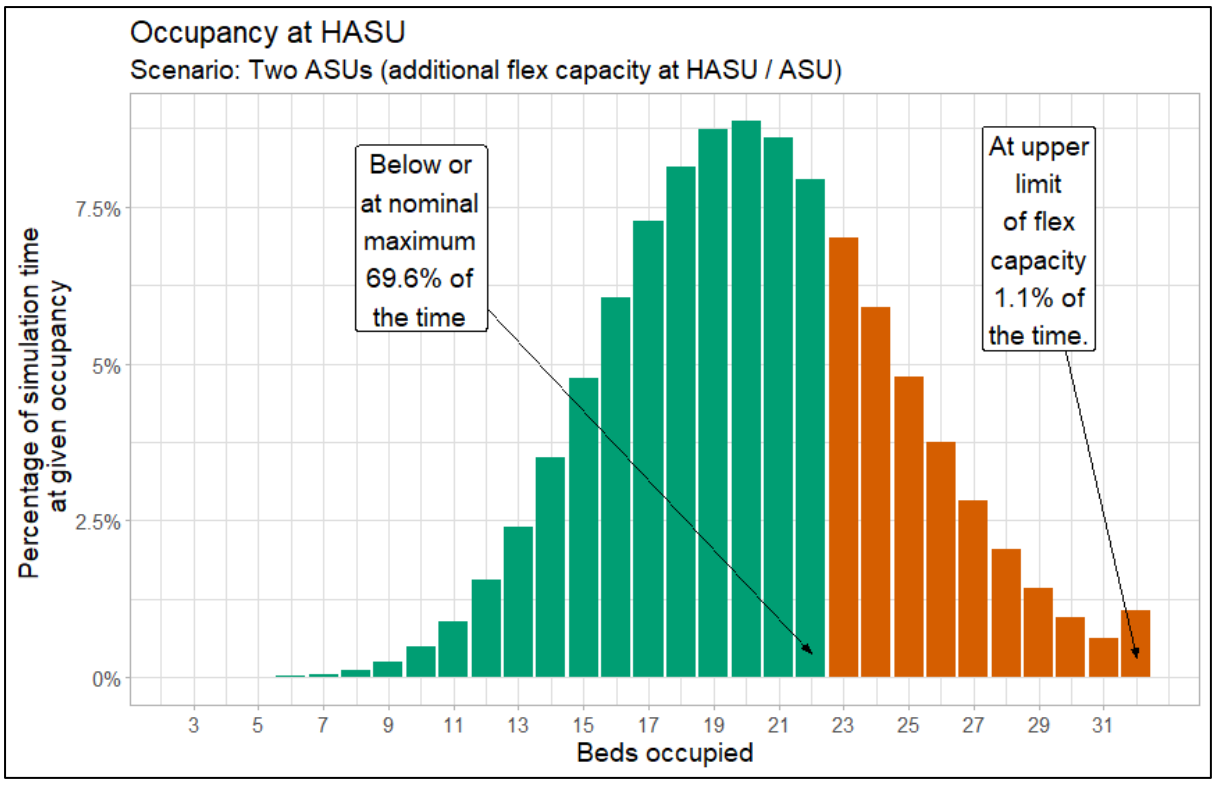


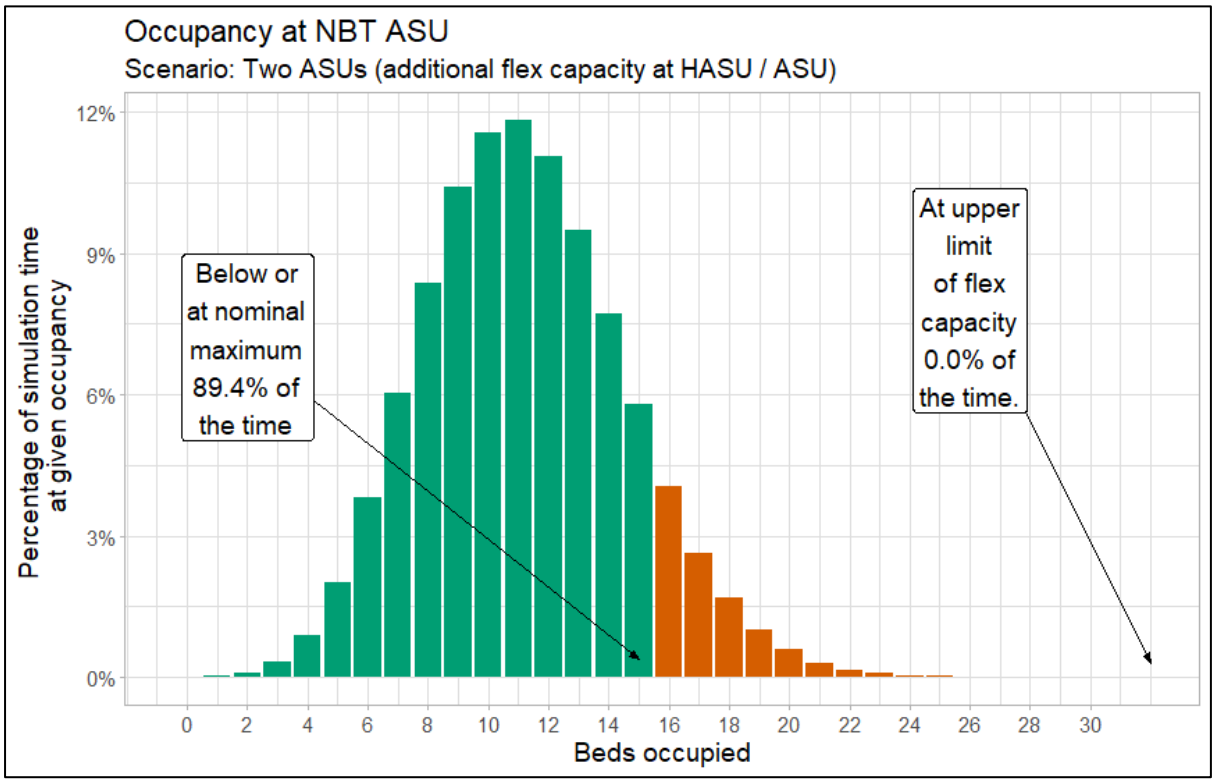
Figure A.3. Configuration of Stroke Pathway Option 2a (including SARU extension)

In the event of additional flex capacity being available at both HASU and ASU, HASU would be at this upper limit of flex capacity 1.1% of the time. NBT ASU and UHBW ASU would never reach their upper limits of flex capacity under this option. HASU would be below or at its nominal capacity 70% of the time, while NBT ASU and UHBW ASU would be below or at their nominal capacities 89% and 76% of the time.

With additional flex capacity available at HASU and both ASU sites, SARU Bristol, SARU North Somerset and SARU South Gloucestershire reach their upper flex capacity limit 1.4%, 1.4% and 2.1% of the time.

Without this flex capacity, SARU Bristol would be full 20% of the time. SARU North Somerset and SARU South Gloucestershire would be full 26% and 35% of the time respectively. Patients would also spend an average of 2.3 days at either NBT ASU or UHBW ASU waiting for capacity to be freed up at one of these units.


Occupancy at HASU
Scenario: Two ASUs (additional flex capacity at HASU / ASU)
Below or at nominal maximum 69.6% of the time
At upper limit of flex capacity 1.1% of the time.
Percentage of simulation time at given occupancy
7.5%
5%
2.5%
0%
3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
Beds occupied


Occupancy at NBT ASU
Scenario: Two ASUs (additional flex capacity at HASU / ASU)
Below or at nominal maximum 89.4% of the time
At upper limit of flex capacity 0.0% of the time.
Percentage of simulation time at given occupancy
12%
9%
6%
3%
0%
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
Beds occupied

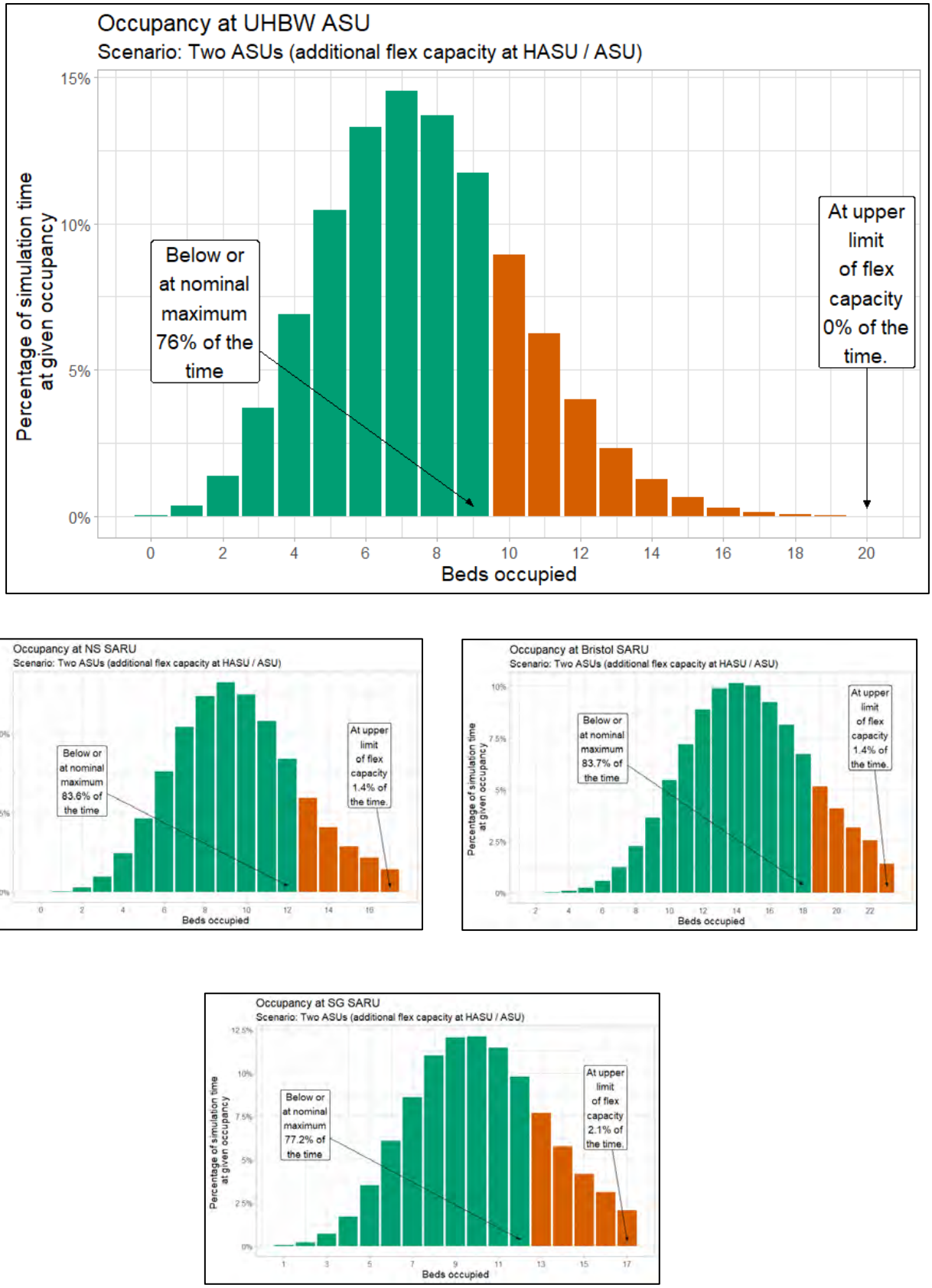


Figure 4. Option 2a: Occupancy assuming additional pre-determined flex capacity

A.4. Conclusion and next steps

Since the last iteration of modelling outputs, further work has taken place in order to establish 'upper limits of flex capacity' for each of the acute units, in order to fully understand the degree of 'flex' capacity that would be required for each option. For Option 1a, HASU ('upper limit of flex capacity' - 32 beds) and ASU (32) would reach these upper limits 1.1% and 0.5% of the time respectively. Meanwhile, HASU (32) would reach this upper limit 1.1% of the time under Option 2a, while NBT ASU (32) and UHBW ASU (20) would never reach their upper limits.

Further simulations could be performed to test the robustness of these revised estimates. It is expected that further revisions to bed capacities and flow rates will follow in due course.

Section Three: Options 1a and 2a without subacute "flex" (three sub-acute units)

Author: Simon Moss, Ben Murch, Rich Wood (BI Modelling and Analytics)
Date: 11 December 2020

2. Background

CCG Modelling and Analytics have supported the Stroke Programme Board since December 2016, mainly through the demand and capacity model we have developed specifically for this project. This model has been peer reviewed and published.

The motivation for developing this model is the inadequacy of commonly-used 'averages-based' approaches in appreciating realistic variability in arrivals, length of stay, and delays to transfers of care. Indeed, one recently published study – modelling a stroke service – finds that averages-based methods under-estimate required acute beds by at least 30-40%. Conversely, naïve interpretation of the appropriate 'stochastic' models can yield *over-estimation*, if used without consideration to the wider bed base, and how this can be 'flexed'.

The purpose of this paper is to outline the degree of 'flex' that would be required at certain times were services planned upon the currently considered bed numbers. Note that for this analysis, the same pathway specification is used as per that derivation.

2. Key findings

Having sufficient 'flex' capacity in the system means that additional or alternative (clinically appropriate) beds can be utilised at times of peak demand and bed occupancy. Under Option 1a, HASU would be at the 'upper flex capacity limit' of 32 beds 13% of the time. ASU would reach its limit of 32 beds 24% of the time. For Option 2a, HASU would reach its 'upper flex' limit 1.6% of the time, while NBT ASU (32 beds) and UHBW ASU (20 beds) would reach their upper limits of 'flex capacity' 1.6% and 1.7% of the time respectively.

In addition to the acute elements of the pathway, the latest iteration of modelling inputs account for the inclusion of three Sub-Acute Rehabilitation Units (SARUs). Each of these units is allocated to one local authority area in Bristol, North Somerset and South Gloucestershire. With additional flex capacity at HASU and ASU, the Bristol SARU, South Glos SARU and North Somerset SARU would be full 15%, 30% and 22% of the time under Option 1a. For Option 2a, these same units would be at full capacity 26%, 35% and 20% of the time.

Appendix: Methodology and full results (allocated beds plus additional 'flex' capacity)

A.1. Summary

Two options for the reconfigured BNSSG Stroke Pathway have been proposed – both with a single Hyper Acute Stroke Unit (HASU), and with either one or two Acute Stroke Units (ASUs). Fixed bed capacities for these two options have been proposed using averages-based estimates of usage. Because arrivals and lengths of stay are subject to random variation, these estimates may not be robust.

Computer simulation has therefore been used to assess the extent to which the proposed bed numbers may underestimate the required capacity (in terms of proportions of time the units are full, and whether unacceptable volumes of patients have to queue).

Additional 'upper limits of flex capacity' have also been proposed by the team responsible for the BNSSG Stroke Reconfiguration Programme, in order to provide full consideration to the wider bed base available at times of peak demand and bed occupancy.

A.2. Method

Flow through the proposed Stroke Pathway configurations were simulated using a computerised mathematical model.[2]

A.3. Results

For each of the two options, patient flow was simulated under the assumption of an allocated bed capacity proposed by the team responsible for the BNSSG Stroke Reconfiguration Programme, in addition to a set number of 'flex capacity' beds which could be utilised if required.

The summary results in terms of occupancy, queue size, and proportion of time at full occupancy, are shown in Table A.1. More detailed results and a full specification of the options follow in Sections A.3.1 and A.3.2.

[2] Discrete event simulation using *PathSimR* https://github.com/nhs-bnssg-analytics/PathSimR

Option	Flex permitted	Unit	Beds	Time at or above proposed capacity (%)	Mean Occupancy	Mean Queue
1a	Yes	HASU	32	13	22.1	4.7
1a	Yes	ASU	32	23.7	24.3	N/A
1a	No	SARU (Bristol)	18	15.1	14.4	N/A
1a	No	SARU (North Somerset)	12	22	10	N/A
1a	No	SARU (South Glos)	12	29.8	9.4	N/A
2a	Yes	HASU	32	1.6	20.4	0.1
2a	Yes	NBT ASU	32	1.6	14.4	N/A
2a	Yes	UHBW ASU	20	1.7	9	N/A
2a	No	SARU (Bristol)	18	20.1	10	N/A
2a	No	SARU (North Somerset)	12	26	9.4	N/A
2a	No	SARU (South Glos)	12	35	14.5	N/A

Table A.1. Summary results of simulated scenarios

A.3.1 Option 1a

This option – detailed in Figure A.1 - includes a single HASU and a single ASU (assumed to be on the same site, at NBT). There are prescribed delays to some discharge destinations but not between HASU and ASU. Bed numbers are given as per business case estimates.

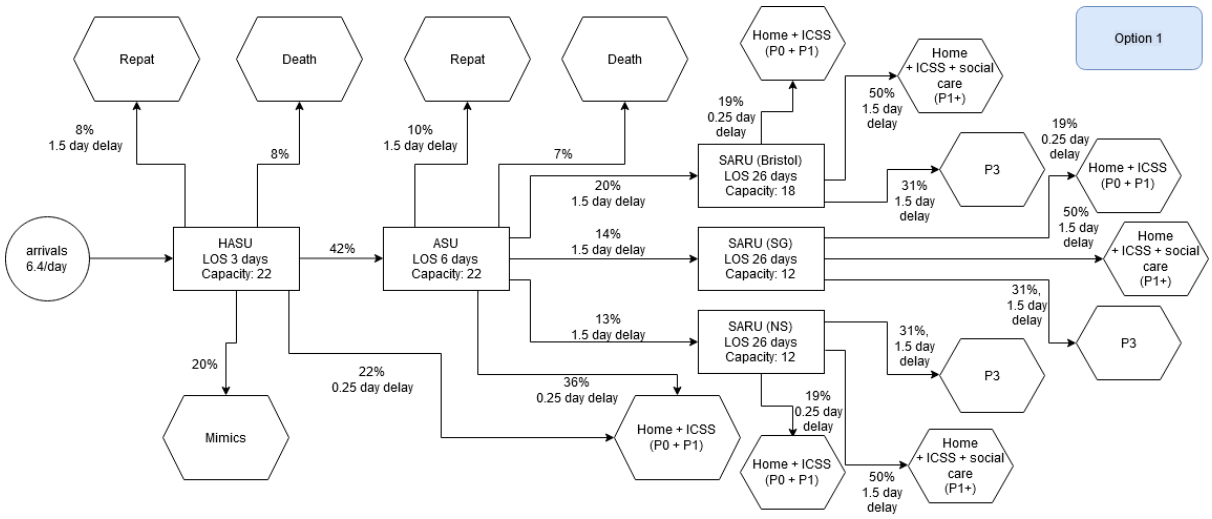
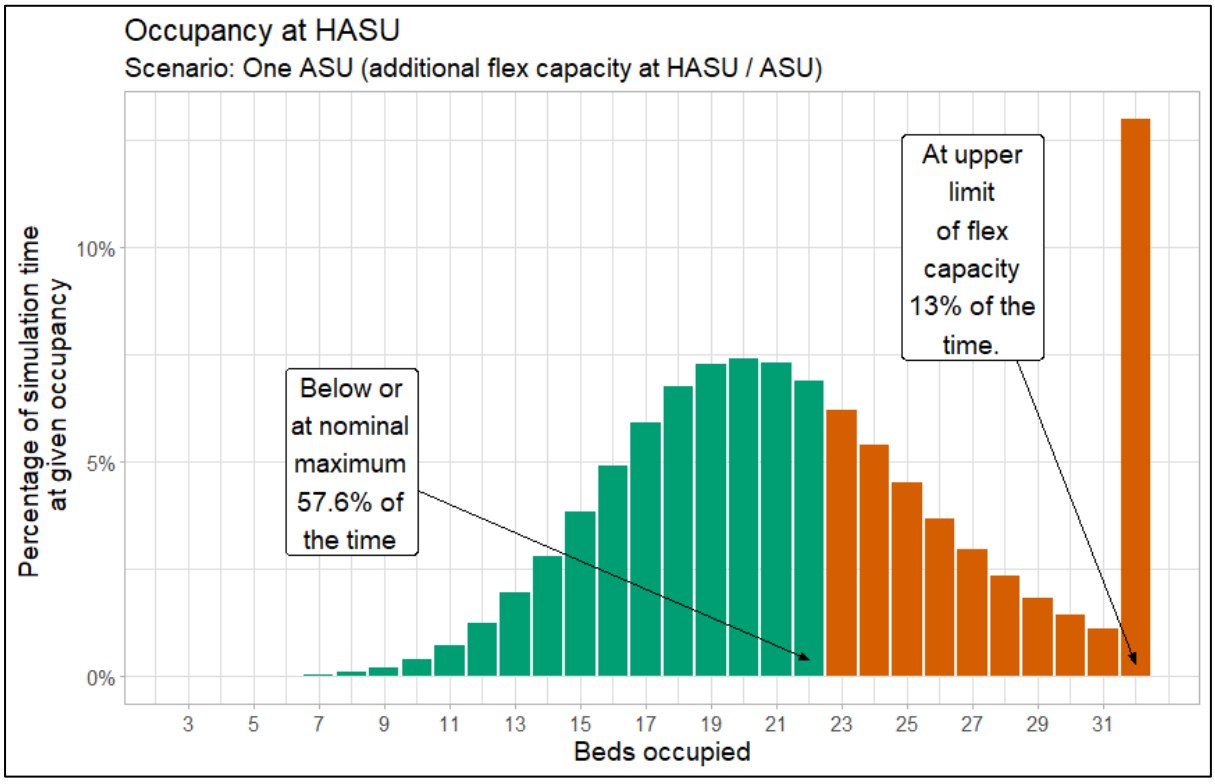


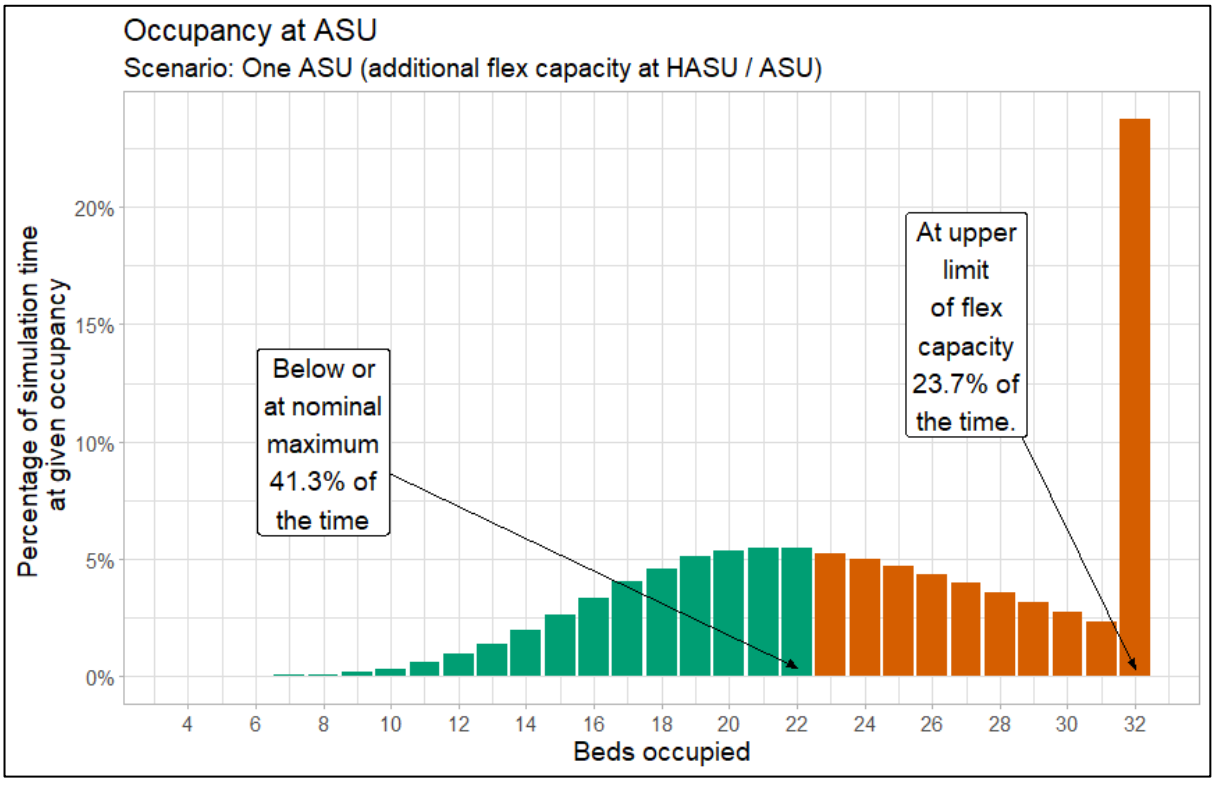
Figure A.1. Configuration of Stroke Pathway Option 1a (including SARU extension)

Simulating flow through the pathways using allocated bed constraints can often fail to provide appropriate consideration to the wider bed base, and how this can be 'flexed'. This would require the ability to readily use additional or alternative (clinically appropriate) beds at times of peak demand and bed occupancy.

Figure A.2 uses agreed 'upper flex capacity limits' to outline the degree of 'flex' that would be required at certain times were services planned upon the currently considered bed numbers.

In the event of additional flex capacity being available at both HASU and ASU, HASU would be at this upper limit of flex capacity 13% of the time. Likewise, ASU would be at its upper limit 24% of the time. Both units would be below or at their nominal capacities 58% and 41% of the time respectively. With additional flex capacity available at HASU and ASU, SARU Bristol, SARU North Somerset and SARU South Gloucestershire become full 15%, 22% and 30% of the time.





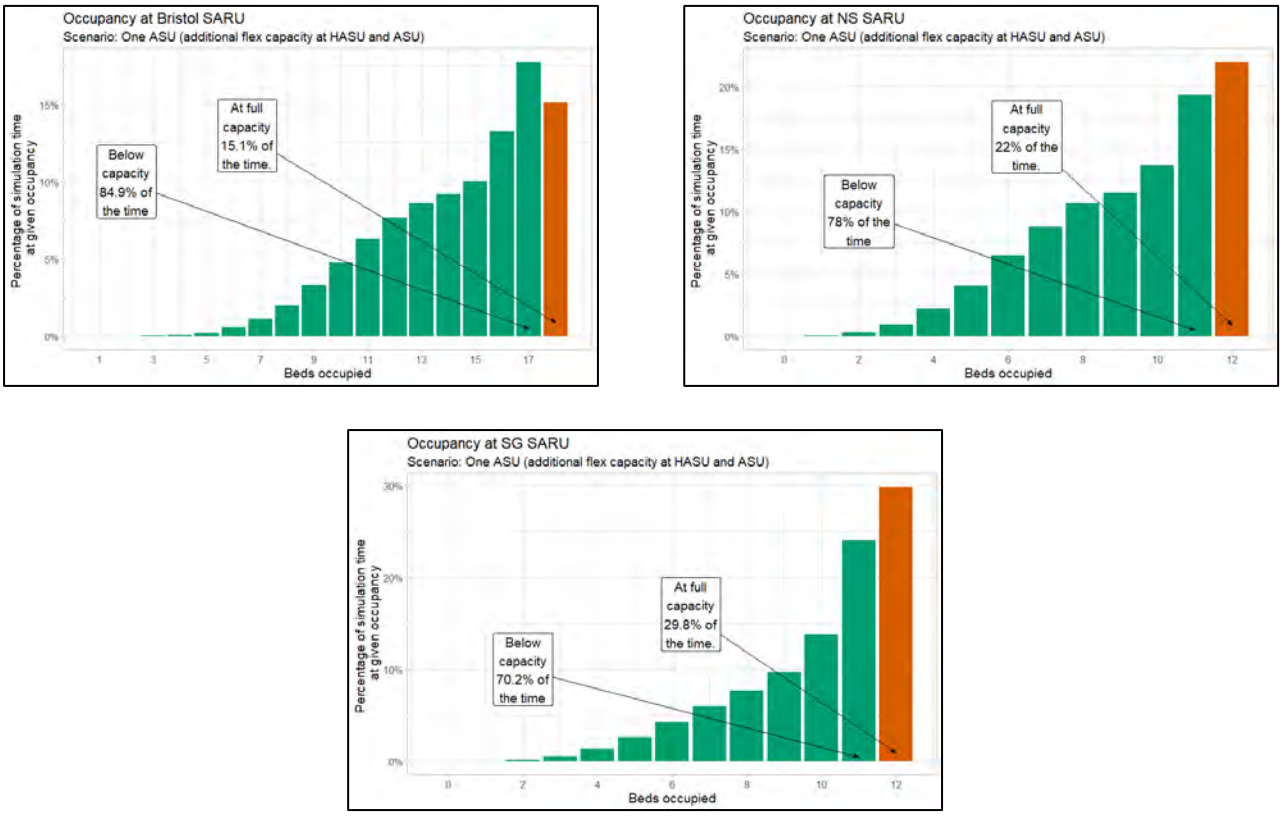


Figure A.2. Option 1a: Occupancy assuming additional pre-determined flex capacity

A.3.2 Option 2a

This option – detailed in Figure A.3 – is very similar to Option 1a, except that ASU capacity is now split between two sites, with an assumed prescribed delay to transfer to the ASU (UHBW ASU) which is not in the same hospital as the HASU. This, along with the consequences of splitting ASU capacity between two different units (which increases the chance of either one of them being full at any given time) leads to greater capacity pressures.

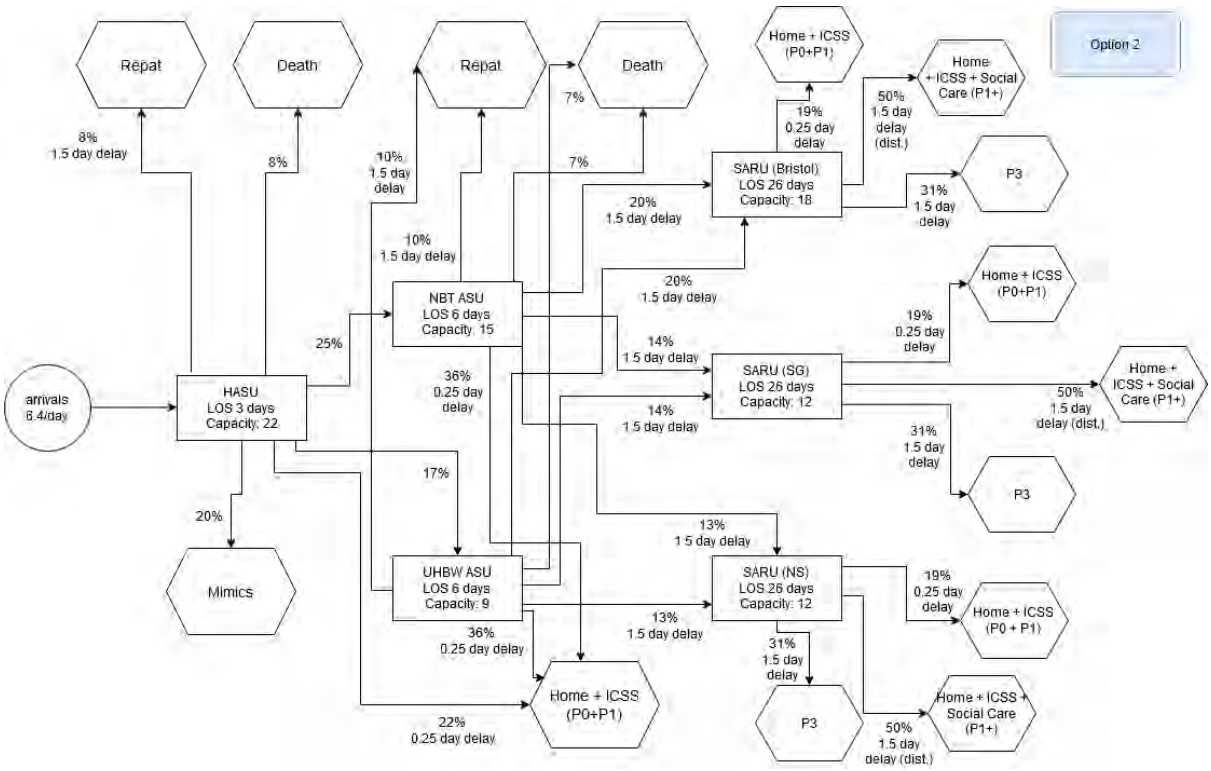
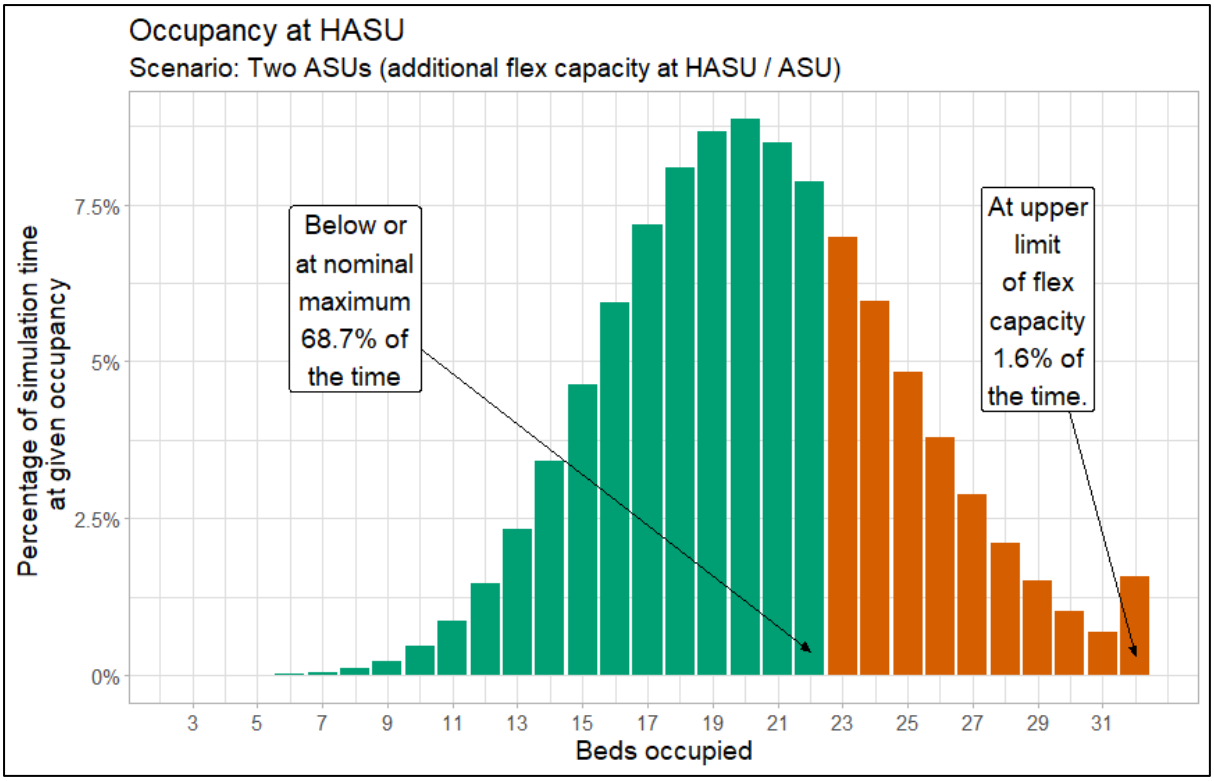
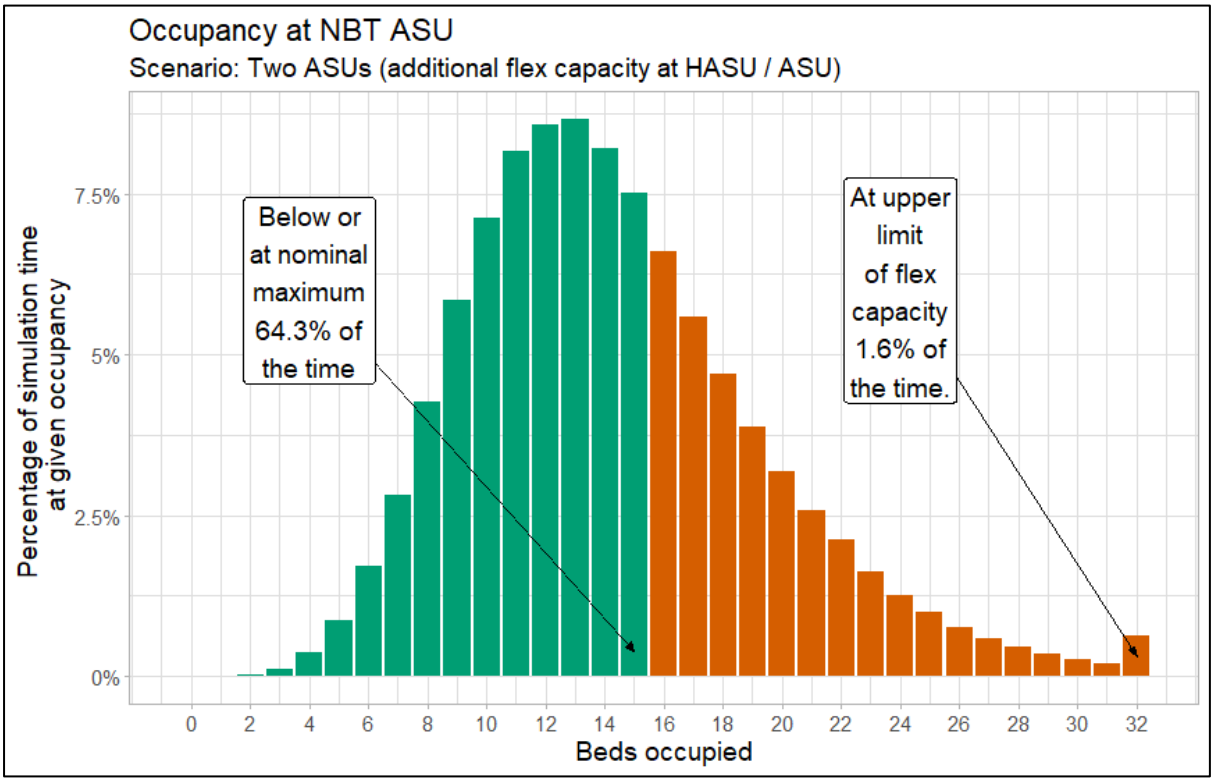


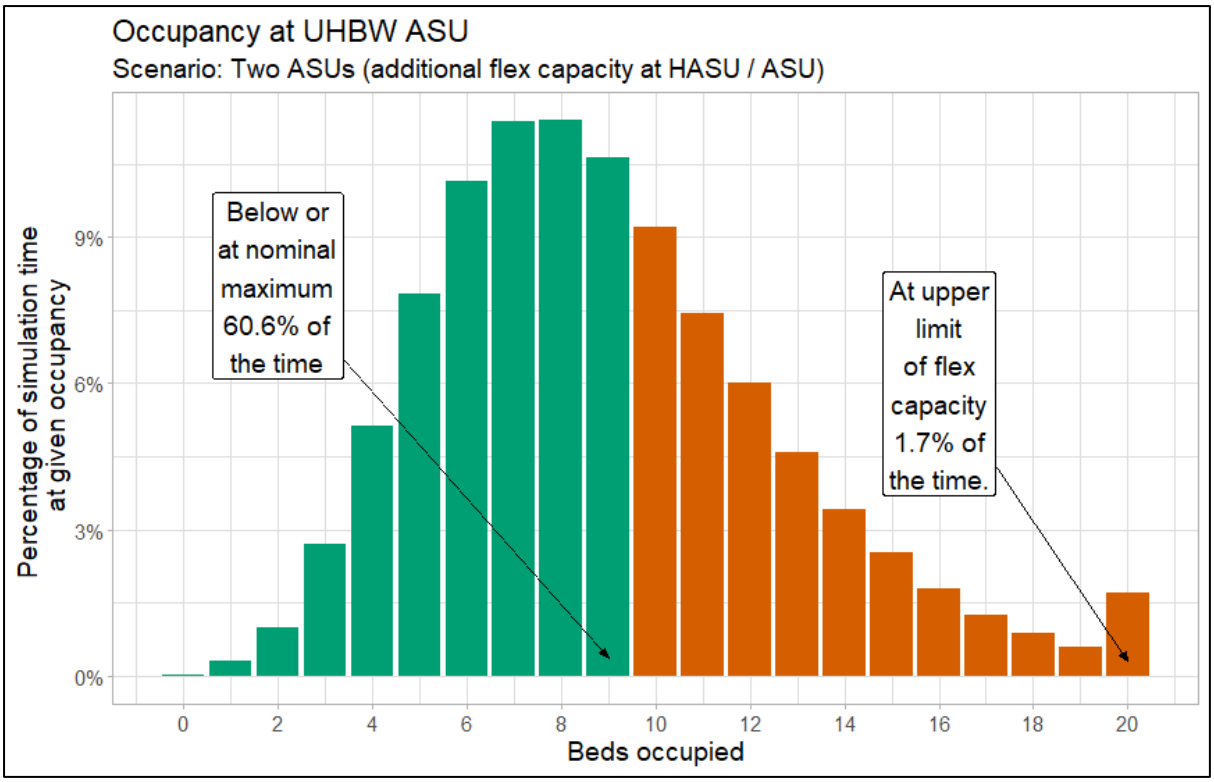
Figure A.3. Configuration of Stroke Pathway Option 2a (including SARU extension)

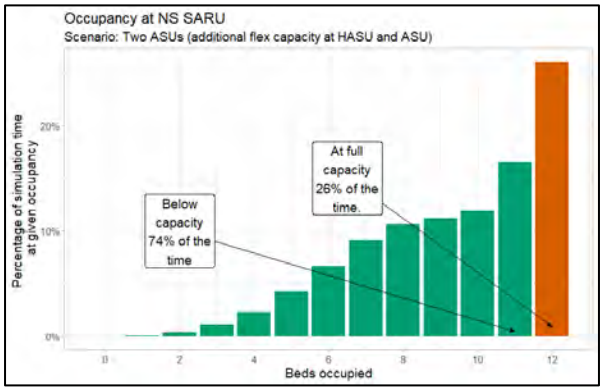
In the event of additional flex capacity being available at both HASU and ASU, HASU would be at this upper limit of flex capacity 1.6% of the time. NBT ASU and UHBW ASU reach their upper limits of flex capacity 1.6% and 1.7% of the time respectively under this option. HASU would be below or at its nominal capacity 69% of the time, while NBT ASU and UHBW ASU would be below or at their nominal capacities 64% and 61% of the time.

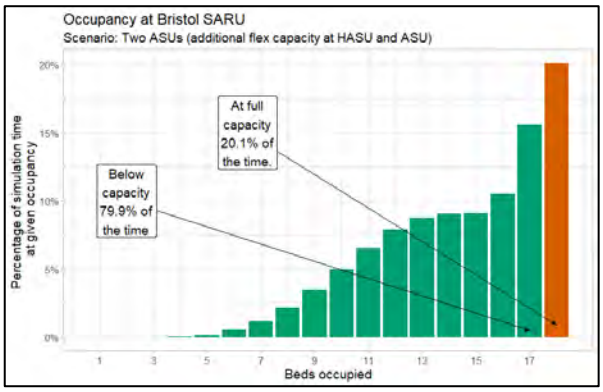
With additional flex capacity available at HASU and both ASU sites, SARU Bristol, SARU North Somerset and SARU South Gloucestershire become full 20%, 26% and 35% of the time.


Occupancy at HASU
Scenario: Two ASUs (additional flex capacity at HASU / ASU)
Percentage of simulation time at given occupancy
7.5%
5%
2.5%
0%
Below or at nominal maximum 68.7% of the time
At upper limit of flex capacity 1.6% of the time.
3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
Beds occupied


Occupancy at NBT ASU
Scenario: Two ASUs (additional flex capacity at HASU / ASU)
Percentage of simulation time at given occupancy
7.5%
5%
2.5%
0%
Below or at nominal maximum 64.3% of the time
At upper limit of flex capacity 1.6% of the time.
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32
Beds occupied







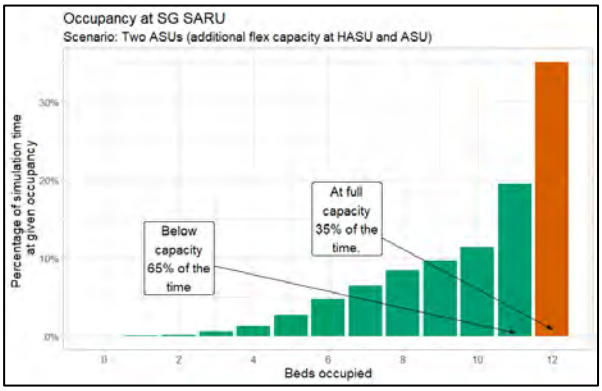


Figure 4. Option 2a: Occupancy assuming additional pre-determined flex capacity

A.4. Conclusion and next steps

Since the last iteration of modelling outputs, further work has taken place in order to establish 'upper limits of flex capacity' for each of the acute units, in order to fully understand the degree of 'flex' capacity that would be required for each option. For Option 1a, HASU ('upper limit of flex capacity' - 32 beds) and ASU (32) would reach these upper limits 13% and 24% of the time respectively. Meanwhile, HASU (32) would reach this upper limit 1.6% of the time under Option 2a, while NBT ASU (32) and UHBW ASU (20) would reach their upper limits 1.6% and 1.7% of the time respectively.

Further simulations could be performed to test the robustness of these revised estimates. It is expected that further revisions to bed capacities and flow rates will follow in due course.

Section Four: Options 1b and 2b with sub-acute "flex" (two sub-acute units)

Author: Simon Moss, Ben Murch, Rich Wood (BI Modelling and Analytics)
Date: 15 December 2020

1. Background

CCG Modelling and Analytics have supported the Stroke Programme Board since December 2016, mainly through the demand and capacity model we have developed specifically for this project. This model has been peer reviewed and published.

The motivation for developing this model is the inadequacy of commonly-used 'averages-based' approaches in appreciating realistic variability in arrivals, length of stay, and delays to transfers of care. Indeed, one recently published study – modelling a stroke service – finds that averages-based methods under-estimate required acute beds by at least 30-40%. Conversely, naïve interpretation of the appropriate 'stochastic' models can yield *over-estimation*, if used without consideration to the wider bed base, and how this can be 'flexed'.

The purpose of this paper is to outline the degree of 'flex' that would be required at certain times were services planned upon the currently considered bed numbers. Note that for this analysis, the same pathway specification is used as per that derivation.

2. Key findings

Having sufficient 'flex' capacity in the system means that additional or alternative (clinically appropriate) beds can be utilised at times of peak demand and bed occupancy. Under Option 1b, HASU would be at the 'upper flex capacity limit' of 32 beds 1.1% of the time. ASU would reach its limit of 32 beds 0.5% of the time. For Option 2b, HASU would reach its 'upper flex' limit 1.1% of the time, while NBT ASU (32 beds) and UHBW ASU (20 beds) would never reach their upper limits of 'flex capacity'.

In addition to the acute elements of the pathway, the latest iteration of modelling inputs account for the inclusion of two Sub-Acute Rehabilitation Units (SARUs). With additional flex capacity at HASU and ASU, SARU 1 would reach its upper limit of flex capacity 0.9% of the time under either option. SARU 2, meanwhile, would reach this limit 2% of the time for Option 1b and 1.8% of the time for Option 2b.

Appendix: Methodology and full results (allocated beds plus additional 'flex' capacity)

A.1. Summary

Two options for the reconfigured BNSSG Stroke Pathway have been proposed – both with a single Hyper Acute Stroke Unit (HASU), and with either one or two Acute Stroke Units (ASUs). Fixed bed capacities for these two options have been proposed using averages-based estimates of usage. Because arrivals and lengths of stay are subject to random variation, these estimates may not be robust.

Computer simulation has therefore been used to assess the extent to which the proposed bed numbers may underestimate the required capacity (in terms of proportions of time the units are full, and whether unacceptable volumes of patients have to queue).

Additional 'upper limits of flex capacity' have also been proposed by the team responsible for the BNSSG Stroke Reconfiguration Programme, in order to provide full consideration to the wider bed base available at times of peak demand and bed occupancy.

A.2. Method

Flow through the proposed Stroke Pathway configurations were simulated using a computerised mathematical model.[3]

A.3. Results

For each of the two options, patient flow was simulated under the assumption of an allocated bed capacity proposed by the team responsible for the BNSSG Stroke Reconfiguration Programme, in addition to a set number of 'flex capacity' beds which could be utilised if required.

The summary results in terms of occupancy, queue size, and proportion of time at full occupancy, are shown in Table A.1. More detailed results and a full specification of the options follow in Sections A.3.1 and A.3.2.

[3] Discrete event simulation using *PathSimR* https://github.com/nhs-bnssg-analytics/PathSimR

Option	Flex permitted	Unit	Beds	Time at or above proposed capacity (%)	Mean Occupancy	Mean Queue
1b	Yes	HASU	32	1.1	20.3	
1b	Yes	ASU	32	0.5	18.9	
1b	Yes	SARU 1	35	0.9	24.4	
1b	Yes	SARU 2	17	2.1	9.9	
2b	Yes	HASU	32	1.1	20.3	
2b	Yes	NBT ASU	32	0	11.2	
2b	Yes	UHBW ASU	20	0	7.6	
2b	Yes	SARU 1	35	0.9	24.5	
2b	Yes	SARU 2	17	1.8	9.9	

Table A.1. Summary results of simulated scenarios

A.3.1 Option 1

This option – detailed in Figure A.1 - includes a single HASU and a single ASU (assumed to be on the same site, at NBT). There are prescribed delays to some discharge destinations but not between HASU and ASU. Bed numbers are given as per business case estimates.

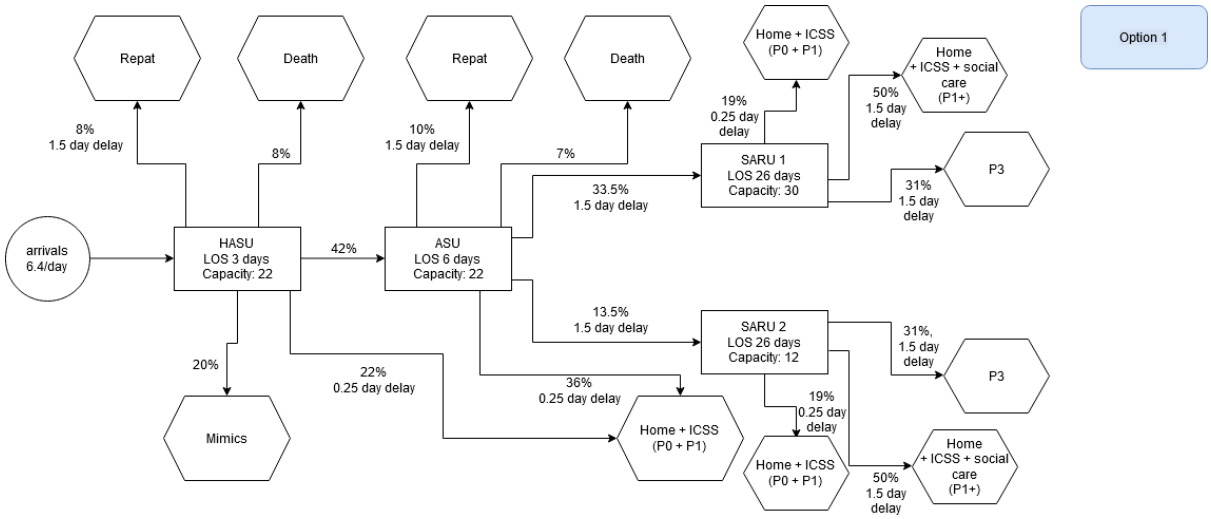
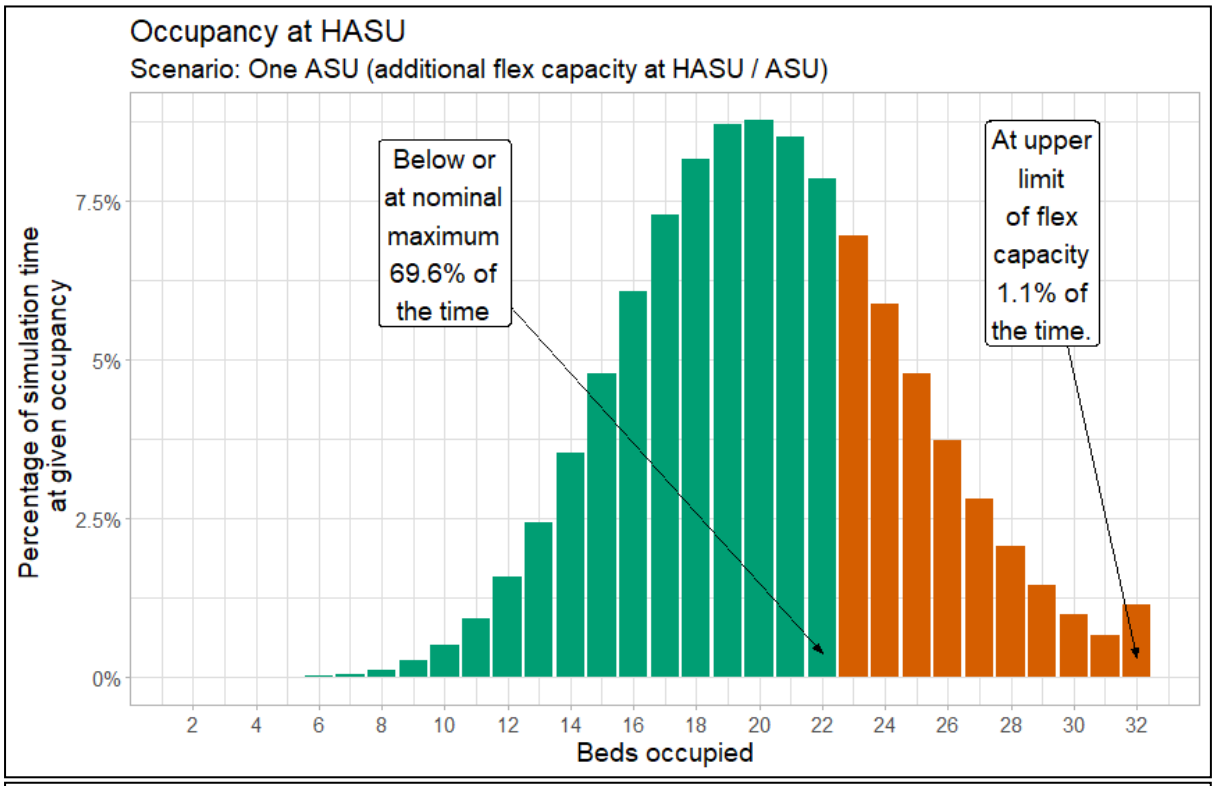


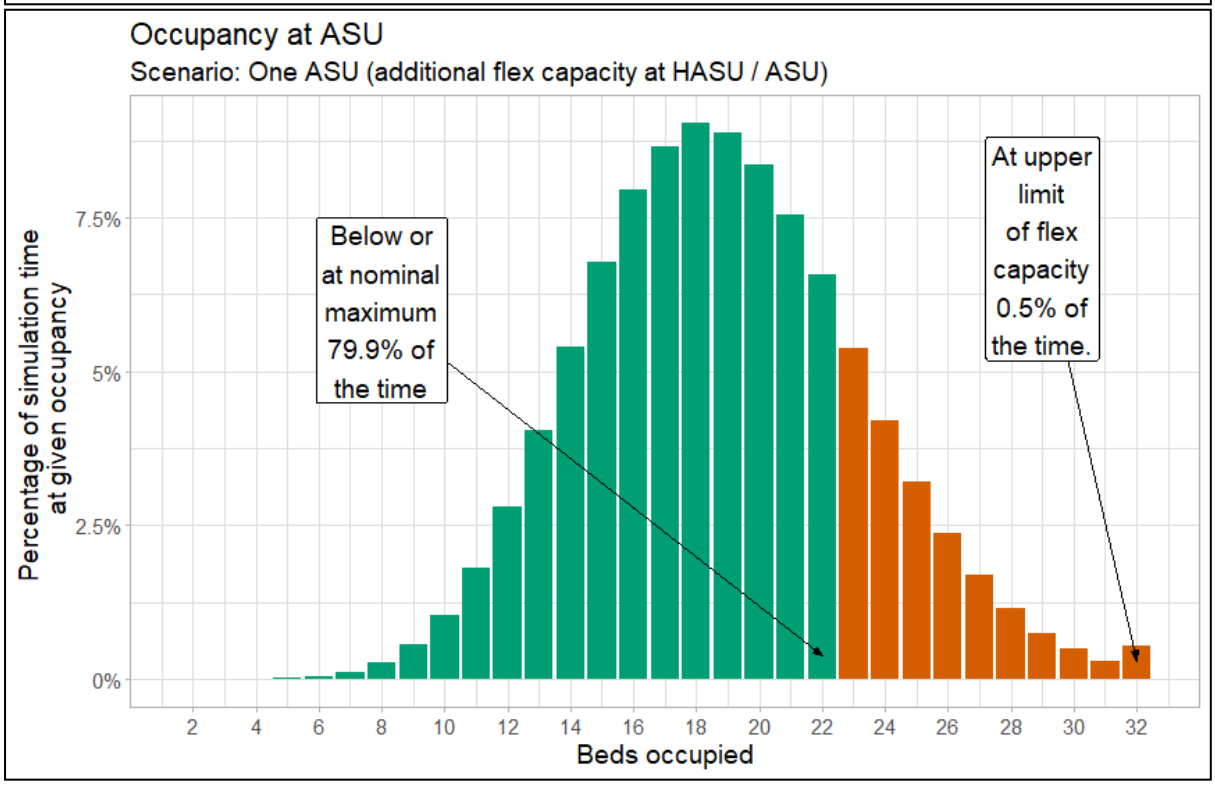
Figure A.1. Configuration of Stroke Pathway Option 1b (including SARU extension)

Simulating flow through the pathways using allocated bed constraints can often fail to provide appropriate consideration to the wider bed base, and how this can be 'flexed'. This would require the ability to readily use additional or alternative (clinically appropriate) beds at times of peak demand and bed occupancy.

Figure A.2 uses agreed 'upper flex capacity limits' to outline the degree of 'flex' that would be required at certain times were services planned upon the currently considered bed numbers.

In the event of additional flex capacity being available at both HASU and ASU, HASU would be at this upper limit of flex capacity 1.1% of the time. Likewise, ASU would be at its upper limit 0.5% of the time. Both units would be below or at their nominal capacities 70% and 80% of the time respectively. With additional flex capacity available at HASU, ASU and the two Sub-Acute Units, SARU 1 and SARU 2 reach their upper capacity limit 0.9% and 2% of the time respectively.





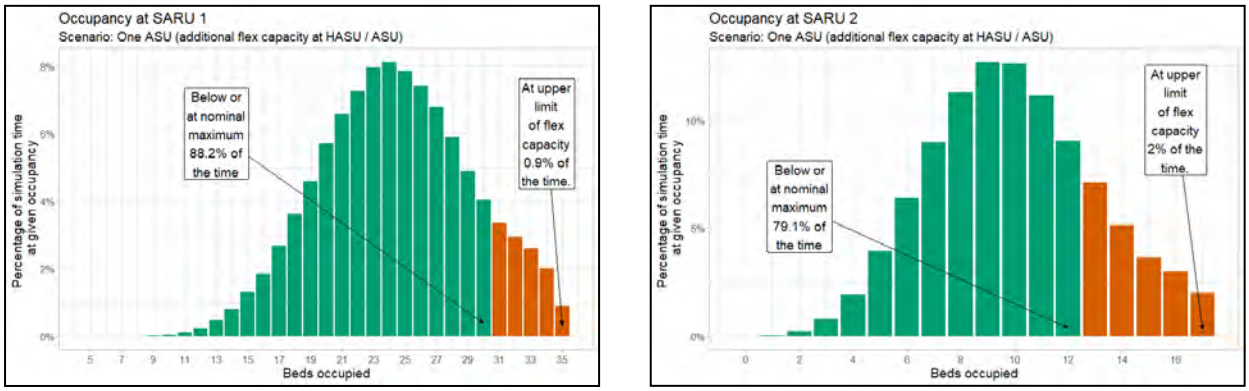


Figure A.2. Option 1b: Occupancy assuming additional pre-determined flex capacity

A.3.2 Option 2b

This option – detailed in Figure A.3 – is very similar to Option 1b, except that ASU capacity is now split between two sites, with an assumed prescribed delay to transfer to the ASU (UHBW ASU) which is not in the same hospital as the HASU. This, along with the consequences of splitting ASU capacity between two different units (which increases the chance of either one of them being full at any given time) leads to greater capacity pressures.

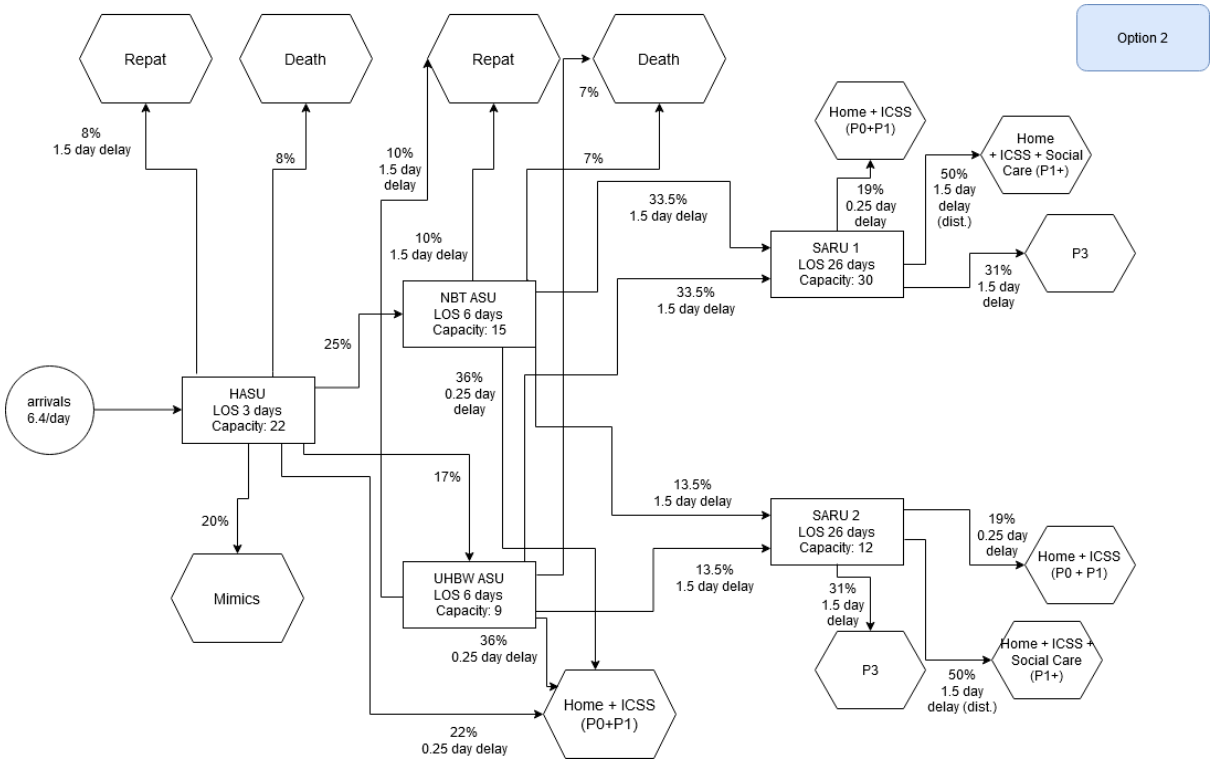
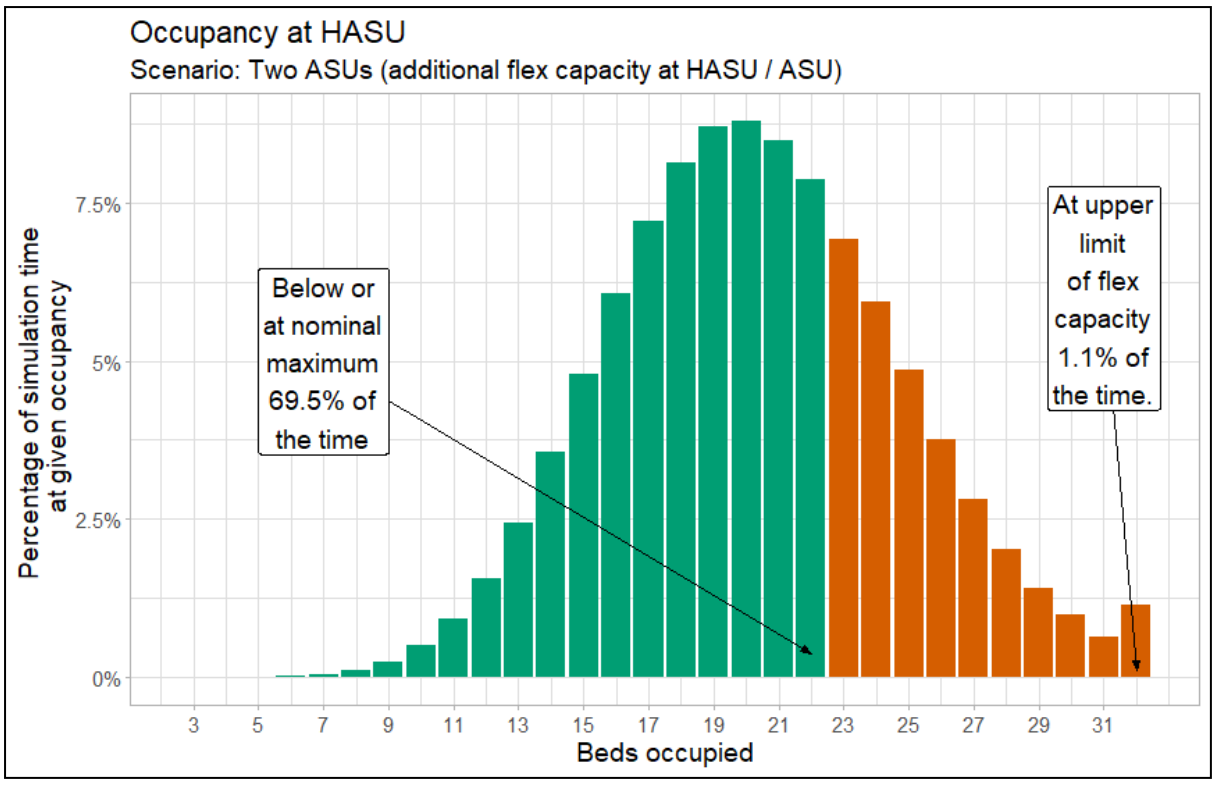
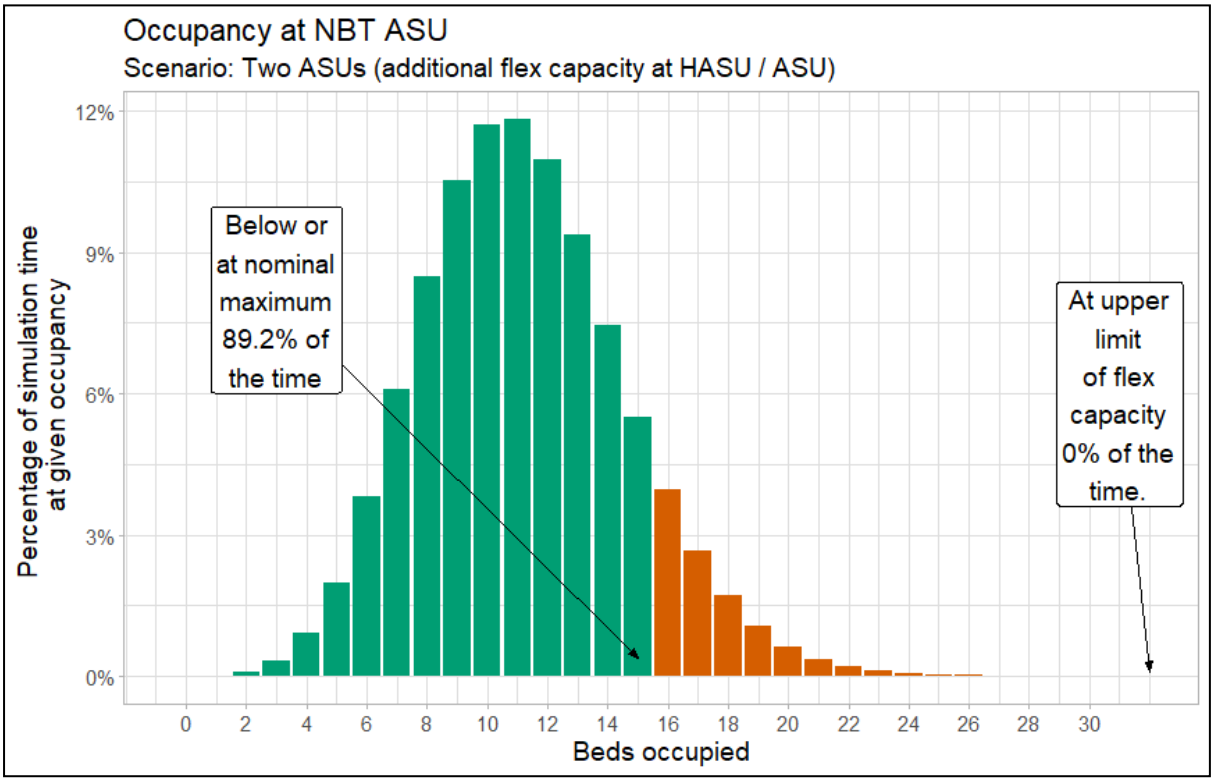


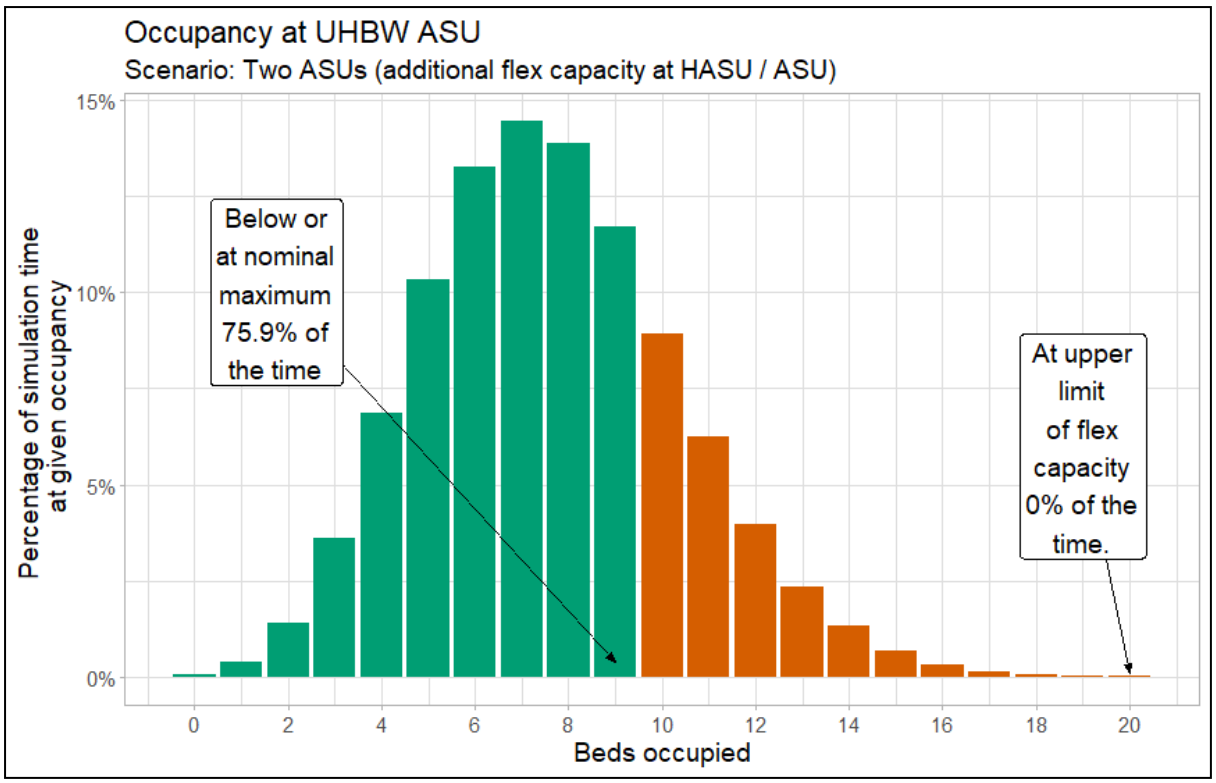
Figure A.3. Configuration of Stroke Pathway Option 2b (including SARU extension)

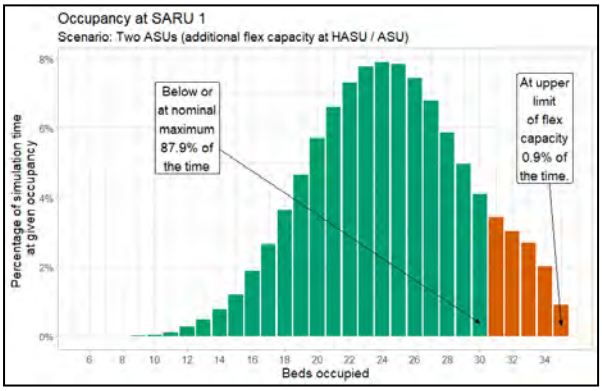
In the event of additional flex capacity being available at both HASU and ASU, HASU would be at this upper limit of flex capacity 1.1% of the time. NBT ASU and UHBW ASU would never reach their upper limits of flex capacity under this option. HASU would be below or at its nominal capacity 70% of the time, while NBT ASU and UHBW ASU would be below or at their nominal capacities 89% and 76% of the time.

With additional flex capacity available at HASU and both ASU sites, each of the SARU sites would reach their upper flex capacity limit 0.9% and 1.8% of the time respectively.


Occupancy at HASU
Scenario: Two ASUs (additional flex capacity at HASU / ASU)
Percentage of simulation time at given occupancy
7.5%
5%
2.5%
0%
Below or at nominal maximum 69.5% of the time
At upper limit of flex capacity 1.1% of the time.
3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
Beds occupied


Occupancy at NBT ASU
Scenario: Two ASUs (additional flex capacity at HASU / ASU)
Percentage of simulation time at given occupancy
12%
9%
6%
3%
0%
Below or at nominal maximum 89.2% of the time
At upper limit of flex capacity 0% of the time.
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
Beds occupied





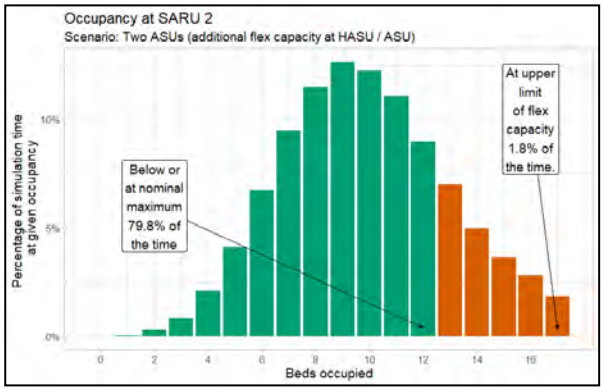


Figure 4. Option 2b: Occupancy assuming additional pre-determined flex capacity

A.4. Conclusion and next steps

Since the last iteration of modelling outputs, further work has taken place in order to establish 'upper limits of flex capacity' for each of the acute units, in order to fully understand the degree of 'flex' capacity that would be required for each option. For Option 1b, HASU ('upper limit of flex capacity' - 32 beds) and ASU (32) would reach these upper limits 1.1% and 0.5% of the time respectively. Meanwhile, HASU (32) would reach this upper limit 1.1% of the time under Option 2b, while NBT ASU (32) and UHBW ASU (20) would never reach their upper limits.

In relation to the two sub-acute rehabilitation units, SARU 1 would reach its upper flex capacity limit 0.9% of the time under Option 1b or Option 2b, while SARU 2 would reach this limit 2% of the time for Option 1b and 1.8% of the time for Option 2b.

Further simulations could be performed to test the robustness of these revised estimates. It is expected that further revisions to bed capacities and flow rates will follow in due course.