Supplementary Material for "Evaluation and Implementation of a Just-In-Time Bed-Assignment Strategy to Reduce Wait Times for Surgical Inpatients"

Braaksma et al., 2023

This Supplementary Material includes additional details that augment the main text of "Evaluation and Implementation of a Just-In-Time Bed-Assignment Strategy to Reduce Wait Times for Surgical Inpatients," by Braaksma et al. Specifically, we include the following:

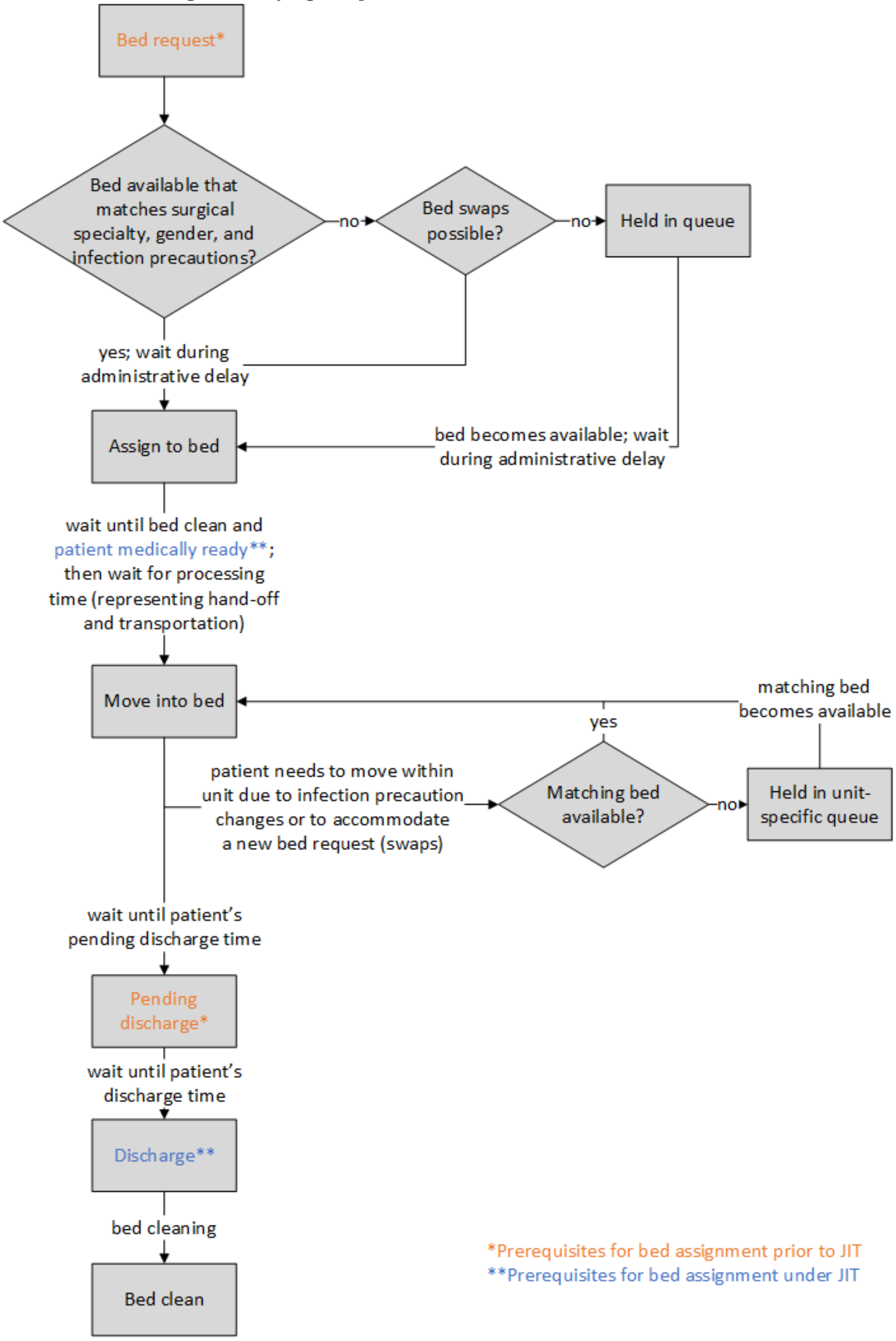
1. details of the simulation model and assumptions;
2. technical details on simulation validation and experiments;
3. details on the SSE reduction scenarios and a sensitivity analysis of these scenarios based on the extent of the reduction of patient demand per the SSE policy;
4. simulation results for bed-idle time and occupancy (Table SM3);
5. ARIMA model parameters for the interrupted time series models; and
6. implementation results (analogous to Table 3) with holiday weeks removed.

1 Simulation model and assumptions

As described in Section 2 in the main text, the simulation input included timestamps of all patient movements within the different areas of the hospital: the perioperative environment, the emergency department, and in the inpatient floors, and the corresponding bed requests. We take timestamps such as when patients were ready to transfer out and their discharge times as fixed; we consider these as part of clinical processes whose modeling is not related to the bed-assignment process.

The patient flow model (Figure SM1) starts with the arrival of each patient at his historical

Fig. SM1 A visual representation of the logic underlying the patient flow simulation model



bed request time. Because the precise historical rules for prioritization are not standardized or documented, in the base scenario the model prioritizes patients for assignment based on the order that they were historically assigned. Once a patient is next to be assigned, the simulation looks for a bed available for assignment that matches his needs in terms of surgical specialty, gender, and infection precautions. The simulation includes an administrative delay, sampled from historical data, to account for the fact that while assignments are made instantaneously when they become feasible in the simulation, in the real world it is a manual process that is not instantaneous.

Once a patient is assigned to a bed, he must wait until becoming medically ready to continue the process. Most patients in the simulation become medically ready at the time of their bed request, but elective surgical patients may need to wait at this point. Once the patient is medically ready he starts waiting for his bed to become available to occupy. This means that the patient or closure that was occupying the bed previously must leave and the bed must be cleaned. This wait can range from zero, when the patient was assigned to a bed that was already ready, to over twelve hours, in the case where a pending discharge was entered far in advance of the actual discharge. Cleaning times are sampled from the historical data. Once the bed becomes available the patient-wait-for-bed time ends. On the other hand, if the patient was assigned to a bed that was ready before the patient's medical readiness, the simulation registers bed-idle time for the bed from the moment it was ready until the moment the patient is medically ready. When both patient and bed are ready, the patient waits for a transfer processing time, also drawn from the historical data, before he occupies his bed.

The patient then stays in his bed until his historical pending discharge time (unless he is subject to infection precautions changes or bed swaps, which are described later). In the base scenario, at the time of the historical pending discharge, the patient's bed becomes available for assignment. Before the bed becomes available for assignment to patients, the simulation first checks whether there is a closure for staffing or maintenance that needs to be implemented on that unit. If there is such a waiting closure, the bed will be closed for the historical duration of the closure.

The patient then waits until his historical departure time from the unit before relinquishing his actual bed for cleaning. The model uses historical departure times based on the belief that small changes in patients' intraday wait times would not affect their eventual discharge times.

The simulation model closely resembles reality by including bed closures, changes in patients' infection precautions, and bed swaps (i.e., moving a patient to another bed in the same floor). In the four floors of interest, 116 out of 129 beds (90%) are semiprivate and there were a total of 69,586 bed-closure hours in 2015, effectively reducing the floors' operational capacity to 121 beds.

Two types of bed closures occur in the simulation. First, historical closures due to maintenance or staffing shortages are replicated in the model. At the historical time of a closure start, the simulation will look for a bed to close on the appropriate unit. If no bed is available at that time, the next bed to become available will be closed. The closure will last for the historical duration of the closure. Second, patients with an infection precaution close the neighboring bed when being in a semiprivate room alone. In the case of MRSA (methicillin-resistant *Staphylococcus aureus*), VRE (vancomycin-resistant *Enterococcus*), or both MRSA and VRE, the bed can be opened by finding an appropriate patient to cohort. As in practice, the model executes bed swaps to improve cohorting. Changes in patients' infection precautions are replicated at their historical times, potentially necessitating bed swaps. Since private rooms are so highly demanded, we assume that patients only stayed in them historically when absolutely required. In the simulation input, such patients were assigned the infection precaution "non-cohortable." The model assumes that only non-cohortable patients can be assigned to private rooms.

Bed swaps are incorporated in the simulation using the following procedure. When a semi-private bed becomes available for assignment (either because of a closure ending or a pending discharge) and there is no waiting patient that is appropriate for the bed, the simulation checks whether there is a patient on the unit that is currently in a room alone and matches the characteristics of the bed that is now available for assignment. If such a patient exists, he will be swapped into the bed that the first patient is leaving and his bed will be made available to waiting patients instead of the original bed. This allows more flexibility in the patients that can be accommodated since the bed that becomes available to waiting patients is now suitable for any patient. Bed swaps can also be initiated when a patient's infection precautions change. Upon a change in a patient's infection precautions, the following procedures are followed.

If the patient is in a semi-private room with a roommate (who will no longer match infection precautions):

i) Check to see if there is a room on the unit that is available for the patient or his roommate to move into with another patient that they now match. If so, execute this move.

ii) If there is no room with a matching patient, see if there is an empty room available to move the patient or roommate to. If so, execute this move.

iii) If this does not work, leave the patient together with his roommate until another bed on the unit becomes available. Any time a bed becomes available, check to see if either the patient or his roommate can be moved into it.

If the patient is in a semi-private room with no roommate:

i) Check to see if there is now an opportunity to cohort this patient with another patient that matches his new infection precautions. If the new infection precaution is non-cohortable, look for a private room for this patient.

ii) If a cohorting situation or private room is not found, leave the patient in the semi-private room.

Finally, if the patient is in a private room and is no longer non-cohortable:

i) Check to see if the patient can now be cohorted with another patient on the unit.

ii) If not, look for an empty semi-private room for this patient.

iii) If neither i) nor ii) are successful, leave the patient in the private room for the time being.

2 Simulation validation and experiments

To validate our simulation model, we first ran a base scenario and statistically compared its performance to historical performance. In the base scenario, patients needed to be assigned to a bed on the same floor that they were historically assigned. Since the historical rules for prioritization were not standardized or documented, the model prioritized patients for assignment based on the order that they were historically assigned. All patients could be assigned to "pending discharge" beds (beds in which the current patient is indicated as leaving at some time later that day), and bed assignments for elective surgical patients could begin as soon as their bed requests had been generated (i.e., before their surgeries).

We compared the distribution of patients' wait times between the 2015 historical data and the output of the simulation's base scenario. Following the approach of Montgomery and Runger [1], we calculated the 95% confidence interval (CI) on the difference in means (with validation occurring whenever the interval contains zero). For the whole patient population, the average patient wait time was 4.76 and 4.88 hours for historical and simulation, respectively, with confidence interval for the difference of $[-0.38, 0.13]$. As 0 is contained in this confidence interval, we concluded that there were no statistically significant differences in the average wait time between historical and the simulation. Likewise, we compared the simulation model for each subset of the population when partitioned by source, by patient infection precautions, by weekday of the bed request, or by specific floor destination (see Table SM1). While the CI for patients from the ED ($[-0.35, -0.01]$) does not contain 0, it is not adjusted for multiple testing and as such is not a concern for model validation (indeed, standard multiple testing corrections, e.g., Holm, yield a non-significant result; in other words, per this approach, the model is validated in this subset).

For the results throughout the text, we present the average across 100 simulation runs. We chose 100 because with this choice of number of simulation runs, the base scenario yielded estimates that were within a practical tolerance for relevant stakeholders at the hospital. In particular, for the average and quantiles of interest, the overall wait time had a standard error below 0.005. Not surprisingly, the standard errors were higher for the sources with fewer observations, but all were still within a practically reasonable tolerance in this setting.

3 SSE reduction scenarios and sensitivity analysis

Before the actual SSE bed strategy was implemented, it was not known how this would change demand for floor beds for these patients. Therefore, we considered a spectrum of possible scenarios. Among the 898 SSE patients in 2015 who went to the four surgical floors of interest, 653 (72.7%) had a total hospital length of stay (LOS) of zero or one days, with the remaining 245 (27.3%) having a LOS of ≥ 2 days. The SSE reduction policy was not designed to affect the floor placement of such longer-LOS SSE patients; therefore, in the simulation we do not consider reductions in this group (in the actual implementation, this average daily number of SSE patients with $\geq$ 2-day LOS decreased slightly, although the change was not statistically significant).

Instead, we consider percent reductions in the zero- or one-day LOS patients (which we call "eligible SSE patients"). In particular, we consider, for $P \in \{0, 1, 2, \ldots, 100\}$, what the change in patient wait times is if P% of eligible SSE patients require a floor bed. The scenario $P = 100$ corresponds to the base scenario (where all of the 653 eligible SSE patients still require a bed) and $P = 0$ corresponds to *none* of the eligible SSE patients going to the floor.

In the main text, we single out one scenario that we denoted $\text{SSE}^{<}$. This corresponds to the case where $P = 50$, i.e., the eligible SSE patients going to the floor are at 50% of their historical volume. We chose this scenario to present because it corresponds closely with the actual reduction observed during the implementation, where the average daily eligible SSE patient volume decreased to 42.7% of its pre-implementation value (CI $[25.8\%, 65.0\%]$).

In Table SM2, we also add the scenario SSE^{0} for comparison; this corresponds with the extreme case where $P = 0$. In Figure SM2, we show the corresponding results for the various eligible SSE patient reduction scenarios (results for the median are qualitatively consistent with these and Table 2 and, as such, are not shown here).

4 ARIMA model specifications

In this section, we include the chosen ARIMA model parameters per the selection process detailed in the main text. The final reported models in the main text do not include seasonality, though we performed a comparison with weekly (7-day) seasonality included (a comparison for daily admissions, as per Table 1, is included below); model estimates for changes post-implementation were generally comparable so we elected to include the simpler approach.

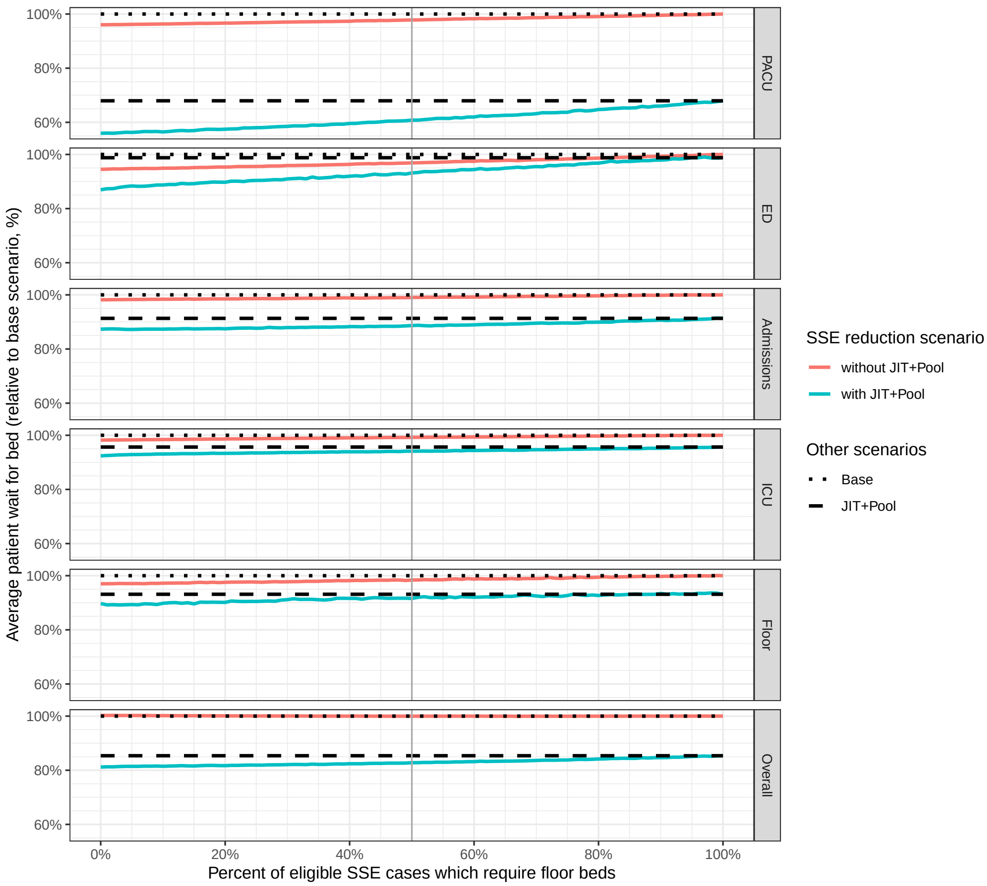
We use ARIMA$(p, d, q)(P, D, Q)$ to denote a model with p autoregressive terms, d differencing terms, q moving average terms, P seasonal autoregressive terms, D seasonal differencing terms, and Q seasonal moving average terms (measurements are at the daily level). Model parameters, coefficients, and summary statistics (namely, corrected Akaike Information Criterion [AICc] and in-sample root mean squared error [RMSE]) are shown as follows: daily admissions in Tables SM4 and SM5 for overall and weekdays, respectively; and occupancy and bed-idle time (both overall and assignment volume per day) in Table SM6.

Finally, we performed a comparison for daily admissions of the non-seasonal model with a version with weekly seasonality. While the automated selection process does identify non-zero seasonal parameters in some cases (i.e., $P + D + Q > 0$), the estimates for the post-implementation coefficient specifically are similar. This is demonstrated in Table SM7 where the corresponding estimated confidence intervals are shown (*cf.* Table 1 in the main text). In all cases, the (p, d, q) parameters were the same. For this reason, we elected to use the simpler models without seasonality.

5 Implementation results with holidays excluded

The post-implementation period included no hospital-wide holidays (overall, there are nine institutional holidays per year, resulting in nine holiday weeks). While holidays themselves typically have reduced demand for hospital beds (due to changes in emergency department visit volume and scheduled surgical volume), surrounding days within holiday *weeks* also tend to have reduced demand as well. Therefore, the results shown in Table 3 in the main text potentially underestimate the effect of implementation (as the pre-implementation period includes 7 holiday weeks

Fig. SM2 SSE reduction sensitivity analysis for relative changes in average patient wait times



Notes. Comparison scenarios are detailed in Table 2 in the main text. All results are averaged over 100 simulations. The vertical line at 50% corresponds to the scenario $SSE^{<}$.

out of a total of 30 complete weeks, compared to 0 out of 11 post-implementation).

To augment those results, we also conducted the comparison where holiday weeks are excluded from the pre-implementation period. The corresponding results, analogous to Table 3, are shown in Table SM8. Overall, the estimates for changes tended to decrease (i.e., larger reductions in wait times).

References

[1] Montgomery, D.C., Runger, G.C.: Applied Statistics and Probability for Engineers, 3rd edn. John Wiley & Sons, Inc., Hoboken, NJ (2003)

Table SM1 Validation results: Patients' wait times for multiple partitions, with historical in gray, simulation in white, and n the number of bed requests in each subset. Note that confidence intervals (CIs) are at the 95% level and are not adjusted for multiple testing.

Partition	n	CI Δ means	Mean	St.dev.	$Q_{0.05}$	$Q_{0.25}$	$Q_{0.5}$	$Q_{0.75}$	$Q_{0.95}$
Overall	10,771	[-0.38, 0.13]	4.76	13.29	0.00	0.00	0.53	3.73	24.61
			4.88	13.30	0.00	0.00	0.62	4.03	25.22
By source									
PACU	6,204	[-0.24, 0.04]	2.45	5.52	0.00	0.00	0.00	2.12	18.63
			2.55	5.73	0.00	0.00	0.00	2.28	19.02
ED	2,824	[-0.35, -0.01]	2.78	4.59	0.03	0.13	0.70	3.01	13.83
			2.96	4.77	0.05	0.18	0.87	3.32	14.80
Admissions	862	[-2.38, 1.65]	11.66	29.42	0.03	0.62	3.15	17.17	41.44
			12.02	29.38	0.10	1.22	3.79	16.98	41.62
ICU	701	[-1.79, 2.08]	24.05	25.44	1.28	5.47	12.05	32.93	76.70
			23.91	25.14	0.97	5.88	12.40	33.68	76.30
Floor	180	[-3.70, 3.74]	7.31	24.71	0.02	0.22	2.49	5.52	22.83
			7.29	24.59	0.02	0.45	2.25	4.99	23.90
By patient infection precautions									
None	9,921	[-0.34, 0.04]	4.04	9.56	0.00	0.00	0.43	3.25	22.55
			4.19	9.61	0.00	0.00	0.52	3.65	22.98
Influenza	10	[-3.04, 1.58]	2.24	3.07	0.00	0.10	0.60	4.26	7.24
			2.97	2.85	0.17	0.17	2.72	5.58	6.45
MRSA	107	[-2.71, 3.02]	7.35	14.61	0.00	0.03	1.52	7.33	31.23
			7.20	14.53	0.00	0.03	1.27	6.08	33.70
VRE	164	[-2.25, 2.96]	9.31	16.48	0.00	0.20	1.87	8.98	38.97
			8.96	16.45	0.00	0.15	1.03	9.29	38.92
MRSA & VRE	15	[-20.14, 21.54]	29.04	37.10	0.13	1.52	19.80	45.63	105.71
			28.34	35.25	0.03	0.68	18.97	47.23	111.80
Non-cohortable	554	[-2.92, 3.70]	15.29	38.74	0.00	0.29	4.83	18.59	57.75
			14.90	38.40	0.00	0.35	4.05	18.35	55.92
By weekday of the bed request									
Sunday	689	[-0.77, 1.15]	4.97	12.54	0.00	0.10	0.55	3.20	30.81
			4.78	12.27	0.00	0.12	0.62	2.85	32.82
Monday	2,028	[-1.01, 0.74]	3.80	19.59	0.00	0.00	0.03	1.62	20.30
			3.94	19.77	0.00	0.00	0.00	1.82	20.90
Tuesday	2,013	[-0.77, 0.35]	5.73	12.50	0.00	0.00	1.03	4.68	26.96
			5.94	12.57	0.00	0.00	1.08	5.25	28.13
Wednesday	1,788	[-0.71, 0.19]	5.17	9.48	0.00	0.00	1.37	5.09	23.92
			5.43	9.53	0.00	0.00	1.52	5.65	25.52
Thursday	1,555	[-0.71, 0.31]	4.04	10.03	0.00	0.00	0.58	3.50	19.39
			4.24	10.02	0.00	0.00	0.78	4.08	19.82
Friday	1,885	[-0.53, 0.53]	4.50	11.52	0.00	0.00	0.32	3.20	25.25
			4.50	11.26	0.00	0.00	0.40	3.72	24.28
Saturday	813	[-0.87, 0.92]	5.67	12.69	0.00	0.12	1.13	4.72	33.41
			5.65	12.70	0.00	0.15	1.07	4.68	32.88
By specific floor destination (# beds)									
Ortho & Uro (36)	3,366	[-0.78, 0.27]	4.05	15.10	0.00	0.00	0.35	3.13	22.51
			4.30	15.24	0.00	0.00	0.48	3.92	23.02
Ortho (30)	2,522	[-0.59, 0.18]	3.58	9.54	0.00	0.00	0.22	2.50	21.65
			3.79	9.64	0.00	0.00	0.32	2.98	22.63
Gen. Surg. (36)	2,735	[-0.39, 0.59]	5.38	12.73	0.00	0.00	0.80	4.33	26.89
			5.28	12.61	0.00	0.00	0.65	4.18	26.82
Gen. Surg. (27)	2,148	[-0.73, 0.53]	6.48	14.51	0.00	0.00	1.23	5.43	31.63
			6.58	14.40	0.00	0.00	1.30	5.92	31.45

Table SM2 Additional simulation results for patients' waits for beds (in hours)

Source	Intervention	Average		$Q_{0.5}$		$Q_{0.75}$	
		Value	Δ_R	Value	Δ_R	Value	Δ_R
PACU	Base	2.59		0.00		2.34	
	SSE^0	2.49	−4.0	0.00		1.96	−16.4
	JIT+Pool+SSE^0	1.45	−44.0	0.00		1.00	−57.4
ED	Base	3.57		1.12		4.22	
	SSE^0	3.37	−5.5	0.98	−12.0	3.93	−6.8
	JIT+Pool+SSE^0	3.10	−13.1	0.81	−27.9	2.89	−31.5
Admissions	Base	10.59		3.71		11.28	
	SSE^0	10.40	−1.8	3.64	−1.8	10.71	−5.1
	JIT+Pool+SSE^0	9.25	−12.7	2.26	−39.1	9.70	−14.0
ICU	Base	26.85		21.31		35.45	
	SSE^0	26.37	−1.8	20.06	−5.9	35.24	−0.6
	JIT+Pool+SSE^0	24.80	−7.6	16.92	−20.6	34.09	−3.8
Floor	Base	9.08		2.75		5.77	
	SSE^0	8.80	−3.0	2.60	−5.4	5.63	−2.4
	JIT+Pool+SSE^0	8.14	−10.3	1.40	−49.1	4.38	−24.2
Overall	Base	4.76		0.54		4.05	
	SSE^0	4.78	0.3	0.43	−21.2	3.89	−4.0
	JIT+Pool+SSE^0	3.87	−18.8	0.37	−32.4	2.17	−46.4

Notes. See notes for Table 2 in the main text. The additional scenario added here, SSE^0, corresponds with *no* eligible SSE patients (i.e., SSE patients with length of stay at most one day) going to the inpatient surgical floors.

Table SM3 Simulation results for other metrics—daily averages for bed-idle time and occupancy

Intervention	Bed-idle time *(in hours)*		Operational occupancy *(%)*	
	Value (SE)	Δ_R	Value (SE)	Δ_A
Base	54.6 (0.008)		88.5 (0.004)	
SSE$^<$	54.5 (0.029)	−0.1	87.5 (0.006)	−1.0
SSE^0	53.9 (0.008)	−1.3	86.6 (0.004)	−1.9
JIT	7.2 (0.003)	−86.8	88.7 (0.004)	0.2
JIT+Pooling	7.7 (0.006)	−85.8	88.6 (0.005)	0.1
JIT+Pooling+SSE$^<$	7.8 (0.007)	−85.7	87.8 (0.006)	−0.7
JIT+Pooling+SSE^0	7.7 (0.005)	−85.8	87.0 (0.005)	−1.6

Notes. We denote standard errors (across 100 simulation runs) as "(SE)"; Δ_A and Δ_R denote absolute and relative (percentage) change as compared with "Base," respectively. Bed-idle time and occupancy are computed on a daily basis with weekends and holidays excluded.

Table SM4 ARIMA model coefficients and summary statistics for changes in **Daily Admissions**. Holiday, Interim, and Post are indicator (0/1) variables; day of week is relative to Sunday; AR_k and MA_k denote autoregressive and moving average terms of order k, respectively; AICc denotes corrected Akaike Information Criterion; and RMSE denotes root mean square error. Seasonal parameters are not estimated ($P = D = Q = 0$) and are therefore omitted. Coefficients not estimated are left blank.

Source	PACU (all)	PACU (non-SSE)	PACU (SSE)	ED	Admissions	ICU	Floor	*Overall*
Variable	*Coefficient (Standard error)*							
(Intercept)	1.94 (0.66)	1.55 (0.65)	0.38 (0.26)	7.88 (0.42)	1.29 (0.24)	1.79 (0.18)	0.28 (0.11)	13.18 (0.80)
Indicators								
Holiday	−21.67 (1.63)	−19.62 (1.53)	−1.62 (0.63)	−0.66 (1.03)	−2.46 (0.59)	0.94 (0.45)	−0.26 (0.28)	−23.72 (1.95)
Interim	−0.93 (0.80)	0.42 (0.95)	−1.15 (0.34)	0.68 (0.55)	−0.02 (0.32)	−0.03 (0.25)	0.37 (0.15)	0.10 (0.91)
Post	−0.59 (0.53)	0.32 (0.63)	−1.02 (0.23)	1.03 (0.37)	0.03 (0.21)	0.03 (0.17)	−0.21 (0.10)	0.31 (0.60)
Day of week								
Mon	25.04 (0.97)	23.54 (0.88)	1.48 (0.36)	−1.15 (0.59)	1.90 (0.34)	−0.97 (0.25)	−0.01 (0.16)	24.76 (1.22)
Tue	24.38 (0.91)	20.01 (0.86)	4.39 (0.35)	−1.86 (0.58)	1.73 (0.33)	−0.37 (0.26)	−0.07 (0.16)	23.80 (1.10)
Wed	21.13 (0.91)	18.67 (0.85)	2.48 (0.35)	−1.93 (0.58)	1.51 (0.33)	−0.39 (0.25)	0.20 (0.16)	20.51 (1.11)
Thu	14.40 (0.91)	12.18 (0.85)	2.23 (0.35)	−1.51 (0.58)	2.01 (0.33)	−0.22 (0.25)	0.45 (0.16)	15.11 (1.11)
Fri	19.93 (0.91)	16.67 (0.85)	3.31 (0.35)	−0.60 (0.57)	0.69 (0.33)	−0.02 (0.26)	0.04 (0.16)	20.05 (1.09)
Sat	1.33 (0.95)	0.85 (0.87)	0.42 (0.35)	−0.44 (0.58)	−0.12 (0.33)	0.35 (0.24)	0.33 (0.16)	1.41 (1.20)
AR_1	−0.09 (0.06)	1.74 (0.03)				−1.47 (0.04)		−0.16 (0.06)
AR_2		−0.91 (0.04)				−0.94 (0.05)		
MA_1		−1.78 (0.02)				1.52 (0.03)		
MA_2		0.98 (0.02)				0.95 (0.04)		
Measure	*Value*							
ARIMA parameters	(1,0,0)	(2,0,2)	(0,0,0)	(0,0,0)	(0,0,0)	(2,0,2)	(0,0,0)	(1,0,0)
AICc	1855.16	1819.15	1253.43	1562.71	1211.08	1060.00	734.75	1972.32
RMSE	4.34	4.05	1.69	2.75	1.58	1.22	0.74	5.22

Table SM5 ARIMA model coefficients and summary statistics for changes in **Weekday Daily Admissions**. Notation as in Table SM4.

Source	PACU (all)	PACU (non-SSE)	PACU (SSE)	ED	Admissions	ICU	Floor	*Overall*
Variable	*Coefficient (Standard error)*							
(Intercept)	1.99 (0.69)	1.80 (0.66)		7.90 (0.44)	1.38 (0.25)	1.77 (0.19)	0.32 (0.12)	13.30 (0.84)
Indicators								
Holiday	−21.66 (1.63)	−19.96 (1.55)	−1.64 (0.63)	−0.66 (1.03)	−2.44 (0.59)	0.94 (0.45)	−0.25 (0.28)	−23.71 (1.95)
Interim	−0.93 (0.80)	0.25 (0.83)	−1.11 (0.33)	0.68 (0.55)	−0.02 (0.32)	−0.03 (0.25)	0.37 (0.15)	0.10 (0.91)
Post-weekday	−0.50 (0.64)	0.86 (0.65)	−1.30 (0.26)	1.06 (0.43)	0.19 (0.25)	−0.01 (0.20)	−0.16 (0.12)	0.52 (0.73)
Post-weekend	−0.79 (1.03)	−0.63 (1.02)	−0.21 (0.38)	0.95 (0.68)	−0.37 (0.39)	0.12 (0.31)	−0.35 (0.18)	−0.20 (1.19)
Day of week								
Mon	24.97 (1.02)	23.20 (0.93)	1.92 (0.28)	−1.18 (0.62)	1.77 (0.35)	−0.94 (0.26)	−0.06 (0.17)	24.59 (1.26)
Tue	24.31 (0.96)	19.63 (0.91)	4.84 (0.26)	−1.89 (0.61)	1.60 (0.35)	−0.34 (0.28)	−0.11 (0.16)	23.63 (1.15)
Wed	21.06 (0.96)	18.30 (0.91)	2.93 (0.26)	−1.95 (0.61)	1.37 (0.35)	−0.36 (0.26)	0.15 (0.16)	20.34 (1.16)
Thu	14.33 (0.96)	11.81 (0.91)	2.67 (0.26)	−1.54 (0.61)	1.87 (0.35)	−0.19 (0.26)	0.40 (0.16)	14.93 (1.16)
Fri	19.87 (0.95)	16.27 (0.91)	3.75 (0.26)	−0.63 (0.60)	0.55 (0.35)	0.00 (0.27)	−0.01 (0.16)	19.88 (1.14)
Sat	1.33 (0.95)	0.93 (0.87)	0.59 (0.27)	−0.44 (0.58)	−0.11 (0.33)	0.35 (0.24)	0.33 (0.16)	1.42 (1.19)
AR_1	−0.09 (0.06)					−1.47 (0.04)		−0.16 (0.06)
AR_2						−0.94 (0.05)		
MA_1						1.52 (0.03)		
MA_2						0.95 (0.05)		
Measure	*Value*							
ARIMA parameters	(1,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(2,0,2)	(0,0,0)	(1,0,0)
AICc	1857.28	1823.71	1250.10	1564.86	1211.75	1062.10	736.13	1974.25
RMSE	4.34	4.13	1.68	2.75	1.57	1.22	0.74	5.22

Table SM6 ARIMA model coefficients and summary statistics for changes in **Bed Occupancy and Bed-Idle Time**. Notation as in Table SM4. Occupancy is measured on a scale of 0-100%, and bed-idle time is reported both overall and in number of daily idle-bed assignments.

Outcome	Occupancy (%)	Total daily bed-idle hours	Total daily bed-idle assignments
Variable	*Coefficient (Standard error)*		
(Intercept)	76.13 (0.89)		1.47 (0.62)
Indicators			
Holiday	−13.04 (1.53)	−50.11 (6.29)	−14.58 (1.45)
Interim	0.27 (1.92)	2.17 (3.34)	0.28 (0.78)
Post-weekday	−1.63 (1.41)	−20.44 (2.64)	1.68 (0.61)
Post-weekend	−4.90 (1.58)	3.91 (3.81)	0.25 (0.95)
Day of week			
Mon	13.32 (0.83)	64.20 (2.76)	17.01 (0.87)
Tue	18.87 (0.84)	41.95 (2.61)	11.87 (0.85)
Wed	18.08 (0.88)	29.38 (2.61)	7.96 (0.85)
Thu	14.11 (0.88)	26.29 (2.62)	6.53 (0.85)
Fri	13.16 (0.84)	35.13 (2.58)	9.58 (0.85)
Sat	4.12 (0.75)	2.97 (2.65)	−0.08 (0.80)
AR_1	1.40 (0.16)		
AR_2	−0.62 (0.12)		
MA_1	−0.93 (0.17)		
MA_2	0.41 (0.08)		
Measure	*Value*		
ARIMA parameters	(2,0,2)	(0,0,0)	(0,0,0)
AICc	1906.34	2718.30	1785.83
RMSE	4.59	16.76	3.86

Table SM7 Comparison of confidence interval (CI) estimates for changes in daily admissions for ARIMA models with and without weekly (7-day) seasonality. ARIMA parameters $(p, d, q)(P, D, Q)$ are also shown.

ARIMA type	Without seasonality		With seasonality	
Measure	CI	Parameters	CI	Parameters
Source				
PACU (all)	[−1.96,0.79]	(1,0,0)(0,0,0)	[−1.96,0.79]	(1,0,0)(0,0,0)
PACU (non-SSE)	[−1.31,1.94	(2,0,2)(0,0,0)	[−1.31,1.94]	(2,0,2)(0,0,0)
PACU (SSE)	[−1.60,−0.44]	(0,0,0)(0,0,0)	[−1.60,−0.44]	(0,0,0)(0,0,0)
ED	[0.09,1.98]	(0,0,0)(0,0,0)	[0.17,1.85]	(0,0,0)(0,0,1)
Admissions	[−0.52,0.57]	(0,0,0)(0,0,0)	[−0.52,0.57]	(0,0,0)(0,0,0)
ICU	[−0.40,0.46]	(2,0,2)(0,0,0)	[−0.43,0.50]	(2,0,2)(0,0,1)
Floor	[−0.47,0.04]	(0,0,0)(0,0,0)	[−0.41,−0.03]	(0,0,0)(1,0,1)
Overall	[−1.23,1.86]	(1,0,0)(0,0,0)	[−1.23,1.86]	(1,0,0)(0,0,0)

Table SM8 Implementation results for patients' waits for beds (in hours), **excluding holiday weeks**

Measure	Source	Measure value *(in hours)* Pre	Post	Change, Pre vs. Post Δ_A *(hours)*	Δ_R *(%)*
Average	PACU	2.60	1.48	-1.12 [$-1.79, -0.47$]	-43.2 [$-59.7, -21.2$]
	ED	4.00	2.45	-1.55 [$-2.72, -0.36$]	-38.7 [$-57.4, -8.2$]
	Admissions	9.41	6.34	-3.07 [$-6.57, 0.81$]	-32.6 [$-62.5, 12.0$]
	ICU	31.01	26.22	-4.78 [$-17.62, 6.63$]	-15.4 [$-45.9, 25.2$]
	Floor	4.85	0.95	-3.90 [$-7.42, -1.92$]	-80.4 [$-97.7, -51.9$]
	Overall	4.66	3.25	-1.41 [$-2.26, -0.45$]	-30.2 [$-44.6, -10.3$]
$Q_{0.5}$	PACU	0.10	0.00	-0.10 -	-100.00 -
	ED	1.97	0.68	-1.29 [$-2.11, -0.76$]	-65.7 [$-78.0, -51.1$]
	Admissions	2.75	1.43	-1.32 [$-2.26, -0.52$]	-47.9 [$-70.1, -20.4$]
	ICU	25.79	11.43	-14.36 [$-20.52, 2.22$]	-55.7 [$-71.8, 8.3$]
	Floor	3.08	0.20	-2.88 [$-5.13, -1.12$]	-93.5 [$-98.2, -23.3$]
	Overall	0.93	0.20	-0.73 [$-1.05, -0.49$]	-78.6 [$-86.7, -65.5$]
$Q_{0.75}$	PACU	2.37	0.94	-1.42 [$-2.00, -0.77$]	-60.2 [$-77.1, -38.9$]
	ED	5.08	2.39	-2.69 [$-5.07, -0.78$]	-53.0 [$-69.1, -14.8$]
	Admissions	8.02	4.33	-3.69 [$-13.05, 0.10$]	-46.0 [$-77.4, 0.7$]
	ICU	45.58	31.52	-14.06 [$-32.33, 13.04$]	-30.9 [$-52.5, 36.9$]
	Floor	5.82	1.70	-4.12 [$-7.42, -0.20$]	-70.8 [$-97.6, -1.5$]
	Overall	3.63	1.87	-1.77 [$-2.67, -1.05$]	-48.6 [$-60.9, -32.8$]

Notes. Changes are relative to the "Pre" period. Absolute changes and relative (percentage) changes are denoted Δ_A and Δ_R, respectively. Bootstrapped CIs are shown. All holiday weeks are excluded (7 weeks in pre, 0 weeks in post period).