National Institute for Health and Care Excellence

Final

Chapter 39 Bed occupancy

Emergency and acute medical care in over 16s: service delivery and organisation

NICE guideline 94

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Chapter 39 Bed Occupancy

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39.1 Introduction

The actual hospital bed capacity of any health and social care system is likely to be influenced by multiple variables across that whole health and social care system. Bed occupancy as a measure has recently been increasing. The National Audit Office has suggested that hospitals with average bed occupancy levels above 85% can expect to have regular bed shortages, periodic bed crises and increased numbers of health care-acquired infections.[57] Occupancy rates for acute beds have increased from 87.7% in 2010/11 to 89.5% in 2014/15 so few hospitals are achieving the 85% figure.[57] High levels of bed occupancy may affect patient care as directing patients to the bed most suitable for their care is less likely to be possible.

We asked the question "What is the appropriate level of bed occupancy in hospital to facilitate optimal patient flow?"

39.2 Review question: What is the appropriate level of bed occupancy in hospital to facilitate optimal patient flow?

For full details see review protocol in Appendix A.

Table 1: PICO characteristics of review question

Population	Adults and young people (16 years and over) with a suspected or confirmed AME in hospitals which admit patients with acute medical emergencies.
Intervention and comparisons	Different levels of bed occupancy compared to one another. Bed occupancy. Capacity (beds per 1000 or subsets). Strata: • Whole hospital. • Specialised units (ED, AMU, and ICU). Note- 85% bed occupancy mainly reported in literature. The level of occupancy will depend on many factors such as demand or patient turnover.
Outcomes	Mortality (CRITICAL) Avoidable adverse events as reported by study (for example, incidents- pressure sores, complaints, falls, hospital acquired infection) (CRITICAL) Quality of life (CRITICAL) Length of stay (CRITICAL) A&E 4 hour waiting target (overcrowding in non-UK studies) (CRITICAL) Outliers/Boarders (CRITICAL) Readmission up to 30 days (IMPORTANT) Patient/carer satisfaction (CRITICAL) Staff satisfaction (IMPORTANT)
Study design	Observational studies, modelling papers for health economics evaluation.

39.3 Clinical evidence

Seven observational studies were included in the review;[3,6,8,38,42,54,64] these are summarised in Table 2 below. Evidence from these studies is summarised in the GRADE clinical evidence profile below (Table 3-Table 8). See also the study selection flow chart in Appendix B, study evidence tables in Appendix D, forest plots in Appendix C, GRADE tables in Appendix F and excluded studies list in Appendix G.

Table 2: Summary of studies included in the review

Study	Intervention and comparison	Population	Outcomes	Comments
Ahyow 2013[3] Retrospective cohort study Conducted in UK	Intervention 1 (reference) (n=69107): patient bed-days at <70% occupancy. Intervention 2 (n=60640): patient bed-days at 70-79.9% occupancy. Intervention 3 (n=139015): patient bed-days at 80-89.9% occupancy. Intervention 4 (n=224500): patient bed-days at 90-99.9% occupancy. Intervention 5 (n=240513): patient bed-days at 100% occupancy.	1963-bed (3 hospitals) offering acute services to about 750,000 people plus specialist services to wider population. Data collected over 24 month period from April 2006 to March 2008. Exclusion: in hospital <2 days (as assumed incubation period is 48 hours), aged <18 years, obstetric admissions, patients on wards with missing exposure data, patients admitted from private and NHS hospitals outside of the trust.	Adverse events - Hospital-acquired Clostridium difficile infection, defined as the first diarrheal stool sample testing positive for the presence of toxins A and/or B during an inpatient admission and occurring at least 2 days after admission to hospital. Adjusted for ward clustering, age, antibiotic policy period, and ward type.	During the study period there were more than 100,000 admissions annually to the 3 hospitals (93,190 analysed). Bed occupancy was defined as proportion of available (open and staffed) beds that were occupied at midnight (measured daily) on every bedded ward. These data were merged with patient data providing daily measurement of exposure to bed occupancy rates for every inpatient.
Blom 2015[6] Retrospective cohort study Conducted in Sweden	Intervention 1 (reference) (n=595): < 95% occupancy at time of discharge. Intervention 2 (n=204): 95-100% occupancy at time of discharge. Intervention 3 (n=113): 100-105% occupancy	All admissions entered into the database at a single 420-bed hospital. Inclusion: Admitted through the main ED at index. Exclusion: transferred to other hospitals during their index inpatient episode, discharged from the inpatient setting after study period.	Readmission through the ED at 30 days Adjusted for sex, age group, in-patient length of stay, time of discharge, and speciality unit responsible for admitting	Data on hospital occupancy per hour was retrieved from an occupancy database used by hospital management for quality assurance purposes.

Study	Intervention and comparison	Population	Outcomes	Comments
	at time of discharge. Intervention 4 (n=124) : >105% occupancy at time of discharge.		the patient at index.	
Boden 2016[8] Before and after study Conducted in UK	Pre-intervention 93.7% average medical bed occupancy (monthly mean). Versus Post-intervention 90.2% average medical bed occupancy (monthly mean).	Large District General Hospital seeing over 140,000 non-elective patients per year. Data collected from January 2012 to October 2014.	Mortality: Hospital standardised mortality ratio (number of in-hospital deaths to expected number of deaths multiplied by 100 for 56 specific clinical classification system groups). Summary hospital-level mortality indicator (number of patients who die following hospitalisation to the number expected to die on the basis of average England figures; all deaths in hospital or within 30 days of discharge). Monthly crude mortality (number of deaths for every 100 patients admitted).	Several interventions were introduced to facilitate a 90% medical bed occupancy target including daily consultant ward rounds on medical wards, CCG-commissioning of additional community beds and planned utilisation of traditional surgical bed base for medical patients.
Krall 2009[38]	Intervention 1 (n= 1953): Admitted	590-bed tertiary care referral centre with an	ED waiting time ('time	Authors arbitrarily divided the 2 occupancy data

Study	Intervention and comparison	Population	Outcomes	Comments
Retrospective cohort study Conducted in USA	at <92% medical/surgical occupancy. Intervention 2 (n= 3437): ≥92% medical/surgical occupancy.	annual ED census of 80,000. Data collected over 4 month period from December 2000 to March 2001. Exclusion: Beds not routinely used for ED admission, such as paediatric and obstetrical beds.	interval from patient posting for admission in the ED to the time the patient arrived to the appropriate hospital bed').	groups at 92% occupancy based on the mean occupancy rate of the medical/surgical beds during the time frame of data analysis. Medical/surgical occupancy was determined at 5am daily. Analysis on 106 days during which 38 days had <92%, 68 days had ≥92% occupancy and 15 days had incomplete time intervals.
Madsen 2014[42] Retrospective cohort study Conducted in Denmark	Intervention 1 (reference): patient time (1000s of days) at <80% occupancy rate. Intervention 2: patient time (1000s of days) at 80-89% occupancy. Intervention 3: patient time (1000s of days) at 90-99% occupancy. Intervention 4: patient time (1000s of days) at 100-109% occupancy. Intervention 5 patient time (1000s of days) at ≥110% occupancy.	2,651,021 admissions to 322 departments, where medicine was the primary specialty, between 1995 and 2012 were analysed. Admissions represented 1,123,959 patients. Exclusion: Aged <16 years and those who died within first 24 hours after admission.	In-hospital and 30-day mortality. Risk ratio adjusted for: sex, age, month at admission, time of admission, comorbidity (Elixhauser comorbidity index), and year of admission.	Analysis of administrative data. Departments excluded from analysis: paediatric, psychiatric and surgical. Bed occupancy rates were calculated by dividing the number of patients assigned to a department by the number of staffed beds in that department. The calculation was performed for all departments individually, every 15 minutes for the 18 year study period. This allowed calculation of bed occupancy rates before, during and after the admission of specific patients. Bed occupancy levels were calculated as a continuous variable for analysis. Outcomes calculated by patient time at risk. Reference time (1000s of days) was 3800 and 15,118 for in-hospital and 30-day mortality respectively.
Sprivulis 2006[54] Retrospect	Intervention 1 (reference) (n= 16579): Whole hospital occupancy <90%	First admissions entered in the Emergency Department Information Systems at 3 400 to 550-bed tertiary hospitals	Length of stay; 7-day mortality	Occupancy levels taken at a census at 23.59 daily

Study	Intervention and comparison	Population	Outcomes	Comments
ive cohort study Conducted in Australia	on day of admission. Intervention 2 (n= 40067): occupancy 90%-99%. Intervention 3 (n= 5849): occupancy ≥100%.	between July 2000 and April 2004 Inclusion: All records where the emergency admission record of the first ED attendance during the study period an any of the hospitals' EDs that resulted in the patient being formally admitted to the hospital	Mortality was adjusted for age, mode of transport, diagnosis, triage urgency, and referral source	
Yergens 2015[64] Retrospective cohort study Conducted in Canada	Intervention 1 (reference) (n=595): Sepsis patients admitted when ICU occupancy < 80%. Intervention 2 (n=204): Sepsis patients admitted when ICU occupancy 80-84%. Intervention 3 (n=113): Sepsis patients admitted when ICU occupancy 85-89%. Intervention 4 (n=124): Sepsis patients admitted when ICU occupancy 90% and over.	All septic patients who had been entered into the administrative databases at 3 general hospitals between January 2006 and September 2009. Inclusion: Sepsis ICD-10-CA code in main diagnosis, pre-admission comorbidity, or second pre-admission comorbidity.	All-cause mortality in-hospital. Adjusted for gender, age, triage level, Charlson index score*, time of first assessment by ED physician and time of admission to ICU. *The Charlson comorbidity index predicts the one-year mortality for a patient who may have a range of comorbid conditions, such as heart disease, AIDS, or cancer (a total of 22 conditions). Each condition is assigned a score of 1, 2, 3, or 6, depending on the risk of dying associated with each one.	Study was stratified by severity of sepsis as defined by additional hematologic, cardiovascular, hepatic, neurologic, renal or respiratory ICD-10-CA codes. Results from severe sepsis population were reported only as non-significant (no further details presented). Occupancy was automatically calculated using the patient movement ADT database* at time of first ED physician assessment. *ADT database included information on patient movement (flow) including time stamps for admission/discharge/transfer in to the hospital and all units throughout the hospital. The authors consider the use of ADT database as one of the limitations of the study; as the ADT database contains patient specific bed location, but does not contain information related to available beds such as staffing availability or ratios.

Table 3: Clinical evidence summary: Higher occupancy versus <70% occupancy

Outcomes	Patient bed-days (studies) Follow up	Quality of the evidence (GRADE)	Relative effect (95% CI)	Anticipated absolute effects	
				Risk with <70% occupancy	Risk difference with higher occupancy (95% CI)
Avoidable adverse events - 70-79.9% versus <70% Clostridium difficile infection	129746 (1 study) in-hospital	⨁⊖⊖⊖ VERY LOW[a,b] due to risk of bias, imprecision	HR 1.3 (0.95 to 1.78)	Control group risk not provided	Absolute effect cannot be calculated
Avoidable adverse events - 80-89.9% versus <70% Clostridium difficile infection	208121 (1 study) in-hospital	⨁⊖⊖⊖ VERY LOW[a,b] due to risk of bias, imprecision	HR 1.56 (1.18 to 2.06)	Control group risk not provided	Absolute effect cannot be calculated
Avoidable adverse events - 90-99.9% versus <70% Clostridium difficile infection	293606 (1 study) in-hospital	⨁⊖⊖⊖ VERY LOW[a,b] due to risk of bias, imprecision	HR 1.52 (1.16 to 1.99)	Control group risk not provided	Absolute effect cannot be calculated
Avoidable adverse events - 100% versus <70% Clostridium difficile infection	309626 (1 study) in-hospital	⨁⊖⊖⊖ VERY LOW[a,b] due to risk of bias, imprecision	HR 1.55 (1.19 to 2.02)	Control group risk not provided	Absolute effect cannot be calculated

(a) All non-randomised studies automatically downgraded due to selection bias. Studies may be further downgraded by 1 increment if other factors suggest additional high risk of bias, or 2 increments if other factors suggest additional very high risk of bias.

(b) Downgraded by 1 increment if the majority of the evidence was at high risk of bias, and downgraded by 2 increments if the majority of the evidence was at very high risk of bias.

Table 4: Clinical evidence summary: Higher occupancy versus <80% occupancy

Outcomes	No of Participants, (studies) Follow up	Quality of the evidence (GRADE)	Relative effect (95% CI)	Anticipated absolute effects	
				Risk with <80% occupancy	Risk difference with higher occupancy (95% CI)

Outcomes	No of Participants, (studies) Follow up	Quality of the evidence (GRADE)	Relative effect (95% CI)	Anticipated absolute effects	
				Risk with <80% occupancy	Risk difference with higher occupancy (95% CI)
Mortality - 80-84% versus <80%	799 (1 study) in-hospital	⨁⊖⊖⊖ VERY LOW[a,b] due to risk of bias, imprecision	OR 1.26 (0.81 to 1.96)	Control group risk not provided	Absolute effect cannot be calculated
Mortality - 85-89% versus <80%	708 (1 study) in-hospital	⨁⊖⊖⊖ VERY LOW[a,b] due to risk of bias, imprecision	OR 1 (0.57 to 1.75)	Control group risk not provided	Absolute effect cannot be calculated
Mortality - 90% and over versus <80%	719 (1 study) in-hospital	⨁⊖⊖⊖ VERY LOW[a,b] due to risk of bias, imprecision	OR 1.72 (1.03 to 2.87)	Control group risk not provided	Absolute effect cannot be calculated
Mortality - 80-89% versus <80%	7120 (1 study) in-hospital	⨁⊖⊖⊖ VERY LOW[a] due to risk of bias	HR 1.01 (0.99 to 1.03)	Control group risk not provided	Absolute effect cannot be calculated
Mortality - 90-99% versus <80%	8307 (1 study) in-hospital	⨁⊖⊖⊖ VERY LOW[a] due to risk of bias	HR 1.02 (1.01 to 1.03)	Control group risk not provided	Absolute effect cannot be calculated
Mortality - 100-109% versus <80%	8343 (1 study) in-hospital	⨁⊖⊖⊖ VERY LOW[a] due to risk of bias	HR 1.03 (1.02 to 1.04)	Control group risk not provided	Absolute effect cannot be calculated
Mortality - >110% versus <80%	6418 (1 study) in-hospital	⨁⊖⊖⊖ VERY LOW[a] due to risk of bias	HR 1.09 (1.07 to 1.11)	Control group risk not provided	Absolute effect cannot be calculated
Mortality - 80-89% versus <80%	26958 (1 study) 30 days	⨁⊖⊖⊖ VERY LOW[a] due to risk of bias	RR 1.01 (0.99 to 1.03)	Control group risk not provided	Absolute effect cannot be calculated

Outcomes	No of Participants, (studies) Follow up	Quality of the evidence (GRADE)	Relative effect (95% CI)	Anticipated absolute effects	
				Risk with <80% occupancy	Risk difference with higher occupancy (95% CI)
Mortality - 90-99% versus <80%	30744 (1 study) 30 days	⨁⊖⊖⊖ VERY LOW[a] due to risk of bias	RR 1.02 (1.01 to 1.03)	Control group risk not provided	Absolute effect cannot be calculated
Mortality - 100-109% versus <80%	31487 (1 study) 30 days	⨁⊖⊖⊖ VERY LOW[a] due to risk of bias	RR 1.03 (1.02 to 1.04)	Control group risk not provided	Absolute effect cannot be calculated
Mortality - >110% versus <80%	25167 (1 study) 30 days	⨁⊖⊖⊖ VERY LOW[a] due to risk of bias	RR 1.09 (1.07 to 1.11)	Control group risk not provided	Absolute effect cannot be calculated

(a) All non-randomised studies automatically downgraded due to selection bias. Studies may be further downgraded by 1 increment if other factors suggest additional high risk of bias, or 2 increments if other factors suggest additional very high risk of bias.

(b) Downgraded by 1 increment if the confidence interval crossed 1 MID or by 2 increments if the confidence interval crossed both MIDs.

Table 5: Clinical evidence summary: Higher occupancy versus <90% occupancy

Outcomes	No of Participants (studies) Follow up	Quality of the evidence (GRADE)	Relative effect (95% CI)	Anticipated absolute effects	
				Risk with <90% occupancy	Risk difference with higher occupancy (95% CI)
Length of stay - 90-99% versus <90%	56646 (1 study) in-hospital	⨁⊖⊖⊖ VERY LOW[a] due to risk of bias		The mean length of stay at <90% occupancy was 6.84 days	The mean length of stay at 100% and greater occupancy was 0.15 higher (0.04 lower to 0.34 higher)
Length of stay - 100% and greater versus <90%	22428 (1 study) in-hospital	⨁⊖⊖⊖ VERY LOW[a] due to risk of bias		The mean length of stay at <90% occupancy was 6.84 days	The mean length of stay at 100% and greater occupancy was 0.25 higher (0.06 lower to 0.56 higher)

Outcomes	No of Participants (studies) Follow up	Quality of the evidence (GRADE)	Relative effect (95% CI)	Anticipated absolute effects	
				Risk with <90% occupancy	Risk difference with higher occupancy (95% CI)
Mortality - 90-99% versus <90%	56646 (1 study) 7 days	⨁⊖⊖⊖ VERY LOW[a,b] due to risk of bias, imprecision	HR 1.2 (1.1 to 1.31)	Moderate 0 per 1000	Absolute effect cannot not be calculated
Mortality - 100% and greater versus <90%	22428 (1 study) 7 days	⨁⊖⊖⊖ VERY LOW[a,b] due to risk of bias, imprecision	HR 1.3 (1.1 to 1.54)	Moderate 0 per 1000	Absolute effect cannot not be calculated

(a) All non-randomised studies automatically downgraded due to selection bias. Studies may be further downgraded by 1 increment if other factors suggest additional high risk of bias, or 2 increments if other factors suggest additional very high risk of bias.

(b) Downgraded by 1 increment if the confidence interval crossed 1 MID or by 2 increments if the confidence interval crossed both MIDs.

Table 6: Clinical evidence summary: ≥92% occupancy versus <92% occupancy

Outcomes	No of Participants (studies) Follow up	Quality of the evidence (GRADE)	Relative effect (95% CI)	Anticipated absolute effects	
				Risk with <92% occupancy	Risk difference with ≥92% occupancy (95% CI)
ED wait time until arrival in hospital bed	5390 (1 study) in-hospital	⨁⊖⊖⊖ VERY LOW[a] due to risk of bias		The mean ED wait at <92% occupancy was 2.5 hours	The mean ED wait at ≥92% occupancy was 1.6 hours higher (1.12 to 2.08 higher)

(a) All non-randomised studies automatically downgraded due to selection bias. Studies may be further downgraded by 1 increment if other factors suggest additional high risk of bias, or 2 increments if other factors suggest additional very high risk of bias.

Table 7: Clinical evidence summary: 93.7% occupancy versus 90.2% occupancy

Outcomes	No of Participants (studies) Follow up	Quality of the evidence (GRADE)	Relative effect (95% CI)	Anticipated absolute effects	
				Risk with 93.7% occupancy	Risk difference with 90.2% occupancy (95% CI)
Mortality Crude mortality (mean monthly)	23698 (1 study) In-hospital	⊕⊖⊖⊖ VERY LOW[a,b] due to indirectness	RR 0.95 (0.78 to 1.16)	Moderate 17 per 1000	1 fewer per 1000 (from 4 fewer to 3 more)

(a) Downgraded by 1 or 2 increments because the majority of evidence was based on indirect interventions.

(b) All non-randomised studies automatically downgraded due to selection bias. Studies may be further downgraded by 1 increment if other factors suggest additional high risk of bias, or 2 increments if other factors suggest additional very high risk of bias.

Table 8: Clinical evidence summary: Higher occupancy versus <95% occupancy

Outcomes	No of Participants (studies) Follow up	Quality of the evidence (GRADE)	Relative effect (95% CI)	Anticipated absolute effects	
				Risk with <95% occupancy	Risk difference with higher occupancy (95% CI)
Readmission - 95-100% versus < 95%	22591 (1 study) 30 days	⊕⊖⊖⊖ VERY LOW[a] due to risk of bias	OR 1.11 (1.01 to 1.22)	Control group risk not provided	Absolute effect cannot not be calculated
Readmission - 100-105% versus < 95%	20843 (1 study) 30 days	⊕⊖⊖⊖ VERY LOW[a,b] due to risk of bias, imprecision	OR 1.17 (1.06 to 1.29)	Control group risk not provided	Absolute effect cannot not be calculated
Readmission - >105% versus < 95%	15171 (1 study) 30 days	⊕⊖⊖⊖ VERY LOW[a,b] due to risk of bias, imprecision	OR 1.15 (0.99 to 1.34)	Control group risk not provided	Absolute effect cannot not be calculated

(a) All non-randomised studies automatically downgraded due to selection bias. Studies may be further downgraded by 1 increment if other factors suggest additional high risk of bias, or 2 increments if other factors suggest additional very high risk of bias.

(b) Downgraded by 1 increment if the confidence interval crossed 1 MID or by 2 increments if the confidence interval crossed both MIDs.

Narrative findings (Boden 2016[8])

In the 18 month period before the implementation of a range of interventions to reduce bed occupancy, mean monthly medical bed occupancy was 93.7%. During this time, mean monthly hospital standardised mortality ratio (ratio of the observed number of in hospital deaths at the end of a continuous inpatient spell to the expected number of in hospital deaths (multiplied by 100) for 56 specific clinical classification system groups) was 109. Mean monthly summary hospital level mortality indicator (ratio between the actual number of patients who die following hospitalisation and the number expected to die on the basis of England figures, covering patients who die while in hospital or within 30 days of discharge) was 110.

In the 16 month period following the implementation of the interventions, mean monthly medical bed occupancy was 90.2%. During this time, mean monthly hospital standardised mortality ratio was 104 (a 4.6% reduction) and mean monthly summary hospital level mortality indicator was 105 (a 4.5% reduction).

39.4 Economic evidence & simulation models

Published literature

One system model was identified and has been included in this review.[5] This is summarised in the evidence profile below (Table 9) and described in Appendix E.

No relevant economic evaluations were identified.

The economic article selection protocol and flow chart for the whole guideline can found in the guideline's Appendix 41A and Appendix 41B.

Table 9: Economic evidence profile: levels of bed occupancy (percent)

Study	Study design	Other comments	Incremental cost	Incremental effects	Cost effectiveness
Bagust 1999[5]	• Discrete event simulation model. • Hospital system reflecting the relation between demand and available bed capacity. • Eleven experiments were conducted with varying factors included in the model. • 1000 day period. • UK NHS perspective.	**Intervention** Random fluctuations in demand and bed capacity, changing the level of bed occupancy (percent). Crisis day not clearly defined. Modelling methods not reported in detail. Outcomes reported in narrative and graphical form only. No incremental analysis undertaken.	n/a	The proportion of days when at least 1 patient requiring immediate admission cannot be accommodated was close to 0% probability at less than 85% occupancy; 1% probability at 90% occupancy with exponential increase up to 19% probability at 100%.	n/a

39.5 Evidence statements

Clinical

Six retrospective cohort studies and 1 before and after study comprising 3,024,678 admissions evaluated the impact of different hospital bed occupancy rates on patients' outcomes in adults and young people at risk of an AME, or with a suspected or confirmed AME. The evidence suggested that, in general, any increase in occupancy leads to an increased risk of adverse patient outcomes including mortality (in-patient, 7-day and 30 day), avoidable adverse events reported as hospital acquired infections (Clostridium difficile infection), length of stay, 30 day readmission and delays in admission for patient waiting in ED. However, the evidence was graded very low for all outcomes due to study design, risk of bias, indirectness and imprecision. It was also noted that only 1 study took into account seasonality (month of admission) in their multivariate analysis.

Economic evidence & simulation models

One simulation model of a 200 bed hospital found that the proportion of days when at least 1 patient requiring immediate admission cannot be accommodated was close to 0% probability at less than 85% occupancy; 1% probability at 90% occupancy with exponential increase up to 19% probability at 100%.

39.6 Recommendations and link to evidence

Recommendations	**22. Healthcare providers should:** • **Monitor total acute hospital bed occupancy, capacity, flow and outcomes in real time, taking account of changes in a 24-hour period and the occupancy levels and needs of specific wards and units.** • **Plan capacity to minimise the risks associated with occupancy rates exceeding 90%.**
Research recommendations	-
Relative values of different outcomes	The guideline committee chose mortality, patient and/or carer satisfaction, avoidable adverse events as reported by the studies, quality of life, length of stay, A&E 4 hour waiting target (overcrowding in non-UK studies) and outliers/boarders (patients managed by a consultant team with the main allocated inpatient area for that consultant or patient specialty) as critical outcomes. Readmission and staff satisfaction were considered important outcomes.
Trade-off between clinical benefits and harms	Seven observational studies assessed hospital bed occupancy, including six retrospective cohort studies and one before and after study. Bed occupancy was measured in different ways and at different times; these included a fixed census time each day (midnight, 5am), a period average, hourly measurement, and real time measurement. Evidence was identified for mortality (in-hospital, 7 day, and 30 day), avoidable adverse events (Clostridium difficile infection), length of stay, 30- day readmission, and waiting time in ED for a hospital bed. No evidence was found for quality of life, outliers/boarders, patient and/or carer satisfaction, and staff satisfaction. Overall, the evidence suggested that, in general, any increase in occupancy leads to an increased risk of adverse patient outcomes including mortality (in-hospital, 7-day and 30 day), avoidable adverse events reported as hospital-acquired infections (Clostridium difficile infection), length of stay, 30 day readmission and delays in admission for patients waiting in ED. The committee noted that the observational studies did not fully account for confounding factors such as seasonality, independent of occupancy. The committee concluded that high levels of occupancy were likely to result in harm, particularly for patients on an emergency admission pathway rather than elective care pathways. In setting an optimal occupancy rate, hospitals would need some flexibility in choosing a safe upper limit which needed to take into account case mix, variations in the proportions of elective and emergency admissions, and the ability of community services to respond to timely hospital discharge. The committee were aware of additional studies that examined the impact of delay in transferring patients from the ED (as a surrogate measure of high hospital bed occupancy) which found that mortality and length of stay were adversely affected, after controlling for case mix including severity and seasonal effects. This reinforced the view that high occupancy and the associated delay in transfer from ED resulted in harm to patients as well as increased costs for the healthcare system. Such studies do not permit an estimate of optimal bed occupancy but instead suggest potential mechanisms by which harm occurs. These are probably multifactorial and include delays in timely processes of care, breaches in infection control or unmeasured aspects of case mix. The demand for a more rapid turnover may limit time for cleaning bed areas, which will add to the risk of hospital-acquired infections.

Recommendations	**22. Healthcare providers should:** • **Monitor total acute hospital bed occupancy, capacity, flow and outcomes in real time, taking account of changes in a 24-hour period and the occupancy levels and needs of specific wards and units.** • **Plan capacity to minimise the risks associated with occupancy rates exceeding 90%.**
Research recommendations	-
	One system modelling paper was included.[5] The study identified that above 85% occupancy the probability of not being able to accommodate a patient increased considerably. A validation[31] of the study showed that the 85% cut off was likely to be correct for a 200 bed hospital as used in the original analysis. However, the optimal level of bed occupancy is dependent on multiple variables including case-mix and ward type. Organisations would therefore need to evaluate their own occupancy levels using dynamic modelling tools. There is a difference between capacity (the number of beds in a ward or hospital) and occupancy (the proportion of those beds which are filled). The committee noted that the convention of regarding an 85% occupancy rate as a safe upper limit was based on the theoretical model proposed by Bagust [5] (1999); this model is unlikely to reflect current practice in the NHS (that is, before the introduction of the A&E 4 hour waiting target, the establishment of Acute Medical Units (AMUs), the development of clinical decision units, and ambulatory care) and may not be applicable to all circumstances. For example, optimum occupancy levels may vary with the size and type of the hospital (small versus large hospitals or tertiary versus general hospitals), case mix, the degree of predictability of bed availability from different wards and seasonal effects (winter period with more infections). It is also likely that different units within the hospital (AMU, Surgical Acute Units or Elderly Care Acute Units) could operate at different occupancy thresholds for optimal efficiency. These levels might also vary throughout the day e.g. an AMU overnight may accommodate more patients for the morning review and this could be possible due to the reduced ED demand at this time. Given clear evidence of harm when occupancy rates exceed 100%, the committee were of the view that health systems needed to take action at a lower level. Ninety percent was chosen as a pragmatic maximum but also because this level did result in increased adverse outcomes in the studies reported. The committee wished to emphasise that some flexibility around this figure might be required, with higher levels permissible for efficiently–managed elective care pathways, and lower levels if there was evidence of harm associated with high occupancy. Health systems should therefore have the flexibility to determine local criteria for safe maximal occupancy rates provided they were monitoring case mix, care processes and outcomes (particularly patient reported outcome measures) on a daily and indeed hourly basis in some hospital areas. Responsibility for achieving safe occupancy rates resides with the whole health economy, not just the hospital. Greater communication between the ambulance trust, primary and secondary care would be of help for example, staggering some referrals from primary care who may have a need to be seen that day but not necessarily urgently. NHS England has produced important guidance on mitigating actions which may be taken by providers, commissioners, and primary, community and social care in response to high volumes of demand in the service: the Operational Pressures Escalation Levels (OPEL) framework describes the 4 level escalation categories

Recommendations	**22. Healthcare providers should:** • **Monitor total acute hospital bed occupancy, capacity, flow and outcomes in real time, taking account of changes in a 24-hour period and the occupancy levels and needs of specific wards and units.** • **Plan capacity to minimise the risks associated with occupancy rates exceeding 90%.**
Research recommendations	-
	and the actions that accompany each level.[44] Preliminary analysis by the Nuffield Trust shows a system under considerable pressure during the winter of 2016/17.[18] It has been reported that it is possible to anticipate hospital bed pressures using models that incorporate temporal patterns of bed utilisation.[62] The monitoring of bed occupancy would need to be real-time and therefore hospital trusts would need to develop systems that enable this. Predictive systems would need to be used in conjunction with escalation protocols such as OPEL to mitigate the detrimental impact on performance of high bed occupancy.
Trade-off between net effects and costs	No economic studies were identified for inclusion in this review. Logically, as a hospital's bed occupancy increases, it should be operating more efficiently, as fixed costs will be averaged across more patients, and therefore the cost per patient will be lower. However, at very high levels of occupancy, the demand for resources is high which could lead to more resource use such as extra out-of-hours payments or agency staff fees. The clinical evidence shows that, as bed occupancy increases, the probability of poor health outcomes increases considerably. For these reasons, it is likely that there will be a point at which increasing bed occupancy also has a detrimental impact on efficiency and the cost per patient and cost per QALY gained will increase. However, it is not clear from the evidence available what this point should be for different specialties. Monitoring and planning bed usage might incur costs in terms of admin staff and specialist software. There might also be increased clinical staff costs or at least changes to rotas to deal with high workload. However, these costs would be offset by avoiding infections, medical errors and other adverse events, and reducing the number of medical outliers and hence length of stay. Costs will also be offset by avoiding readmissions, and reducing ambulance costs from having to queue outside the hospital. The committee's conclusion was that monitoring bed occupancy closely and increasing bed capacity at critical times, would be cost-effective and in some circumstances cost saving.
Quality of evidence	Six retrospective cohort studies, one before and after study and one modelling paper were identified that looked at the effect of different levels of capacity on the outcomes specified above. Although the 6 cohort studies had large sample sizes, the evidence provided for all outcomes was of very low quality due to limitations in the study design, risk of bias or imprecision. There was a difference in design between the studies. Five of the studies compared different levels of occupancy to a reference and adjusted for several confounders for all reported outcomes except for length of stay. The authors of the other cohort study divided the 2 occupancy data groups at 92% occupancy, based on the mean occupancy rate of the hospital during the time frame of data analysis, and performed univariate analysis. However, as this was the only study which reported the critical outcome of ED waiting times (critical outcome) this study was included in the review. The before and after study compared a pre-intervention average medical bed occupancy (93.7%) compared to a post-

Recommendations	**22. Healthcare providers should:** • **Monitor total acute hospital bed occupancy, capacity, flow and outcomes in real time, taking account of changes in a 24-hour period and the occupancy levels and needs of specific wards and units.** • **Plan capacity to minimise the risks associated with occupancy rates exceeding 90%.**
Research recommendations	-
	intervention average medical bed occupancy (90.2%). One modelling paper was found. The study was graded for quality as partially applicable with potentially serious limitations within the health economic criteria. The committee agreed that seasonality was a serious confounder to these studies as there is a higher mortality in hospitals in winter months. Often hospitals counteract this by reducing levels of elective surgery or opening additional wards in November. Only 1 study controlled for month of admission which would take into account these issues to some extent but would not fully explore the impact of acuity of illness at initial presentation.
Other considerations	Many hospitals are currently facing difficulties because, what was once seasonal high demand during winter months is now a consistent challenge all year. This relatively consistent and predictable background rate is complicated by sudden surges in demand, for example, for abrupt changes in weather. 'Flexing' bed capacity may be achievable for short periods but is difficult to maintain over weeks or months. The recommendation for a maximum occupancy rate of 90% should therefore be applied with a degree of flexibility according to local case mix, infrastructure, and care pathways between the community and the hospital. The recommendation for all hospitals to conduct their own analysis of maximal occupancy will require sufficient analytical capacity within trusts and reliable data on occupancy. Rather than using traditional measures (occupancy at 1 time point, typically overnight), models should be constructed to reflect the dynamic change in bed occupancy through a 24 hour cycle of admission and discharge, which may help to identify when and where patient pathways become blocked. Also, the model should take into consideration specific pinch-points in the patient pathway such as the AMU, CCU, ICU and speciality wards. Reliable data on outcomes such as mortality, length of stay and hospital acquired infection will be needed to determine a safe bed occupancy level. A systematic review[35] suggested an association between occupancy rates and spread of hospital acquired infections in various settings; however this review was not included as studies in the review either used alternative measures of overcrowding and understaffing instead of bed occupancy rates or had no comparison groups. Hospitals will need to engage with clinical commissioning groups, community service provider trusts, out of hours primary care providers, as well as social care providers and the voluntary sector, to determine how best to plan additional capacity or treatment pathways during periods where hospital occupancy approaches or exceeds a safe level. Healthcare systems should establish real-time intelligence to detect when high levels of emergency demand in the health economy cause hospital overcrowding, and take action to minimise the adverse impact that this has on patients and their families. These actions will include optimising efficient patient flow, discharge processes and community services to permit rapid turnover, minimise length of stay and ensure patient support in the community.

Appendices

Appendix A: Review protocol

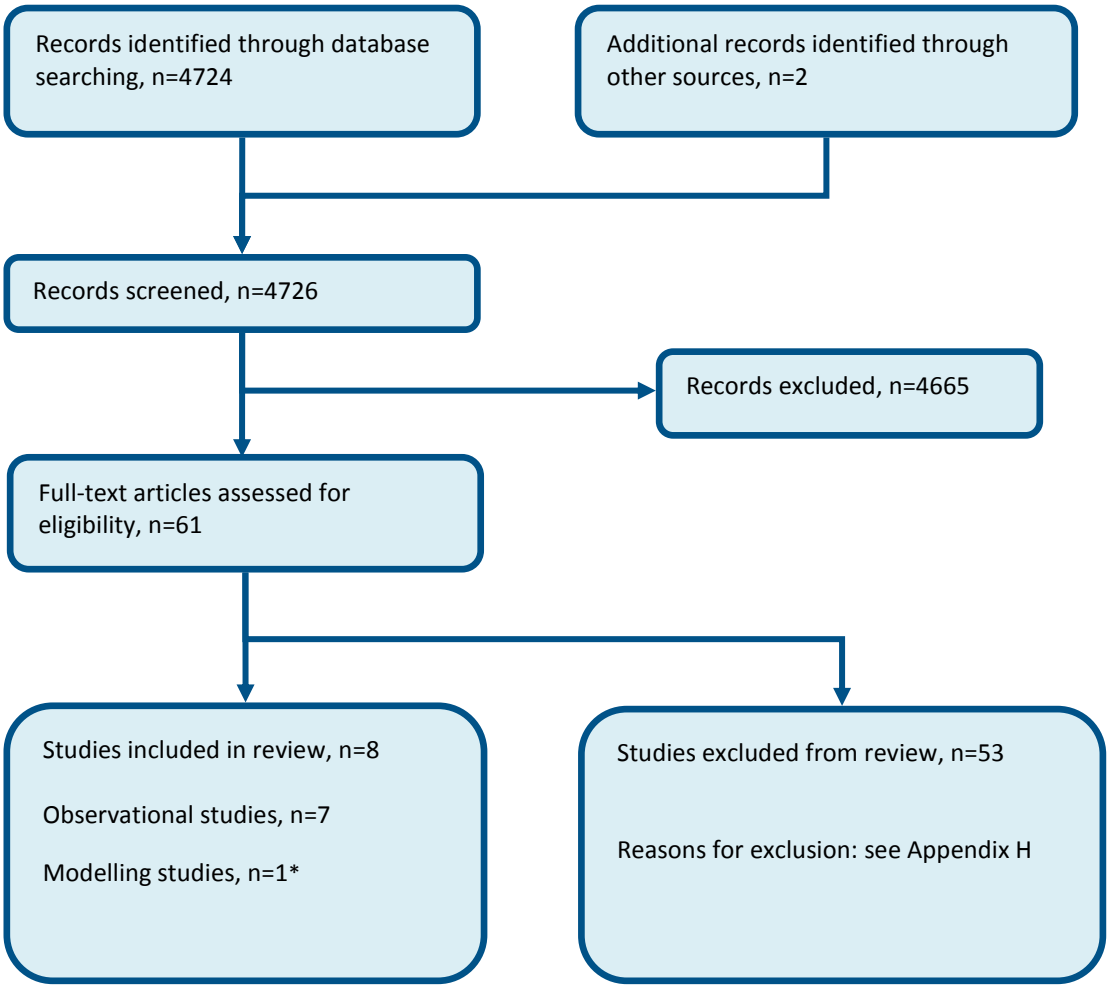
Table 10: Review protocol: Bed occupancy

Review question	What is the appropriate level of bed occupancy in hospital to facilitate optimal patient flow?
Guideline condition and its definition	Acute medical emergencies. Definition: People with suspected or confirmed acute medical emergencies or at risk of an acute medical emergency.
Review population	Adults and young people (16 years and over) with a suspected or confirmed AME in hospitals which admit patients with acute medical emergencies.
	Above 16.
	Line of therapy not an inclusion criterion.
Interventions and comparators: generic/class; specific/drug (All interventions will be compared with each other, unless otherwise stated)	Different levels of capacity (bed occupancy); any bed capacity. Another level of capacity (bed occupancy); any other level of capacity.
Outcomes	- Mortality during the study period (Dichotomous) CRITICAL - Patient satisfaction during the study period (Dichotomous) CRITICAL - Length of stay during the study period (Continuous) CRITICAL - Avoidable adverse events during the study period (Dichotomous) CRITICAL - Quality of life during the study period (Continuous) CRITICAL - Readmission up to 30 days during the study period (Dichotomous) - A&E 4 hour waiting target met during the study period (Dichotomous) CRITICAL - Outliers/Boarders during the study period (Dichotomous) - Staff satisfaction during the study period (Dichotomous)
Study design	RCT Quasi-RCT Retrospective cohort study Prospective cohort study Before and after study Non randomised study Systematic Review
Unit of randomisation	Patient Hospital Ward
Crossover study	Not permitted
Minimum duration of study	Not defined
Other exclusions	Hospitals with exclusively elective case mix (for example, cancer hospitals, or private hospitals in the UK).
Stratification	Whole Hospital Specialised units (ED, AMU, ICU)
Reasons for stratification	Recommendations may be different between units and hospitals as a whole

Review question	What is the appropriate level of bed occupancy in hospital to facilitate optimal patient flow?
Subgroup analyses if there is heterogeneity	- Frail (Frail; Non frail); Effects may be different in this subgroup.
Search criteria	Databases: Medline, Embase, the Cochrane Library, HMIC Date limits for search: none Language: English

Appendix B: Clinical article selection

Figure 1: Flow chart of clinical article selection for the review of optimal level of hospital bed occupancy

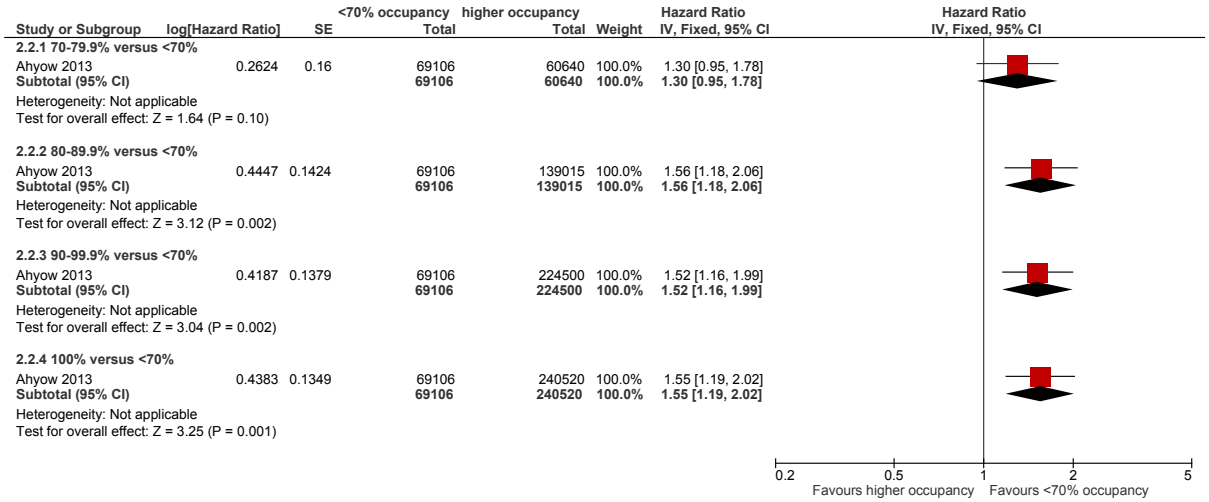


* reviewed in economic evidence section 1.4

Appendix C: Forest plots

C.1 Higher occupancy versus <70% occupancy

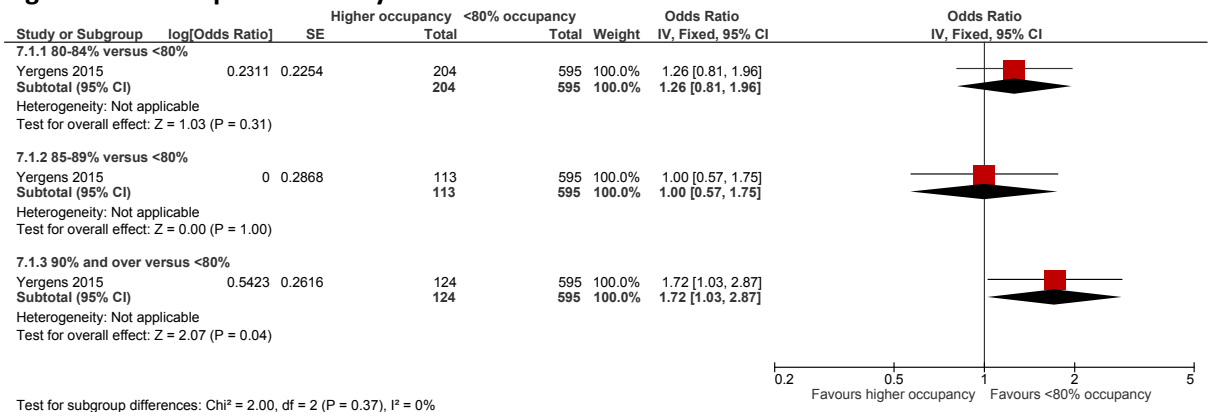
Figure 2: Avoidable adverse events



Adjusted for ward clustering, age, antibiotic policy period, and ward type.

C.2 Higher occupancy versus <80% occupancy

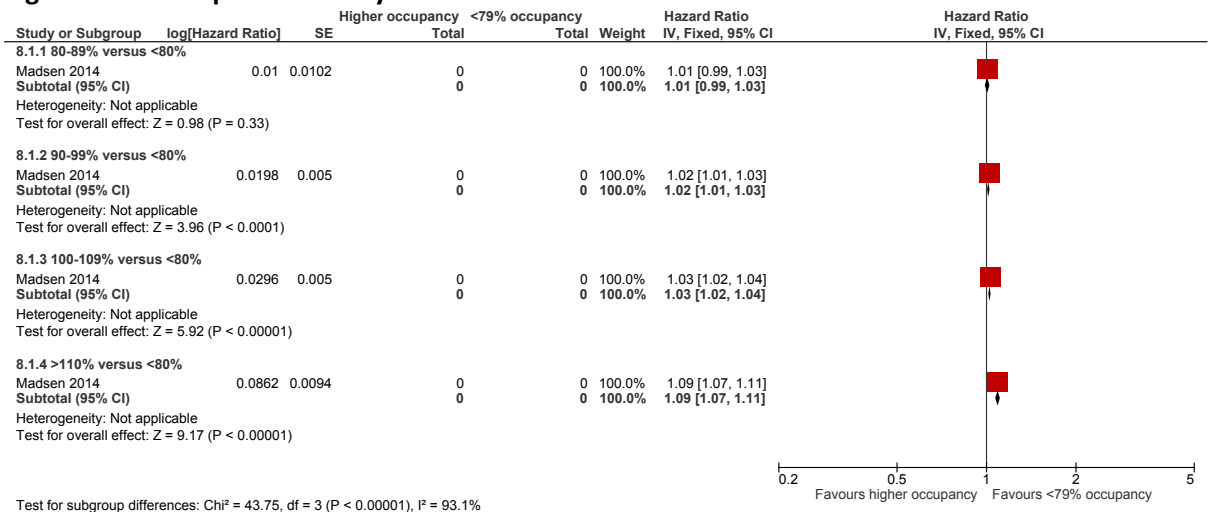
Figure 3: In-hospital mortality



Test for subgroup differences: Chi² = 2.00, df = 2 (P = 0.37), I² = 0%

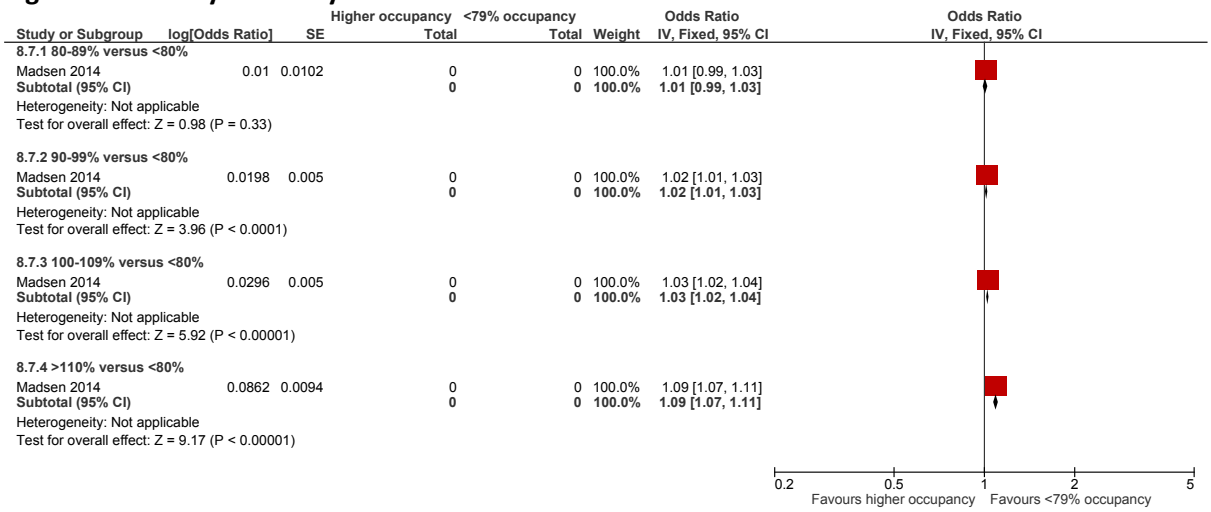
Adjusted for gender, age, triage level, Charlson index score, ED physician first assessment time, and admission to ICU.

Figure 4: in-hospital mortality



Adjusted for: sex, age, month at admission, time of admission, Elixhauser comorbidity index, and year of admission.

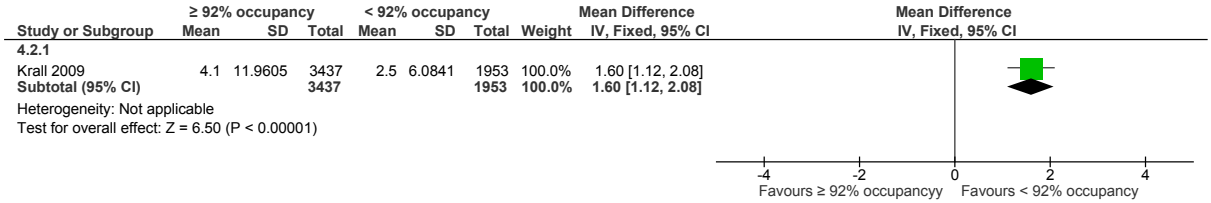
Figure 5: 30-day mortality



Adjusted for: sex, age, month at admission, time of admission, Elixhauser comorbidity index, and year of admission.

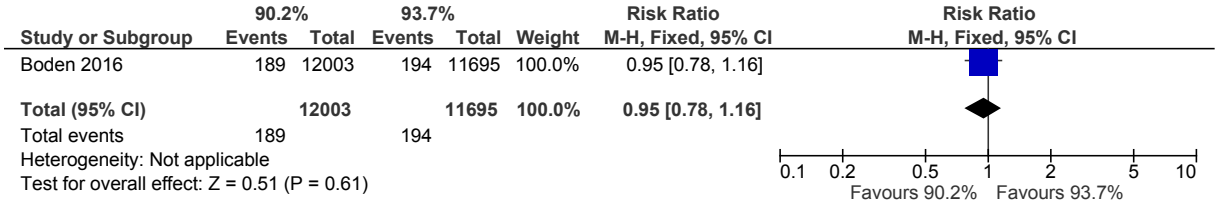
C.3 ≥92% occupancy versus <92% occupancy

Figure 6: ED waiting time



C.4 93.7% occupancy versus 90.2% occupancy

Figure 7: Mortality (in-hospital)



C.5 Higher occupancy versus <90% occupancy

Figure 8: Length of stay

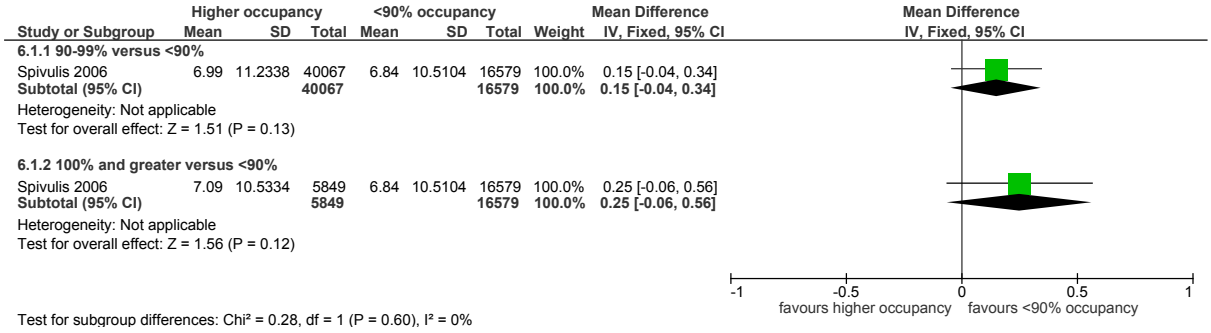
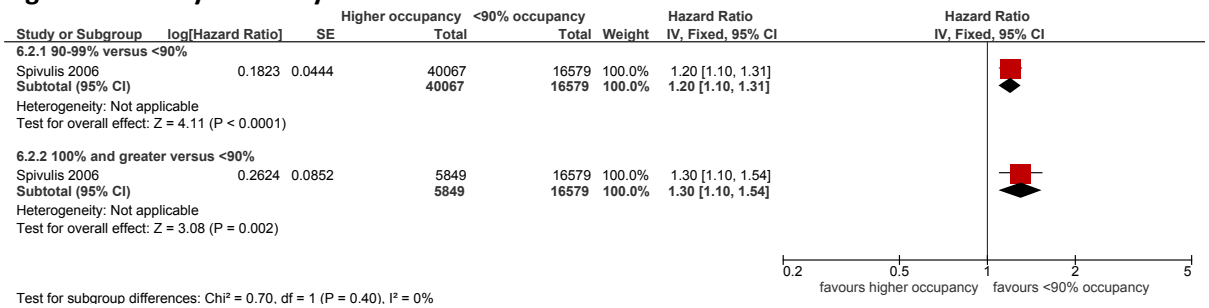


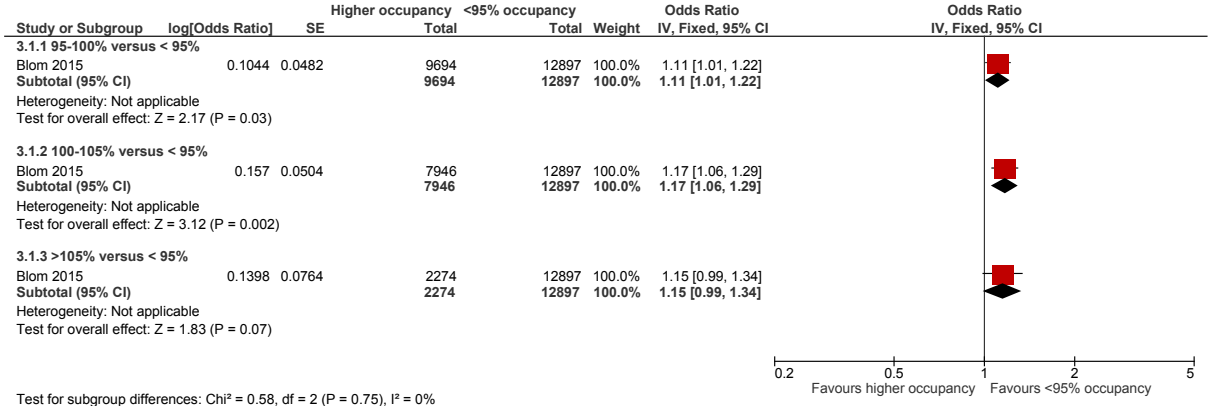
Figure 9: 7-day mortality



Adjusted for age, mode of transport, diagnosis, triage urgency, and referral source.

C.6 Higher occupancy versus <95% occupancy

Figure 10: Readmission



Adjusted for age group and speciality unit responsible for admitting the patient at index.

Appendix D: Clinical evidence tables

Study	Bed occupancy and hospital-acquired Clostridium difficile infection trial: Ahyow 2013[3]
Study type	Retrospective cohort study.
Number of studies (number of participants)	1 (n=93,190)
Countries and setting	Conducted in United Kingdom; Setting: 1963-bed (3 hospitals) University Hospitals of Leicester NHS Trust, UK, offering acute clinical services to about 750,000 people plus specialist services to wider population. Data were collected over 24 month period from April 2006 to March 2008.
Line of therapy	1st line.
Duration of study	Other: 24 months.
Method of assessment of guideline condition	Adequate method of assessment/diagnosis.
Stratum	Whole Hospital.
Subgroup analysis within study	Not applicable.
Inclusion criteria	During the study period there were more than 100,000 admissions annually to the 3 hospitals of which 93,190 were analysed.
Exclusion criteria	Excluded patient from analysis: in hospital <2 days (as assumed incubation period is 48 hours), aged <18 years, obstetric admissions, patients on wards with missing exposure data. For patients admitted from private and NHS hospitals outside of the trust, no previous data were available, so they were therefore excluded. Wards and clinical areas that are empty at midnight do not record bed occupancy rates and were therefore excluded, for example, discharge lounge, day care units, surgical recovery wards, and radiology departments. In total 18 of the 150 wards/clinical areas were excluded.
Recruitment/selection of patients	During the study period there were more than 100,000 admissions annually to the 3 hospitals (93,190 analysed). Study was performed on anonymised, routine data with record linkage to pathology IT systems. Data were extracted from the patient administration system, which prospectively records the date and source of an admission, ward transfers and referrals during the inpatient admission, as well as limited information on diagnoses and procedures.
Age, gender and ethnicity	Age - Median (IQR): 74 years (60-83 years). Gender (M:F): 1/1. Ethnicity: White 86.7%, Black 1.52%, Asian 10.3%, mixed 0.35%, other 0.59%, unknown 0.53%.
Further population details	n/a
Extra comments	Bed occupancy was defined as the proportion of available (open and staffed) beds that were occupied at midnight on every bedded ward, and this was measured daily.

Study	Bed occupancy and hospital-acquired Clostridium difficile infection trial: Ahyow 2013[3]
Indirectness of population	No indirectness.
Interventions	(n=93,190) Intervention 1: Different levels of capacity (bed occupancy) -. Different bed occupancy levels 70-79.9%, 80-89.9%, 90-99.9% and 100% compared to the reference occupancy of 0-69.9%. Duration: 24 months. Concurrent medication/care: n/a. Comments: Hazard ratio analysis (adjusted). (n=93,190) Intervention 2: Another level of capacity (bed occupancy) - Any other level of capacity. Different bed occupancy levels 70-79.9%, 80-89.9%, 90-99.9% and 100% compared to the reference occupancy of 0-69.9%. Duration: 24 months. Concurrent medication/care: n/a. Comments: Hazard ratio analysis (adjusted).
Funding	Academic or government funding
RESULTS (NUMBERS ANALYSED) AND RISK OF BIAS FOR COMPARISON: BED CAPACITY 0-69% versus BED CAPACITY 70-79.9%, 80-89.9%, 90-99.9%, 100% Protocol outcome 1: Avoidable adverse events - Actual outcome for Whole Hospital: Hospital acquired Clostridium difficile infection in-hospital; Risk of bias: All domain - Low, Selection - Low, Blinding - Low, Incomplete outcome data - Low, Outcome reporting - Low, Measurement - Low, Crossover - Low; Indirectness of outcome: No indirectness ; Baseline details: HR adjusted for confounders; Key confounders: HR adjusted for ward clustering, ward type, age, antibiotic policy period Reference 0-69.9% versus 70-79.9% bed occupancy: HR 1.30 (95%CI 0.95 to 1.76). Reference 0-69.9% versus 80-89.9% bed occupancy: HR 1.56 (95%CI 1.18 to 2.04). Reference 0-69.9% versus 90-99.9% bed occupancy: HR 1.52 (95%CI 1.16 to 1.98). Reference 0-69.9% versus 100% bed occupancy: HR 1.55 (95%CI 1.19 to 2.01).	
Protocol outcomes not reported by the study	Mortality; Patient and/or carer satisfaction; Length of stay; Quality of life; Readmission; A&E 4 hour waiting target met; Outliers/Boarders; Staff satisfaction.

Study	Bed occupancy and length of stay trial: Krall 2009[38]
Study type	Retrospective cohort study.
Number of studies (number of participants)	1 (n=23,384)
Countries and setting	Conducted in United Kingdom; Setting: 590-bed tertiary care referral centre with an annual emergency department

Study	Bed occupancy and length of stay trial: Krall 2009[38]
	census of 80,000 in Texas, US. Beds not routinely used for ED admission, such as paediatric and obstetrical beds, were removed, leaving a total of 480 medical/surgical beds for analysis.
Line of therapy	1st line.
Duration of study	Other: 4 months.
Method of assessment of guideline condition	Adequate method of assessment/diagnosis.
Stratum	Whole Hospital.
Subgroup analysis within study	Not applicable.
Inclusion criteria	All patients presenting to the emergency department.
Exclusion criteria	Beds not routinely used for ED admission, such as paediatric and obstetrical beds, were removed.
Recruitment/selection of patients	Data collected over 4 month period from December 2000 to March 2001. Data for this study were drawn from several manual databases used in tracking all patients presenting to the emergency department on a daily basis.
Age, gender and ethnicity	Age: n/a. Gender (M:F): n/a. Ethnicity: n/a
Further population details	n/a.
Extra comments	Medical/surgical bed occupancy was determined at 5am daily.
Indirectness of population	No indirectness.
Interventions	(n= 1953) Intervention 1: Different levels of capacity (bed occupancy) - Any bed capacity. <92% occupancy. Duration: 4 months. Concurrent medication/care: n/a. Comments: numbers are calculated from number of bed days analysed multiplied by average number of patients seen daily in the low and high occupancy group. (n= 3437) Intervention 2: Another level of capacity (bed occupancy) - Any other level of capacity. ≥92% occupancy. Duration: 4 months. Concurrent medication/care: n/a. Comments: numbers are vaguely calculated from number of bed days analysed multiplied by average number of patients seen daily in the low and high occupancy group.
Funding	Funding not stated.
RESULTS (NUMBERS ANALYSED) AND RISK OF BIAS FOR COMPARISON: BED CAPACITY <92% versus BED CAPACITY ≥92% Protocol outcome 1: A&E 4 hour waiting target met.	

Study	Bed occupancy and length of stay trial: Krall 2009[38]
- Actual outcome for Whole Hospital: ED transfer wait time (time interval from patient posting for admission in the ED to the time the patient arrived to the appropriate hospital bed) at 4 months; mean ED wait at <92% occupancy was 2.5 hours; mean ED wait at ≥92% occupancy was 1.6 hours higher (1.12 to 2.08 higher); Risk of bias: All domain - Very high, Selection - Very high, Blinding - High, Incomplete outcome data - Low, Outcome reporting - High, Measurement - High, Crossover - Low; Indirectness of outcome: No indirectness ; Baseline details: no patient characteristics given	
Protocol outcomes not reported by the study	Mortality; Patient satisfaction; Length of stay; Avoidable adverse events; Quality of life; Readmission; Outliers/Boarders; Staff satisfaction.

Study	Bed Occupancy and Mortality trial: Madsen 2014[42]
Study type	Retrospective cohort study.
Number of studies (number of participants)	1 (n=1,123,959)
Countries and setting	Conducted in Denmark; Setting: 2,651,021 admissions to 322 departments of medicine at 72 Danish hospitals (where medicine was the primary specialty) between 1st January 1995 and 31st December 2012 were analysed.
Line of therapy	1st line.
Duration of study	Other: 18 years.
Method of assessment of guideline condition	Adequate method of assessment/diagnosis.
Stratum	Whole Hospital.
Subgroup analysis within study	Not applicable.
Inclusion criteria	The departments included the following sub-specialties: allergy, cardiology, endocrinology, gastroenterology, geriatrics, haematology, hepatology, infectious disease, nephrology, pulmonology, and rheumatology.
Exclusion criteria	Excluded were paediatric, psychiatric, and surgical departments. Patients were excluded if they were younger than age 16 and if they died within the first 24 hours after admission.
Recruitment/selection of patients	The authors used administrative data covering admissions to all departments where medicine was the primary specialty in all hospitals in Denmark during the 18 year period to determine the association between bed occupancy and mortality. Mortality was tracked using the unique personal identification numbers (PINs) that are assigned to Danish citizens at birth or immigration and are available to researchers in a national registry.
Age, gender and ethnicity	Age - Mean (range): 66 years (16 to 109 years). Gender (M:F): 1/1. Ethnicity: Danish.
Further population details	n/a.
Extra comments	Author's comments: Until recently, there have been no EDs in Danish hospitals and emergency medicine is not yet a specialty. Instead patients are admitted directly to the indicated hospital department. Hospital departments cannot

Study	Bed Occupancy and Mortality trial: Madsen 2014[42]
	deny admission to patients. In Denmark, acute care is primarily organised by general practitioners (24 hour basis either in their own clinics or out-of-office GP regional units). Acute service is also provided by the wards of the hospitals' acute departments.
Indirectness of population	No indirectness
Interventions	(n=1,123,959) Intervention 1: Different levels of capacity (bed occupancy) - Any bed capacity. Occupancy rates were categorised as: 0-79%, 80-89%, 90-99%, 100-109%, 110% or more reference was the 0-79% group. Duration: 18 years. Concurrent medication/care: n/a. (n=1,123,959) Intervention 2: Another level of capacity (bed occupancy) - Any other level of capacity. Authors categorised occupancies into: 0-79%, 80-89%, 90-99%, 100-109%, 110% or more Reference category was 0-79%. Duration: 18 years. Concurrent medication/care: n/a.
Funding	Other.

RESULTS (NUMBERS ANALYSED) AND RISK OF BIAS FOR COMPARISON: BED CAPACITY 0-79% versus BED CAPACITY 80-89%, 90-99%, 100-109%, 110%

Protocol outcome 1: Mortality
- Actual outcome for Whole Hospital: Mortality in-hospital; Risk of bias: All domain - High, Selection - High, Blinding - Low, Incomplete outcome data - Low, Outcome reporting - Low, Measurement - Low, Crossover - Low; Indirectness of outcome: No indirectness

Adjusted mortality risk:

Reference 0-79% occupancy: RR 1.00.

80-89% occupancy: RR 1.02 (95% CI 1.00 to 1.04).

90-99% occupancy: RR 1.00 (95% CI 0.99 to 1.02).

100-109% occupancy: RR 1.02 (95% CI 1.00 to 1.04).

110% occupancy or more: RR 1.09 (95% CI 1.07 to 1.11).

Analysis adjusted for confounders: sex, age, month at admission, whether or not the admission was during normal working hours, the 31 indicators in the Elixhauser comorbidity index, and the year periods 1998-2000, 2001-2003, 2004-2006,2007-2009 and 2010-2012.

Protocol outcome 1: Mortality
- Actual outcome for Whole Hospital: 30-day mortality at 18 years; Risk of bias: All domain - High, Selection - High, Blinding - Low, Incomplete outcome data - Low, Outcome reporting - Low, Measurement - Low, Crossover - Low; Indirectness of outcome: No indirectness

Study	Bed Occupancy and Mortality trial: Madsen 2014[42]
Adjusted mortality risk: Reference 0-79% occupancy: RR 1.00. 80-89% occupancy: RR 1.01 (95% CI 0.99 to 1.02). 90-99% occupancy: RR 1.02 (95% CI 1.01 to 1.04). 100-109% occupancy: RR 1.03 (95% CI 1.02 to 1.05). 110% occupancy or more: RR 1.09 (95% CI 1.07 to 1.11). Analysis adjusted for confounders: sex, age, month at admission, whether or not the admission was during normal working hours, the 31 indicators in the Elixhauser comorbidity index, and the year periods 1998-2000, 2001-2003, 2004-2006,2007-2009 and 2010-2012.	
Protocol outcomes not reported by the study	Patient and/or carer satisfaction; Length of stay; Avoidable adverse events; Quality of life; Readmission; A&E 4 hour waiting target met; Outliers/Boarders; Staff satisfaction.

Study	Blom 2015[6]
Study type	Retrospective cohort study.
Number of studies (number of participants)	1 (n=32811 admissions).
Countries and setting	Conducted in Sweden.
Line of therapy	Not applicable.
Duration of study	Intervention time: 1 year.
Method of assessment of guideline condition	Adequate method of assessment/diagnosis: Admission through ED.
Stratum	Whole Hospital.
Subgroup analysis within study	Not applicable.
Inclusion criteria	Admitted through the main ED at index.
Exclusion criteria	Transferred to other hospitals during their index inpatient episode, discharged from the inpatient setting after study period.
Recruitment/selection of patients	All admissions entered into the database.
Age, gender and ethnicity	Age - Other: NR. Gender (M:F): NR. Ethnicity: not reported.
Further population details	1. Frail: Not applicable Not stated/Unclear.

Study	Blom 2015[6]
Indirectness of population	No indirectness.
Interventions	(n=12897) Intervention 1: Different levels of capacity (bed occupancy) - Any bed capacity. < 95% occupancy at time of discharge. Duration: 1 year. Concurrent medication/care: None stated. (n=9694) Intervention 2: Different levels of capacity (bed occupancy) - Any bed capacity. 95-100% occupancy at time of discharge. Duration: 1 year. Concurrent medication/care: None stated. (n=7946) Intervention 3: Different levels of capacity (bed occupancy) - Any bed capacity. 100-105% occupancy at time of discharge. Duration: 1 year. Concurrent medication/care: None stated. (n=2274) Intervention 4: Different levels of capacity (bed occupancy) - Any bed capacity. >105% occupancy at time of discharge. Duration: 1 year. Concurrent medication/care: None stated.
Funding	Academic or government funding (Swedish Medical Association).
RESULTS (NUMBERS ANALYSED) AND RISK OF BIAS FOR COMPARISON: <95% BED CAPACITY versus BED CAPACITY 95%-100%, 200-205%, >105% Protocol outcome 1: Readmission during the study period. - Actual outcome for Whole Hospital: Readmission through the ED at 30 days; OR 1.11 (95%CI 1.01 to 1.22) (p-value 0.02); Risk of bias: All domain - Very high, Selection - High, Blinding - High, Crossover - Low; Indirectness of outcome: No indirectness ; Key confounders: sex, age group, in-patient length of stay, time of discharge, and speciality unit responsible for admitting the patient at index RESULTS (NUMBERS ANALYSED) AND RISK OF BIAS FOR COMPARISON: ANY BED CAPACITY versus ANY BED CAPACITY Protocol outcome 1: Readmission during the study period - Actual outcome for Whole Hospital: Readmission through the ED at 30 days; OR 1.17 (95%CI 1.06 to 1.29) (p-value 0.001); Risk of bias: All domain - Very high, Selection - High, Blinding - High, Crossover - Low; Indirectness of outcome: No indirectness ; Key confounders: sex, age group, in-patient length of stay, time of discharge, and speciality unit responsible for admitting the patient at index RESULTS (NUMBERS ANALYSED) AND RISK OF BIAS FOR COMPARISON: ANY BED CAPACITY versus ANY BED CAPACITY Protocol outcome 1: Readmission during the study period. - Actual outcome for Whole Hospital: Readmission through the ED at 30 days; OR 1.15 (95%CI 0.99 to 1.34) (p-value 0.07); Risk of bias: All domain - Very high, Selection - High, Blinding - High, Crossover - Low; Indirectness of outcome: No indirectness ; Key confounders: sex, age group, in-patient length of stay, time of discharge, and speciality unit responsible for admitting the patient at index	
Protocol outcomes not reported by the study	Mortality during the study period; Patient and/or carer satisfaction during the study period; Length of stay during the

Study	Blom 2015[6]
	study period; Avoidable adverse events during the study period; Quality of life during the study period; A&E 4 hour waiting target met during the study period; Outliers/Boarders during the study period; Staff satisfaction during the study period.

Study	Boden 2016[8]
Study type	Before and after study.
Number of studies (number of participants)	1 (n=210, 510)
Countries and setting	Conducted in United Kingdom; Setting: large District General Hospital, UK.
Line of therapy	Not applicable.
Duration of study	Other: January 2012 - October 2014.
Method of assessment of guideline condition	Adequate method of assessment/diagnosis.
Stratum	Whole Hospital: N/A.
Subgroup analysis within study	Not applicable: N/A.
Inclusion criteria	Not reported.
Exclusion criteria	Not reported.
Recruitment/selection of patients	Consecutive patients over the study period.
Age, gender and ethnicity	Age - --: not reported. Gender (M:F): not reported. Ethnicity: not reported.
Further population details	1. Frail: Not applicable/Not stated/Unclear.
Indirectness of population	No indirectness: N/A.
Interventions	(n=11695) Intervention 1: Different levels of capacity (bed occupancy) - Any bed capacity. 93.7% average medical bed occupancy. Duration: January 2012-June 2013. Concurrent medication/care: N/A. (n=12003) Intervention 2: Another level of capacity (bed occupancy) - Any other level of capacity. 90.2% average medical bed occupancy. Duration: July 2013-October 2014. Concurrent medication/care: not reported.
Funding	Funding not stated.
RESULTS (NUMBERS ANALYSED) AND RISK OF BIAS FOR COMPARISON: BED CAPACITY 93.7% versus BED CAPACITY 90.2% Protocol outcome 1: Mortality	

Study	Boden 2016[8]
- Actual outcome for Whole Hospital: monthly crude mortality at study period; Group 1: 194/11695, Group 2: 189/12003; Risk of bias: All domain - Low, Selection - High, Blinding - Low, Incomplete outcome data - Low, Outcome reporting - Low, Measurement - Low, Crossover - Low; Indirectness of outcome: No indirectness, Comments: NA	
Protocol outcomes not reported by the study	Patient and/or carer satisfaction; Length of stay; Avoidable adverse events; Quality of life; Readmission; A&E 4 hour waiting target met; Outliers/Boarders; Staff satisfaction.

Study	Sprivulis 2006[54]
Study type	Retrospective cohort study.
Number of studies (number of participants)	1 (n=62495 admissions)
Countries and setting	Conducted in Australia; Setting: 3 tertiary Hospitals.
Line of therapy	Not applicable.
Duration of study	3 years.
Method of assessment of guideline condition	Adequate method of assessment/diagnosis: Admission via emergency department.
Stratum	Whole Hospital.
Subgroup analysis within study	Not applicable.
Inclusion criteria	All records where the emergency admission record of the first ED attendance during the study period in any of the hospitals' EDs that resulted in the patient being formally admitted to the hospital.
Exclusion criteria	None stated.
Recruitment/selection of patients	First admissions entered in the Emergency Department Information Systems.
Age, gender and ethnicity	Age - Other: % over 50 - <90% occupancy: 60.1%; 90-99% occupancy: 64.4%; 100% or over occupancy: 72.1%. Gender (M:F): 33049:29446. Ethnicity: not reported.
Further population details	1. Frail: Not applicable/Not stated/Unclear.
Indirectness of population	No indirectness.
Interventions	(n=16579) Intervention 1: Different levels of capacity (bed occupancy) - Any bed capacity. Whole hospital occupancy <90% on day of admission (census taken at 23.59 daily). Duration: 3 years. Concurrent medication/care: None stated. (n=40067) Intervention 2: Different levels of capacity (bed occupancy) - Any bed capacity. Whole hospital occupancy

Study	Sprivulis 2006[54]
	90-99% on day of admission (census taken at 23.59 daily). Duration: 3 years. Concurrent medication/care: None stated. (n=5849) Intervention 3: Different levels of capacity (bed occupancy) - Any bed capacity. Whole hospital occupancy 100% or greater on day of admission (census taken at 23.59 daily). Duration: 3 years. Concurrent medication/care: None stated.
Funding	Academic or government funding (Commonwealth Fund, New York; Australian Health Ministers' Advisory Council Priority Driven Research Funding Program).
RESULTS (NUMBERS ANALYSED) AND RISK OF BIAS FOR COMPARISON: BED CAPACITY <90% versus BED CAPACITY 90-99%, 100% or greater Protocol outcome 1: Mortality during the study period. - Actual outcome for Whole Hospital: Mortality at 7 days; HR 1.2 (95%CI 1.1 to 1.3) Reported; Risk of bias: All domain Very high, Selection - Very high, Blinding - Low, Crossover - Low; Indirectness of outcome: No indirectness ; Baseline details: Higher hospital occupancy was associated with a slightly higher proportion of elderly, female, illness admissions, and was more likely during weekdays and during winter; Key confounders: Adjusted for age, mode of transport, diagnosis, triage urgency, and referral source Protocol outcome 2: Length of stay during the study period - Actual outcome for Whole Hospital: Mean length of stay, adjusted for deaths at in-hospital; Group 1: mean 6.84 days (SD 10.51); n=16579, Group 2: mean 6.99 days (SD 11.23); n=40067; Risk of bias: All domain Very high, Selection - Very high, Blinding - High, Measurement - High, Crossover - Low; Indirectness of outcome: No indirectness ; Baseline details: Higher hospital occupancy was associated with a slightly higher proportion of elderly, female, illness admissions, and was more likely during weekdays and during winter; Key confounders: Adjusted for mortality RESULTS (NUMBERS ANALYSED) AND RISK OF BIAS FOR COMPARISON: ANY BED CAPACITY versus ANY BED CAPACITY Protocol outcome 1: Mortality during the study period. - Actual outcome for Whole Hospital: Mortality at 7 days; HR 1.3 (95%CI 1.1 to 1.6) Reported; Risk of bias: All domain very high, Selection - Very high, Blinding - Low, Crossover - Low; Indirectness of outcome: No indirectness ; Baseline details: Higher hospital occupancy was associated with a slightly higher proportion of elderly, female, illness admissions, and was more likely during weekdays and during winter; Key confounders: Adjusted for age, mode of transport, diagnosis, triage urgency, and referral source Protocol outcome 2: Length of stay during the study period - Actual outcome for Whole Hospital: Mean length of stay, adjusted for deaths at in-hospital; Group 1: mean 6.84 days (SD 10.51); n=16579, Group 2: mean 7.09 days (SD 10.53); n=5849; Risk of bias: All domain Very high, Selection - Very high, Blinding - High, Measurement - High, Crossover - Low; Indirectness of outcome: No indirectness ; Baseline details: Higher hospital occupancy was associated with a slightly higher proportion of elderly, female, illness admissions, and was more likely during weekdays and during winter; Key confounders: Adjusted for mortality	
Protocol outcomes not reported by the study	Patient and/or carer satisfaction during the study period; Avoidable adverse events during the study period; Quality of

Study	Sprivulis 2006[54]
	life during the study period; Readmission during the study period; A&E 4 hour waiting target met during the study period; Outliers/Boarders during the study period; Staff satisfaction during the study period.

Study	Yergens 2015[64]
Study type	Retrospective cohort study.
Number of studies (number of participants)	1 (n=1770)
Countries and setting	Conducted in Canada; Setting: 3 hospitals which provide all acute hospital care in a health service area.
Line of therapy	Not applicable.
Duration of study	Intervention time: 3 years, 10 months.
Method of assessment of guideline condition	Adequate method of assessment/diagnosis: Sepsis ICD-10-CA code in either main diagnosis, pre-admission comorbidity, or second pre-admission comorbidity.
Stratum	Specialised units (ED, AMU, ICU): Sepsis.
Subgroup analysis within study	Stratified then randomised: Sepsis and severe-sepsis.
Inclusion criteria	Sepsis ICD-10-CA code in either main diagnosis, pre-admission comorbidity, or second pre-admission comorbidity.
Exclusion criteria	None stated.
Recruitment/selection of patients	All patients who had been entered into the administrative databases at the hospitals.
Age, gender and ethnicity	Age – Median (IQR): Group 1: 65.83 (53.31-77.56); Group 2: 66.83 (55.25-78.25); Group 3: 63.67 (49.75-77.5); Group 4: 65.83 (53.96-78.08). Gender (M:F): 958:812. Ethnicity: not reported.
Further population details	1. Frail: Not applicable/Not stated/Unclear
Extra comments	Occupancy is automatically calculated using the patient movement ADT database at time of first ED physician assessment.
Indirectness of population	No indirectness.
Interventions	(n=595) Intervention 1: Different levels of capacity (bed occupancy) - Any bed capacity. Sepsis patients admitted when ICU occupancy < 80%. Duration: 3 years, 9 months. Concurrent medication/care: None stated. (n=204) Intervention 2: Different levels of capacity (bed occupancy) - Any bed capacity. Sepsis patients admitted when ICU occupancy 80-84%. Duration 3 years, 9 months. Concurrent medication/care: None stated. (n=113) Intervention 3: Different levels of capacity (bed occupancy) - Any bed capacity. Sepsis patients admitted when

Study	Yergens 2015[64]
	ICU occupancy < 85-89%. Duration: 3 years, 9 months. Concurrent medication/care: None stated. (n=124) Intervention 4: Different levels of capacity (bed occupancy) - Any bed capacity. Sepsis patients admitted when ICU occupancy over 90%. Duration: 3 years, 9 months. Concurrent medication/care: None stated.
Funding	Study funded by industry (Alberta Innovates Health Solutions).
RESULTS (NUMBERS ANALYSED) AND RISK OF BIAS FOR COMPARISON: ANY BED CAPACITY versus ANY BED CAPACITY Protocol outcome 1: Mortality during the study period - Actual outcome for Specialised units (ED, AMU, ICU): All-cause mortality at in-hospital; OR 1.26 (95%CI 0.81 to 1.195) (p-value 0.3); Risk of bias: All domain - Very high, Selection - Low, Blinding - Low, Incomplete outcome data - Low, Outcome reporting - Low, Measurement - Low, Crossover - Low, Subgroups - Very high; Indirectness of outcome: No indirectness ; Key confounders: Adjusted for gender, age, triage level, Charlson index score, ED physician first assessment time, and admission to ICU RESULTS (NUMBERS ANALYSED) AND RISK OF BIAS FOR COMPARISON: BED CAPACITY <80% versus BED CAPACITY <85%-89%, >90% Protocol outcome 1: Mortality during the study period - Actual outcome for Specialised units (ED, AMU, ICU): All-cause mortality at in-hospital; OR 1.00 (95%CI 0.57 to 1.71) (p-value 0.99); Risk of bias: All domain - Very high, Selection - Low, Blinding - Low, Incomplete outcome data - Low, Outcome reporting - Low, Measurement - Low, Crossover - Low, Subgroups - Very high; Indirectness of outcome: No indirectness ; Key confounders: Adjusted for gender, age, triage level, Charlson index score, ED physician first assessment time, and admission to ICU RESULTS (NUMBERS ANALYSED) AND RISK OF BIAS FOR COMPARISON: ANY BED CAPACITY versus ANY BED CAPACITY Protocol outcome 1: Mortality during the study period - Actual outcome for Specialised units (ED, AMU, ICU): All-cause mortality at in-hospital; OR 1.72 (95%CI 1.03 to 2.83) (p-value 0.03); Risk of bias: All domain - Very high, Selection - Low, Blinding - Low, Incomplete outcome data - Low, Outcome reporting - Low, Measurement - Low, Crossover - Low, Subgroups - Very high; Indirectness of outcome: No indirectness ; Key confounders: Adjusted for gender, age, triage level, Charlson index score, ED physician first assessment time, and admission to ICU	
Protocol outcomes not reported by the study	Patient and/or carer satisfaction during the study period; Length of stay during the study period; Avoidable adverse events during the study period; Quality of life during the study period; Readmission during the study period; A&E 4 hour waiting target met during the study period; Outliers/Boarders during the study period; Staff satisfaction during the study period.

Appendix E: Economic and simulation model evidence tables

Study	Bagust 1999[5]			
Study details	**Population & interventions**	**Costs**	**Health outcomes**	**Cost effectiveness**
Economic analysis: n/a (health outcome: no health outcomes) **Study design:** Discrete event simulation model **Approach to analysis:** Modelling the dynamics of the hospital system to reflect the relation between demand and available bed capacity. Demand for patient admission and available inpatient bed capacity were randomly fluctuated. Eleven experiments were conducted varying factors included in the model. **Perspective:** UK NHS **Time horizon:** 1,000 day period **Treatment effect duration**[(a)]**:** n/a **Discounting:** Costs: n/a ; Outcomes: n/a	**Population:** Patients requiring immediate admission into hospital **Cohort settings:** Baseline cohort taken from detailed analysis of admissions records and length of stay distributions of 2 NHS trusts. Start age: NR Male: NR **Intervention:** Random fluctuations in demand and bed capacity, changing the level of bed occupancy.	n/a	**At least 1 patient requiring immediate admission cannot be accommodated:** There is minimal number of crisis days at fewer than 85% occupancy. At 90% occupancy and above, the system is regularly subject to bed crises. Close to 0% probability at fewer than 85% occupancy. 1% probability at 90% occupancy with exponential increase up to 19% probability at 100%.[(b)] **Crisis days:** It is expected that there are 4 crisis days in a year at 85% occupancy. Close to 0% probability at fewer than 85% occupancy. 5% probability at 90% occupancy with exponential increase up to 78% probability at 100%.[(b)]	n/a
Data sources				
Health outcomes: Outcomes taken from model output. **Quality-of-life weights:** n/a **Cost sources:** n/a				
Comments				
Source of funding: NHS Executive, West Midlands **Applicability and limitations:** System dynamic model concerned with patient flow. No costs or health outcomes. Poor outcome not defined. Modelling methods not reported in detail. Outcomes reported in narrative and graphical form only. No incremental analysis undertaken. Analysis of eleven experiments only brief. No formal sensitivity analysis.				

Abbreviations: NR: not reported.

(a) For studies where the time horizon is longer than the treatment duration, an assumption needs to be made about the continuation of the study effect. For example, does a difference in utility between groups during treatment continue beyond the end of treatment and if so for how long.(b) No numerical values reported.

Appendix F: GRADE tables

Table 11: Clinical evidence profile: Higher occupancy versus <70% occupancy

Quality assessment							No of patients		Effect		Quality	Importance
No of studies	Design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Higher occupancy	Control	Relative (95% CI)	Absolute		
Avoidable adverse events - 70-79.9% versus <70% (follow-up in-hospital; assessed with: Clostridium difficile infection)												
1	observational studies	serious risk of bias[2]	no serious inconsistency	no serious indirectness	serious[1]	none	0/69106 (0%)	0%	HR 1.3 (0.95 to 1.78)	-	⊕OOO VERY LOW	CRITICAL
Avoidable adverse events - 80-89.9% versus <70% (follow-up in-hospital; assessed with: Clostridium difficile infection)												
1	observational studies	serious risk of bias[2]	no serious inconsistency	no serious indirectness	serious[1]	none	0/69106 (0%)	0%	HR 1.56 (1.18 to 2.06)	-	⊕OOO VERY LOW	CRITICAL
Avoidable adverse events - 90-99.9% versus <70% (follow-up in-hospital; assessed with: Clostridium difficile infection)												
1	observational studies	serious risk of bias[2]	no serious inconsistency	no serious indirectness	serious[1]	none	0/69106 (0%)	0%	HR 1.52 (1.16 to 1.99)	-	⊕OOO VERY LOW	CRITICAL
Avoidable adverse events - 100% versus <70% (follow-up in-hospital; assessed with: Clostridium difficile infection)												
1	observational studies	serious risk of bias[2]	no serious inconsistency	no serious indirectness	serious[1]	none	0/69106 (0%)	0%	HR 1.55 (1.19 to 2.02)	-	⊕OOO VERY LOW	CRITICAL

[1] All non-randomised studies automatically downgraded due to selection bias. Studies may be further downgraded by 1 increment if other factors suggest additional high risk of bias, or 2 increments if other factors suggest additional very high risk of bias.
[2]Downgraded by 1 increment if the confidence interval crossed 1 MID or by 2 increments if the confidence interval crossed both MIDs.

Table 12: Clinical evidence profile: Higher occupancy versus <80% occupancy

Quality assessment							No of patients		Effect		Quality	Importance
No of studies	Design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Higher occupancy	Control	Relative (95% CI)	Absolute		
Mortality - 80-84% versus <80% (follow-up in-hospital)												
1	observational studies	very serious[1]	no serious inconsistency	no serious indirectness	serious[2]	none	0/204 (0%)	0%	OR 1.26 (0.81 to 1.96)	-	⊕OOO VERY LOW	CRITICAL
Mortality - 85-89% versus <80% (follow-up in-hospital)												
1	observational studies	very serious[1]	no serious inconsistency	no serious indirectness	very serious[2]	none	0/113 (0%)	0%	OR 1 (0.57 to 1.75)	-	⊕OOO VERY LOW	CRITICAL
Mortality - 90% and over versus <80% (follow-up in-hospital)												
1	observational studies	very serious[1]	no serious inconsistency	no serious indirectness	serious[2]	none	0/124 (0%)	0%	OR 1.72 (1.03 to 2.87)	-	⊕OOO VERY LOW	CRITICAL
Mortality - 80-89% versus <80% (follow-up in-hospital)												
1	observational studies	serious[1]	no serious inconsistency	no serious indirectness	no serious imprecision	none	-	0%	HR 1.01 (0.99 to 1.03)	-	⊕OOO VERY LOW	CRITICAL
Mortality - 90-99% versus <80% (follow-up in-hospital)												
1	observational studies	serious[1]	no serious inconsistency	no serious indirectness	no serious imprecision	none	-	0%	HR 1.02 (1.01 to 1.03)	-	⊕OOO VERY LOW	CRITICAL
Mortality - 100-109% versus <80% (follow-up in-hospital)												
1	observational studies	serious[1]	no serious inconsistency	no serious indirectness	no serious imprecision	none	-	0%	HR 1.03 (1.02 to 1.04)	-	⊕OOO VERY	CRITICAL

											LOW	
Mortality - >110% versus <80% (follow-up in-hospital)												
1	observational studies	serious[1]	no serious inconsistency	no serious indirectness	no serious imprecision	none	-	0%	HR 1.09 (1.07 to 1.11)	-	⊕OOO VERY LOW	CRITICAL
Mortality - 80-89% versus <80% (follow-up 30 days)												
1	observational studies	serious[1]	no serious inconsistency	no serious indirectness	no serious imprecision	none	-	0%	RR 1.01 (0.99 to 1.03)	-	⊕OOO VERY LOW	CRITICAL
Mortality - 90-99% versus <80% (follow-up 30 days)												
1	observational studies	serious[1]	no serious inconsistency	no serious indirectness	no serious imprecision	none	-	0%	RR 1.02 (1.01 to 1.03)	-	⊕OOO VERY LOW	CRITICAL
Mortality - 100-109% versus <80% (follow-up 30 days)												
1	observational studies	serious[1]	no serious inconsistency	no serious indirectness	no serious imprecision	none	-	0%	RR 1.03 (1.02 to 1.04)	-	⊕OOO VERY LOW	CRITICAL
Mortality - >110% versus <80% (follow-up 30 days)												
1	observational studies	serious[1]	no serious inconsistency	no serious indirectness	no serious imprecision	none	-	0%	RR 1.09 (1.07 to 1.11)	-	⊕OOO VERY LOW	CRITICAL

[1] All non-randomised studies automatically downgraded due to selection bias. Studies may be further downgraded by 1 increment if other factors suggest additional high risk of bias, or 2 increments if other factors suggest additional very high risk of bias.
[2] Downgraded by 1 increment if the confidence interval crossed 1 MID or by 2 increments if the confidence interval crossed both MIDs.

Table 13: Clinical evidence profile: Higher occupancy versus <90% occupancy

Quality assessment	No of patients	Effect	Quality	Importance

No of studies	Design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Higher occupancy	Control	Relative (95% CI)	Absolute		
Length of stay - 90-99% versus <90% (follow-up in-hospital; Better indicated by lower values)												
1	observational studies	very serious[1]	no serious inconsistency	no serious indirectness	no serious imprecision	none	40067	16579	-	MD 0.15 higher (0.04 lower to 0.34 higher)	⊕OOO VERY LOW	CRITICAL
Length of stay - 100% and greater versus <90% (follow-up in-hospital; Better indicated by lower values)												
1	observational studies	very serious[1]	no serious inconsistency	no serious indirectness	no serious imprecision	none	5849	16579	-	MD 0.25 higher (0.06 lower to 0.56 higher)	⊕OOO VERY LOW	CRITICAL
Mortality - 90-99% versus <90% (follow-up 7 days)												
1	observational studies	very serious[1]	no serious inconsistency	no serious indirectness	serious[2]	none	0/40067 (0%)	0%	HR 1.2 (1.1 to 1.31)	-	⊕OOO VERY LOW	CRITICAL
Mortality - 100% and greater versus <90% (follow-up 7 days)												
1	observational studies	very serious[1]	no serious inconsistency	no serious indirectness	serious[2]	none	0/5849 (0%)	0%	HR 1.3 (1.1 to 1.54)	-	⊕OOO VERY LOW	CRITICAL

[1] All non-randomised studies automatically downgraded due to selection bias. Studies may be further downgraded by 1 increment if other factors suggest additional high risk of bias, or 2 increments if other factors suggest additional very high risk of bias

[2] Downgraded by 1 increment if the confidence interval crossed 1 MID or by 2 increments if the confidence interval crossed both MIDs.

Table 14: Clinical evidence profile: ≥92% occupancy versus <92% occupancy

Quality assessment							No of patients		Effect		Quality	Importance
No of studies	Design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Higher occupancy	Control	Relative (95% CI)	Absolute		

ED wait time until arrival in hospital bed (Better indicated by lower values)												
1	observational studies	very serious[1]	no serious inconsistency	no serious indirectness	no serious imprecision	none	3437	1953	-	MD 1.6 higher (1.12 to 2.08 higher)	⊕OOO VERY LOW	IMPORTANT

[1] All non-randomised studies automatically downgraded due to selection bias. Studies may be further downgraded by 1 increment if other factors suggest additional high risk of bias, or 2 increments if other factors suggest additional very high risk of bias.

Table 15: Clinical evidence profile: 93.7% occupancy versus 90.2% occupancy

Quality assessment							No of patients		Effect		Quality	Importance
No of studies	**Design**	**Risk of bias**	**Inconsistency**	**Indirectness**	**Imprecision**	**Other considerations**	**90.2%**	**Control**	**Relative (95% CI)**	**Absolute**		
Readmission - 95-100% versus < 95% (follow-up 30 days)												
1	observational studies	no serious risk of bias[1]	no serious inconsistency	serious[2]	no serious imprecision	none	189/12003 (1.6%)	1.70%	RR 0.95 (0.78 to 1.16)	1 fewer per 1000 (from 4 fewer to 3 more)	⊕OOO VERY LOW	CRITICAL

[1] All non-randomised studies automatically downgraded due to selection bias. Studies may be further downgraded by 1 increment if other factors suggest additional high risk of bias, or 2 increments if other factors suggest additional very high risk of bias.
[2]Downgraded by 1 or 2 increments because the majority of the evidence was based on indirect interventions.

Table 16: Clinical evidence profile: Higher occupancy versus <95% occupancy

Quality assessment							No of patients		Effect		Quality	Importance
No of studies	**Design**	**Risk of bias**	**Inconsistency**	**Indirectness**	**Imprecision**	**Other considerations**	**Higher occupancy**	**Control**	**Relative (95% CI)**	**Absolute**		
Readmission - 95-100% versus < 95% (follow-up 30 days)												

1	observational studies	very serious[1]	no serious inconsistency	no serious indirectness	no serious imprecision	none	0/9694 (0%)	0%	OR 1.11 (1.01 to 1.22)	-	⊕OOO VERY LOW	IMPORTANT
Readmission - 100-105% versus < 95% (follow-up 30 days)												
1	observational studies	very serious[1]	no serious inconsistency	no serious indirectness	serious[2]	none	0/7946 (0%)	0%	OR 1.17 (1.06 to 1.29)	-	⊕OOO VERY LOW	IMPORTANT
Readmission - >105% versus < 95% (follow-up 30 days)												
1	observational studies	very serious[1]	no serious inconsistency	no serious indirectness	serious[2]	none	0/2274 (0%)	0%	OR 1.15 (0.99 to 1.34)	-	⊕OOO VERY LOW	IMPORTANT

[1]. All non-randomised studies automatically downgraded due to selection bias. Studies may be further downgraded by 1 increment if other factors suggest additional high risk of bias, or 2 increments if other factors suggest additional very high risk of bias.
[2] Downgraded by 1 increment if the confidence interval crossed 1 MID or by 2 increments if the confidence interval crossed both MIDs.

Appendix G: Excluded clinical studies and modelling papers

Table 17: Studies excluded from the clinical review

Study	Exclusion reason
Akcali 2006[4]	Modelling paper containing no clinical data/protocol outcomes. Also excluded by HE protocol as US study
Anon1980D[1]	Library service unable to locate a copy
Anon1996F[2]	Book containing no clinical data
Blom 2014[7]	Prognostic/predictive study containing no relevant clinical data and no relevant comparison
Boden 2016[8]	Incorrect interventions. Multi-component intervention, with bed capacity as one of the outcomes of interest
Borg 2003[9]	Association study containing no comparison
Borg 2008[10]	Non-OECD (Malta)
Boyle 2014[11]	Modelling paper containing no relevant clinical data and no comparison
Cardoso 2011[12]	Incorrect interventions. Grouped by ICU admission delay (access block)
Conrad 2010[13]	Association study containing no comparison
Cooke 2004[14]	No extractable outcome. Scattergram of the proportion of A&E attendees waiting more than 4 hours against bed occupancy
Costa 2003[15]	Modelling paper containing no relevant clinical data and no comparison. Capacity used as one of a number of variables to predict bed numbers needed.
Dexter 2007[16]	Study design (descriptive)
DuFour 1974[17]	No relevant clinical data and no relevant comparison. Pre-1990 study
Flabouris 2012[19]	Incorrect interventions. Grouped by increased ED length of stay
Forster 2003[20]	Prognostic/predictive time series analysis; associations rather than comparisons
Gopakumar 2016[21]	No relevant outcomes reported
Gorunescu 2002[23]	Modelling paper containing no clinical data. Effect of different scenarios on bed occupancy – capacity as outcome rather than comparison/intervention
Gorunescu 2002B[22]	Modelling paper containing no relevant comparison. Effect of number of beds on bed occupancy – capacity as outcome rather than comparison/intervention
Green 2002[24]	Modelling paper containing no relevant clinical data. Capacity planning tool – estimating amount of unused capacity in units
Halpern 2015[25]	Study design (literature review)
Harper 2002B[26]	Modelling paper for capacity planning within a single hospital containing no relevant comparison
Harris 2015[27]	Abstract only. No outcomes of interest
Harrison 2013[28]	Modelling paper containing no relevant clinical data. Effect of bed

Study	Exclusion reason
	demand on discharge rate
Huang 2010[29]	Incorrect interventions. Grouped by delay in admission (access block)
Hung 2014[30]	Incorrect interventions. Grouped by delay to reaching in-patient bed (access block)
Jones 2011[31]	Modelling paper containing no relevant comparison. Intervention is bed capacity not levels of occupancy.
Junhasavasdikul 2013[32]	Incorrect interventions. No capacity levels in analysis
Kaier 2010[34]	Modelling paper containing no relevant comparison. Bed occupancy as one of a number of variables to predict MRSA cases. Correlation from regression – not comparing different levels of occupancy with each other
Kaier 2011[33]	Prognostic/predictive study containing no relevant clinical data and no relevant comparison
Kaier 2012[35]	Systematic review (references checked)
Kang 2015[36]	Non-OECD country (South Korea)
Khanna 2012A[37]	Modelling paper containing no relevant clinical data and no relevant comparison. Intervention is hospital capacity not levels of occupancy.
Kroneman 2004[39]	Modelling paper containing no relevant clinical data. Capacity as an outcome, not intervention/comparison
Laugharne 2016 [40]	Incorrect population; no relevant extractable outcomes
Lee 1986[41]	Modelling paper containing no relevant clinical data and no relevant comparison. Pre-1990 study.
Mathews 2015[43]	Modelling paper containing no relevant clinical data and no relevant comparison. Capacity as an outcome, not intervention/comparison
O'callaghan 2012[45]	Incorrect interventions. Grouped by ICU admission delay (access block)
Phua 2010[46]	Incorrect interventions. Grouped by delay to ICU admission (access block)
Plunkett 2011[47]	Incorrect interventions. Grouped by increased wait time (access block)
Richardson 2002[48]	Incorrect interventions. Grouped by delay in reaching inpatient bed (access block)
Robert 2015[49]	Incorrect interventions. High bed availability versus Low bed availability. No percentage level of capacity
Sakamoto 2010[50]	Association study containing no comparison
Slade 2015 [51]	Incorrect population; no relevant extractable outcomes
Smith 1996[52]	Modelling paper containing no relevant clinical data. US study concerned with closing hospitals and cost saving rather than comparing different levels of capacity and their impact on clinical outcomes
Sobieraj 2007[53]	Modelling paper containing no relevant clinical data. Modelling normal and extended capacity (that is, surge planning)
Sun 2015[55]	Non-OECD country (Singapore)
Teitelbaum 2016[56]	Not review population. Psychiatric patients on a closed or physcogeriatric ward`
Tierney 2014[58]	Study design (literature review)

Study	Exclusion reason
Todisco 2015[59]	Incorrect interventions. Different organisational layout not level of capacity
Usman 2015[60]	Non-OECD country (Pakistan)
Vella 2016[61]	No extractable outcomes
WHO 2003[63]	Narrative review/report; references checked

Appendix H: Excluded economic studies

No studies were excluded for reasons of poor quality.

References

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