Appendix A: Model Documentation

The system dynamics model used in this study is an expansion of the fully documented generic model of emergency patient flow that was populated with empirical evidence from the medical and administrative literature.[21] The documentation presented in this section is with regards to the changes and additions to the aforementioned model. Parameter values are set to fall in the ranges provided in the respective sources cited in this section, and are calibrated to maximize the face validity of the model against departmental occupancy rates. It should be noted that the term Dmnl in the documentations stands for dimensionless.

IMCU-Transfer Critical Patients

Model Section 1 shows the flow of IMCU-Transfer critical patients through the hospital.

Model Section 1 Variables and Equations	**Units**	**Source**
1. Admission of IMCU-Transfer Critical Patients to ICU(t) = ("Critical Patients Boarding in ED"(t) * "% IMCU-Transfer Critical Patients" * "Effect of ICU Occupancy on ICU Admission"(t)) / "Patient Transfer or Discharge Time"	Person/Day	
2. Patient Transfer or Discharge Time = 0.0416667	Day	
3. % IMCU -Transfer Critical Patients = 0.136 (13.6%) 0.23 (23%)	Dmnl	53 (see reference in the main article)

0.35 (35%) 0.76 (76%)		54 (see reference in the main article) 55 (see reference in the main article) 53 (see reference in the main article)
4. Effect of ICU Occupancy on ICU Admission = IF THEN ELSE(ICU Occupancy <1,1,0)	Dmnl	
5. IMCU-Transfer Critical Patients Receiving Critical Care in ICU(t) = ∫("Admission of IMCU-Transfer Critical Patients to ICU"(t) - "Completion of Critical Care for IMCU-Transfer Critical Patients"(t))dt + "Initial # of IMCU-Transfer Critical Patients Receiving Critical Care in ICU"	Person	
6. Initial # of IMCU-Transfer Critical Patients Receiving Critical Care in ICU = 0	Person	
7. Completion of Critical Care for IMCU-Transfer Critical Patients(t) = "IMCU-Transfer Critical Patients Receiving Critical Care in ICU"(t) / "ICU LOS for IMCU-Transfer Critical Patients"	Person/Day	
8. ICU LOS for IMCU-Transfer Critical Patients = 2.5	Day	54, 61 (see reference in the main article)

9. IMCU-Transfer Critical Patients in ICU Pending IMCU Admission(t) = ∫("Completion of Critical Care for IMCU-Transfer Critical Patients"(t) - "Admission of Ward-Transfer Critical Patients to IMCU"(t) - "Admission of Death-in-IMCU Critical Patients to IMCU"(t))dt + "Initial # of IMCU-Transfer Critical Patients in ICU Pending IMCU Admission"	Person	
10. Initial # of IMCU-Transfer Critical Patients in ICU Pending IMCU Admission = 0	Person	
11. Admission of Death-in-IMCU Critical Patients to IMCU(t) = ("IMCU-Transfer Critical Patients in ICU Pending IMCU Admission"(t) * "Effect of IMCU Occupancy on IMCU Admission"(t) * "% IMCU Mortality") / "Patient Transfer or Discharge Time"	Person/Day	
12. % IMCU Mortality= 0.01	Dmnl	[(2),51 (see reference in the main article)], 1(see reference in this file)
13. Effect of IMCU Occupancy on IMCU Admission = IF THEN ELSE(IMCU Occupancy<1, 1 , 0)	Dmnl	

14. Death-in-IMCU Critical Patients Receiving Intermediate Care in IMCU(t) = ∫("Admission of Death-in-IMCU Critical Patients to IMCU"(t) - "Death in IMCU"(t))dt + "Initial # of Death-in-IMCU Critical Patients Receiving Intermediate Care in IMCU"	Person	
15. Initial # of Death-in-IMCU Critical Patients Receiving Intermediate Care in IMCU = 0	Person	
16. Death in IMCU(t) = "Death-in-IMCU Critical Patients Receiving Intermediate Care in IMCU"(t) / "IMCU LOS for Critical Patients"	Person/Day	
17. IMCU LOS for Critical Patients = 1.54	Day	61, 52 (see reference in the main article)
18. Admission of Ward-Transfer Critical Patients to IMCU(t) = ("IMCU-Transfer Critical Patients in ICU Pending IMCU Admission(t)" * "Effect of IMCU Occupancy on IMCU Admission"(t) * (1-"% IMCU Mortality")) / "Patient Transfer or Discharge Time"	Person/Day	
19. Ward-Transfer Critical Patients Receiving Intermediate Care in IMCU(t) = ∫("Admission of Ward-Transfer Critical Patients to IMCU"(t) - "Completion of Intermediate Care for Ward-	Person	

Transfer Critical Patients"(t))dt + "Initial # of Ward-Transfer Critical Patients Receiving Intermediate Care in IMCU"		
20. Initial # of Ward-Transfer Critical Patients Receiving Intermediate Care in IMCU = 0	Person	
21. Completion of Intermediate Care for Ward-Transfer Critical Patients(t) = "Ward-Transfer Critical Patients Receiving Intermediate Care in IMCU"(t) / "IMCU LOS for Critical Patients"	Person/Day	
22. Ward-Transfer Critical Patients in IMCU Pending Ward Admission(t) = ∫("Completion of Intermediate Care for Ward-Transfer Critical Patients"(t) - "Admission of Death-in-Ward Critical Patients to Ward"(t) - "Admission of Discharge-from-Ward Critical Patients to Ward"(t))dt + "Initial # of Ward-Transfer Critical Patients in IMCU Pending Ward Admission"	Person	
23. Initial # of Ward-Transfer Critical Patients in IMCU Pending Ward Admission = 0	Person	
24. Admission of Death-in-Ward Critical Patients to Ward(t) = ("Ward-Transfer Critical Patients in IMCU Pending Ward Admission"(t) * "%IMCU-Transfer Critical Patients Mortality in Ward" *	Person/Day	

"Effect of Ward Occupancy on Ward Admission"(t)) / "Patient Transfer or Discharge Time"		
25. %IMCU-Transfer Critical Patients Mortality in Ward = 0.04	Dmnl	21 (see reference in the main article)
26. Effect of Ward Occupancy on Ward Admission = IF THEN ELSE(Ward Occupancy<1, 1 , 0)	Dmnl	
27. Death-in-Ward Critical Patients Receiving General Care in Ward(t) = ∫("Admission of Death-in-Ward Critical Patients to Ward"(t) - "IMCU-Transfer Critical Patients Death in Ward"(t))dt + "Initial # of Death-in-Ward Critical Patients Receiving General Care in Ward"	Person	
28. Initial # of Death-in-Ward Critical Patients Receiving General Care in Ward = 0	Person	
29. IMCU-Transfer Critical Patients Death in Ward(t) = "Death-in-Ward Critical Patients Receiving General Care in Ward"(t) / "Non-Survivors LOS in Ward"	Person/Day	
30. Non-Survivors LOS in Ward = 12.4	Day	2 (see reference in this file)
31. Admission of Discharge-from-Ward Critical Patients to Ward(t) = ("Ward-Transfer Critical	Person/Day	

Patients in IMCU Pending Ward Admission"(t) * "Effect of Ward Occupancy on Ward Admission"(t) * (1-"% IMCU-Transfer Critical Patients Mortality in Ward")) / "Patient Transfer or Discharge Time"		
32. Discharge-from-Ward Critical Patients Receiving General Care in Ward(t) = ∫("Admission of Discharge-from-Ward Critical Patients to Ward"(t) - "IMCU-Transfer Critical Patients Discharge from Ward"(t))dt + "Initial # of Discharge-from-Ward Critical Patients Receiving General Care in Ward"	Person	
33. Initial # of Discharge-from-Ward Critical Patients Receiving General Care in Ward = 0	Person	
34. IMCU-Transfer Critical Patients Discharge from Ward(t) = "Discharge-from-Ward Critical Patients Receiving General Care in Ward"(t) / "Ward LOS for IMCU-Transfer Critical Patients"	Person/Day	
35. Ward LOS for IMCU-Transfer Critical Patients = 7.1	Day	54 (see reference in the main article)

Table A-1: Model Section 1 Variables and Equations.

Capacity and Initial Value Documentation

	Unit	Value	Source
Number of ED beds	Person	16	18 [44 (see reference in the main article)] (88 EDs)
Number of ICU beds	Person	8	9 [3 (see reference in this file)] (89 ICUs)
Number of General Ward beds	Person	86*	

Table A-2: Capacity of Departments.

*We have used the proportion of the ICU beds to the whole hospital beds that is documented in the literature to calculate the number of beds in the ward. The ratio of ICU beds to whole hospital beds is documented to be around 2-8%[4] and 5-10%.[5] Using a value of 7.3 for this ratio, we assigned a value of 86 to the number of beds in the general ward.

Variables	Value
Initial # of Death-in-Ward Non-Critical Admitted Patients Receiving Emergency Care in ED	0.460532
Initial # of Death-in-Ward Non-Critical Admitted Patients Receiving Post Emergency Care in ED	0.101888
Initial # of Death-in-Ward Non-Critical Admitted Patients Receiving General Care in Ward	12.1246
Initial # of Non-Admitted Patients Receiving Emergency Care in ED	12.7902
Initial # of Death-in-ED Patients Receiving Emergency Care in ED	0.192895
Initial # of Non-Critical Admitted Patients Receiving Emergency Care in ED	1.95674
Initial # of Non-Critical Admitted Patients Receiving Post Emergency Care in ED	0.432908
Initial # of Non-Critical Admitted Patients Receiving General Care in Ward	51.516
Initial # of Critical Patients Receiving Emergency Care in ED	0.331527

Initial # of Critical Patients Boarding in ED	0.0783753
Initial # of Death-in-ICU Critical Patients Receiving Critical Care in ICU	0.845593
Initial # of Ward-Transfer Critical Patients Receiving Critical Care in ICU	5.68457
Initial # of Readmission-Required Critical Patients Receiving First Critical Care in ICU	0.246537
Initial # of Ward-Transfer Critical Patients in ICU Pending Ward Admission	0.0690982
Initial # of Readmission-Required Critical Patients in ICU Pending Ward Admission	0.00269497
Initial # of Discharge-from-Ward Critical Patients Receiving General Care in Ward	8.35811
Initial # of Death-in-Ward Critical Patients Receiving General Care in Ward	0.822543
Initial # of Readmitted Critical Patients Receiving Critical Care in ICU	0.189135
Initial # of Readmission-Required Critical Patients Receiving General Care in Ward	0.194037
Initial # of Critical Patients Requiring ICU Readmission in Ward Pending ICU Readmission	0.00269497
Initial # of Readmitted Death-in-ICU Patients Receiving Critical Care in ICU	0.111791

Table A-3: Initial Values of Stock Variables.

Cost Calculation Documentation

ICU Cost Calculation

Total ICU cost at the end of any year *n* within the simulation period is equal to the value of the variable "Total ICU Cost (Year n)" on the 365th day of year *n*. Model Section 2 shows the calculation method of the ICU operation expenses at year n.

Model Section 2 Variables and Equations	**Units**	**Source**
1. Increase in Accumulated Total ICU Occupancy (Year n) (t) = "ICU Occupancy"(t) *pulse((n-1)*365, 365)	Dmnl	

2. Accumulated Total ICU Occupancy (Year n) (t) = ∫ ("Increase in Accumulated Total ICU Occupancy (Year n)"(t))dt *pulse((n-1)*365, 365)	Day	
3. Average ICU Occupancy (Year n) (t) = ("Accumulated Total ICU Occupancy (Year n)"(t)/ "Day per Year")	Dmnl	
4. Day per Year = 365	Day	
5. ICU Cost per Inpatient Day = 2575	$/Day* Person	56 (see reference in the main article)
6. ICU Capacity = 8	Person	3 (see reference in this file
7. Total ICU Cost (Year n) = "ICU Capacity" *"Average ICU Occupancy (Year n)"(t) *"Day per Year" *"ICU Cost per Inpatient Day"	$	
Total ICU Cost at the end of year k = $\sum_{n=1}^{k} \text{Total ICU Cost}_n$, 1≤ k ≤10	$	

Table A-4: Model Section 2 Variables and Equations.

IMCU Cost Calculation

Model Section 3 shows the calculation method of the IMCU operation expenses at year n.

Model Section 3 Variables and Equations	**Units**	**Source**

1. Increase in Accumulated Total IMCU Occupancy (Year n) (t) = "IMCU Occupancy"(t) *pulse((n-1)*365, 365)	Dmnl	
2. Accumulated Total IMCU Occupancy (Year n) (t) = ∫ ("Increase in Accumulated Total IMCU Occupancy (Year n)"(t))dt *pulse((n-1)*365, 365)	Day	
3. Average IMCU Occupancy (Year n) (t) = ("Accumulated Total IMCU Occupancy (Year n) "(t)/ "Day per Year")	Dmnl	
4. Day per Year = 365	Day	
5. IMCU Cost per Inpatient Day = "ICU Cost per Inpatient Day"/"Ratio of ICU to IMCU Cost per Inpatient Day"	$/Day* Person	
6. Ratio of ICU to IMCU Cost per Inpatient Day = [1.35 – 3]	Dmnl	[56-60 (see reference in the main article)]
7. IMCU Capacity = 2	Person	
8. Total IMCU Cost (Year n) = "IMCU Capacity" *"Average IMCU Occupancy (Year n)"(t) *"Day per Year" *"IMCU Cost per Inpatient Day"	$	
Total IMCU Cost at the end of year k = $\sum_{n=1}^{k} \text{Total IMCU Cost}_n$, 1≤ k ≤10	$	

Table A-5: Model Section 3 Variables and Equation.

Ward Cost Calculation

Model Section 4 shows the calculation method of the Ward operation expenses at year n.

Model Section 4 Variables and Equations	Units	Source
1. Increase in Accumulated Total Ward Occupancy (Year n) (t) = "Ward Occupancy"(t) *pulse((n-1)*365, 365)	Dmnl	
2. Accumulated Total Ward Occupancy (Year n) (t) = ∫ ("Increase in Accumulated Total Ward Occupancy (Year n)"(t))dt *pulse((n-1)*365, 365)	Day	
3. Average Ward Occupancy (Year n) (t) = ("Accumulated Total Ward Occupancy (Year n)"(t)/ "Day per Year")	Dmnl	
4. Day per Year = 365	Day	
5. Ward Cost per Inpatient Day = 1488	$/Day* Person	56 (see reference in the main article)
6. Ward Capacity = 86	Person	
7. Total Ward Cost (Year n) = "Ward Capacity" *"Average Ward Occupancy (Year n)"(t) *"Day per Year" *"Ward Cost per Inpatient Day"	$	
Total Ward Cost at the end of year k = $\sum_{n=1}^{k} \text{Total Ward Cost}_n,$ 1≤ k ≤10	$	

Table A-6: Model Section 4 Variables and Equation.

Hospital Readmission

Model Section 5 documents the hospital readmission calculations.

Model Section 5 Variables and Equations	**Units**	**Source**
1. Discharge Rate of Readmission-Required Patients(t) = ("Critical Patients Discharge from Ward"(t) +"Non-Admitted Patients Discharge from ED"(t) +"Non-Critical Admitted Patients Direct Discharge from ED"(t) +"Non-Critical Admitted Patients Discharge from Ward"(t))*"% Hospital Readmission"	Person/Day	
2. % Hospital Readmission = 0.138	Dmnl	6,7 (see reference in this file)
3. Readmission-Required Patients(t) = ∫("Discharge Rate of Readmission-Required Patients"(t)-"Readmission Rate to Hospital"(t))dt + "Initial # of Readmission-Required Patients"	Person	
4. Initial # of Readmission-Required Patients = 439.432	Person	
5. Time Taken Until Readmission = 30	Day	6,7 (see reference in this file)
6. Readmission Rate to Hospital(t) = "Readmission-Required Patients"(t)/"Time Taken Until Readmission"	Person/Day	

Table A-7: Model Section 5 Variables and Equation.

Accumulated Total Hospital Mortality

Model Section 6 documents the Accumulated Total Hospital Mortality calculations under the IMCU introduction policy.

Model Section 6 Variables and Equations	Unit
1. Hospital-Wide Hourly Mortality Rate(t) ="Death in ED"(t)+ "Death in ICU"(t)+ "Death in Ward"(t)+ "Readmitted Patients Death in ICU"(t)+ "Non-Critical Admitted Patients Death in Ward"(t)+ "Non-Critical Admitted Patients Death in ED"(t)+ "IMCU-Transfer Critical Patients Death in Ward"(t)	Person/Hour
2. Accumulated Total Hospital Mortality(t)= ∫ "Hospital-Wide Hourly Mortality Rate"(t)dt Initial Value = 0	Person

Table A-8: Model Section 6 Variables and Equation.

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