Epidemic Surge Model Use to Improve Patient, Staff, and System Safety and Resiliency

Tool Status & Primary Accomplishments 2024

AHRQ grant R01HS028458
James Benneyan (PI)

January 1, 2025

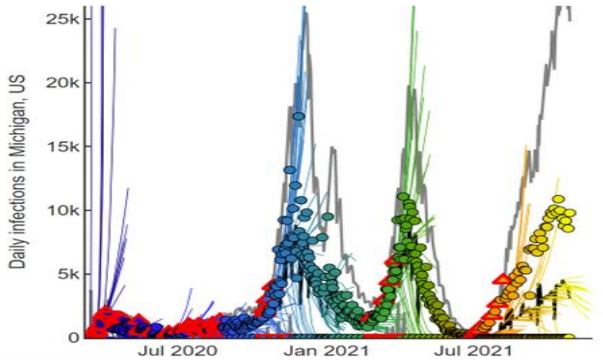
Grant – Big picture

Motivation	Epidemic (surge) and endemic (routine) hospital capacity, equipment demand, staff availability are common serious problems (even more so during Covid-19, currently, & expected future epidemics ($p \approx .47$, $t = 25$)). We were, and remain, unprepared. We should learn from the past and prepare for the future.
Deliverables	1. Improved tools (technically, features, usability) [aim 1] 2. Model use, perception, trust [aim 2] 3. Impact/value of models [aim 3] 4. Dissemination publications
Approach	1. Modeling, simulation, curve-fit forecasting, surveillance, optimization 2. Qualitative methods, surveys, interviews 3. Data analysis, scenario simulation, safety science methods 4. Paper writing

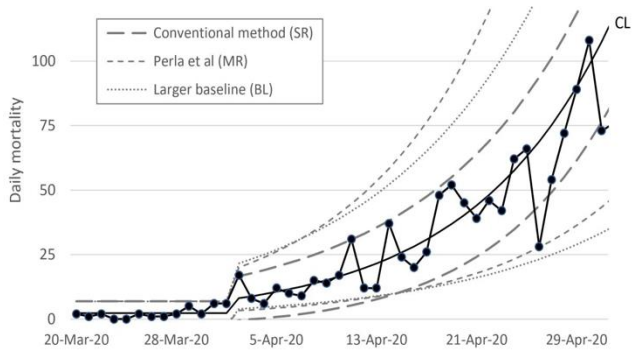
Illustration

Epidemic/Endemic Patterns

Daily infections (not well behaved "S" curve!)

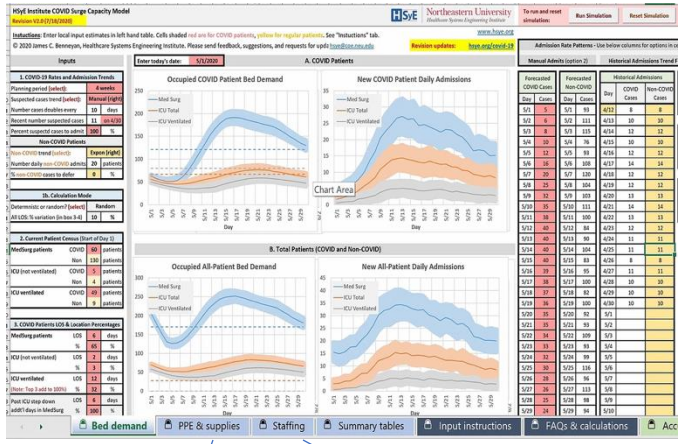


Phase changes



Hospital Capacity Models

(rolling basis ala weather app)

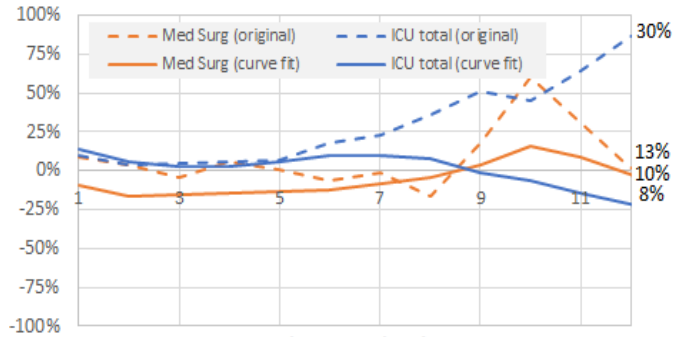


PPE and equipment sub-model

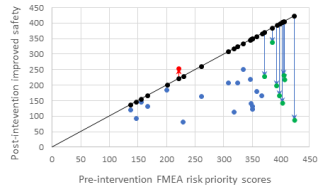
Staffing sub-model

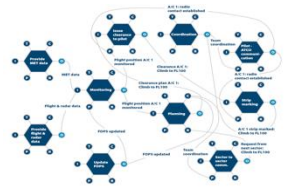
Model Use & Impact

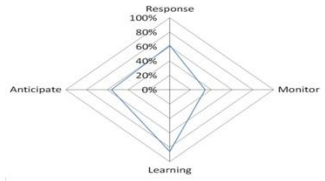
Accuracy

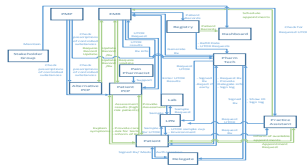


System Safety









Research Aims

(modeling aims)

1. Tool/Technical Improvements

a. Usability and accessibility
- Interface, UI, talk-throughs
- Online versions
- Easy updating and what if'ing

b. Accuracy and Performance
- Technical details
- Computation speed
- Self-adapting/optimizing

c. Features (tbd)
- Benchmark, accuracy analysis
- Long-term staff projections
- Generalizability (units, pats)
- Surveillance, alerting

(model use)

2. Tool Use / Qualitative Aims

a. Qualitative surveys and interviews

b. Hospital user group

- How used, perceived, trusted
- Decision-making process (and types of decisions)
- Past & future data for analysis and model refinement

(model impact - so what?)

3. Impact / Safety Aims

a. Data analysis
- Safe operating days (staffed beds, safe PPE levels, etc)

b. Qualitative
- Perceptions, walk throughs

c. Engineering methods
- FMEA, RAG studies
- Simulation scenario analysis

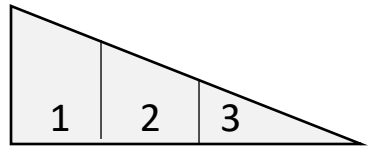
Secondary Research Aims

- Statistical surveillance methods
- Staffing modeling and impacts
- Epidemic modeling (multiple pops, game theory, 4-10 hybrid, infection ABM chains)

Grant timeline

	Research Activity	Year 1				Year 2				Year 3				Year 4				Year 5			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Aim 1. Modeling Research	Analysis of model accuracy Conduct usability analysis Implement identified technical extensions Model expansion beyond critical care	Years 1-3																			
Aim 2. Impact Research	Development of research data set Statistical impact analysis (retrospective) Simulation generalizability impact Safety science prospective analysis									Years 2-4											
Aim 3. Model Use Research	Develop focus group & survey materials Conduct model user survey (years 1, 3) Conduct three rounds of focus groups Results coding and analysis													Years 3-5							
Grant Management	Grant administration, IRB, DUAs, Hospital User Group semi-annual mtgs Advisory Committee semi-annual																				

Major accomplishments – Fall 2024



Aim 1 - Tool/Methods Technical

- Overhauled Excel version of tool
- Fully implemented online version of tool
- Thoroughly debugged and cross-validated both tools
- Expanded features: New case adaptive curve fitting, start-up logic, epidemic simulator, accuracy analysis and optimization

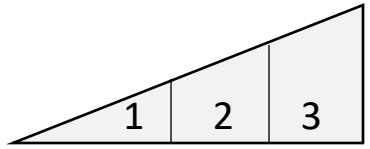
Aim 2 - Tool Use and Usability

- First round of usability studies (both tools)
- Addressed identified needs
- Finalized qualitative materials - user survey and interviews (year 2)
- Numerous UI improvements

Aim 3 - Tool Impact

- Developed simulation test bed and planned general impact studies
- Began preparing system science impact analysis plans and materials

Winter 2025 plans – Next steps



Aim 1 – Tool Technical

- Online tool – Benchmarking, optimization, auto-updating, auto accuracy, simulation, defaults
- Excel tool – Optimization, accuracy functions
- Expand EpiSim - Recurrent waves, system operational status, adaptive rules
- Analysis – Thorough impact, accuracy, and optimization analysis across multiple real and simulated conditions

Aim 2 – Tool Use and Usability

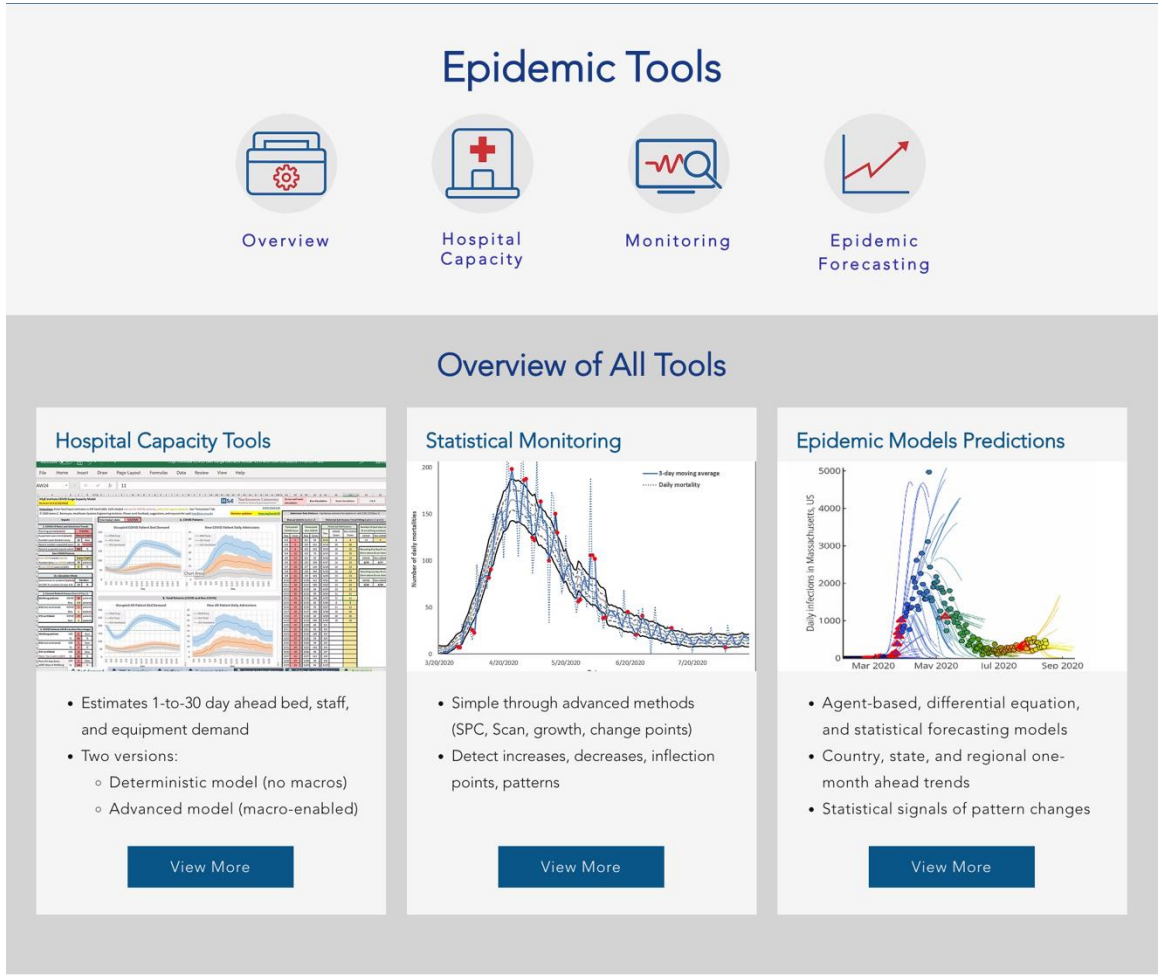
- Any/all outstanding 2024 action items
- Second round of usability analysis and address all identified needs (both tools)
- Complete survey and interviews of users/hospitals (use, impact, impressions)
- Smart-phone friendly and functional version of tool (or app)

Aim 3 – Tool Impact

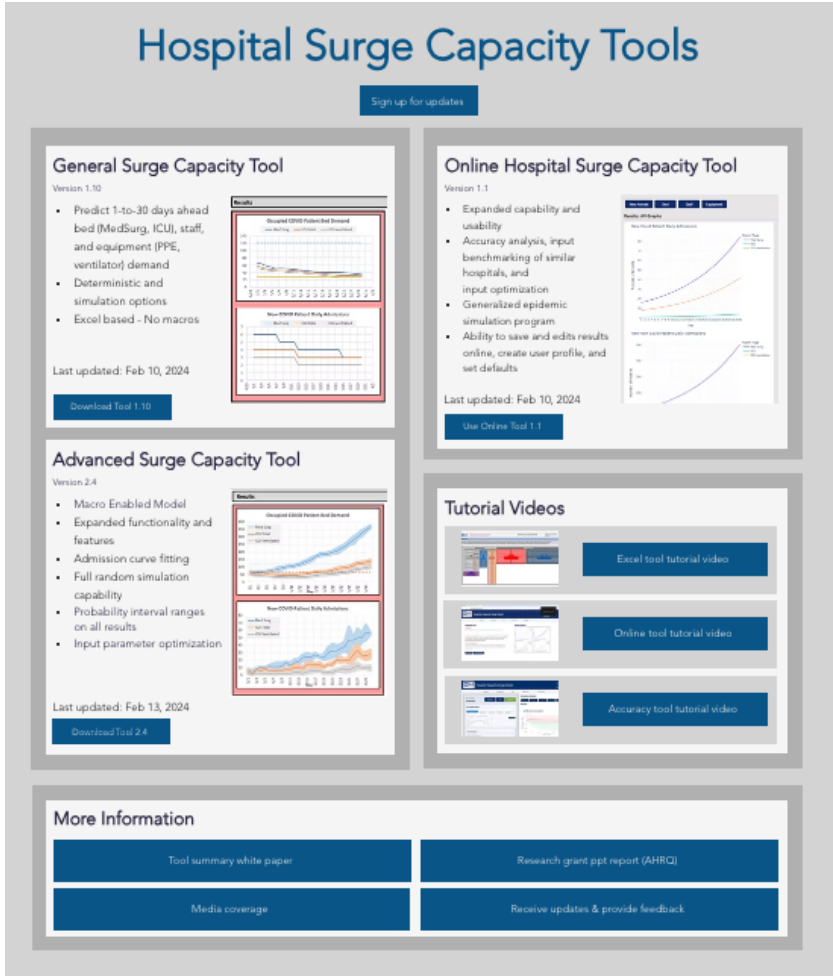
- Hospital user group
- Empirical – (a) Prospective use, accuracy, and impact. (b) Retrospectively apply rule base to 2020-onwards data
- Simulation – System safety and adaptive rule base under varied conditions
- System science – Failure and resiliency analysis (FMEA, RAG)

Tools website

Landing Page



Capacity Tools Page



Excel tool

[Click for video demo (5 min)]

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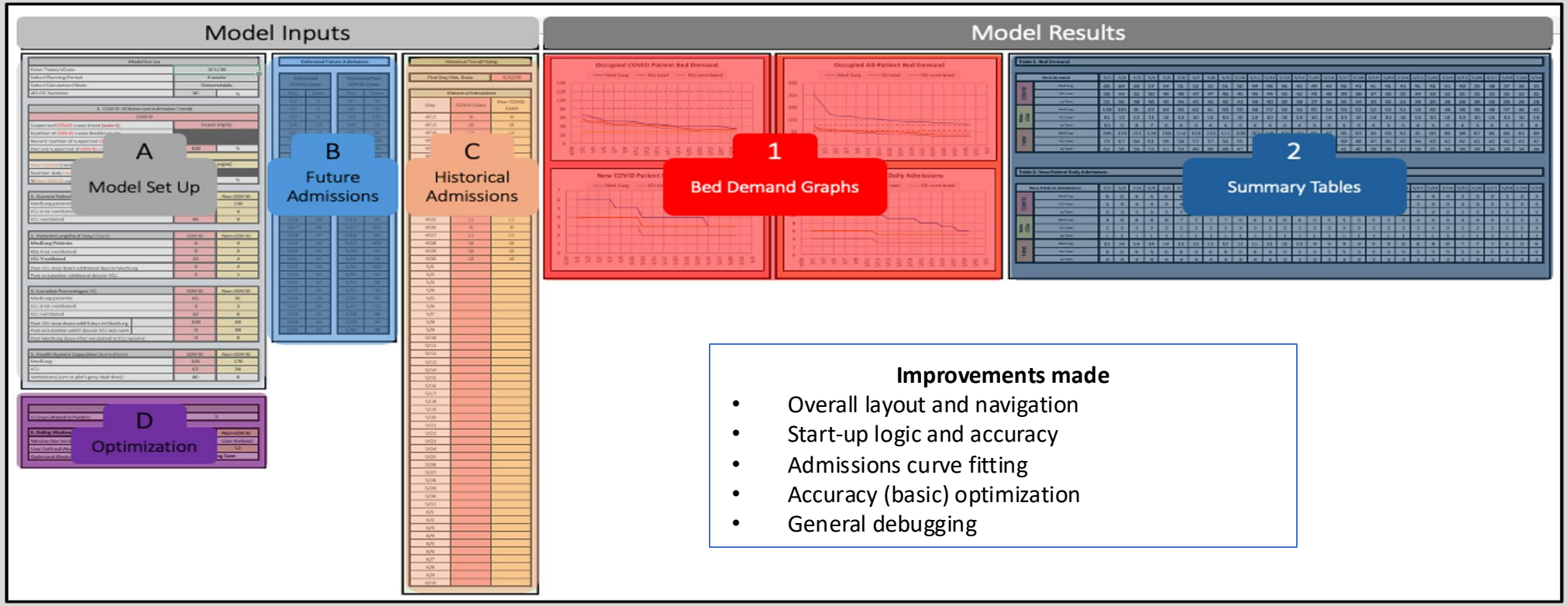
COVID Surge Capacity Model

version: 1.10 - Deterministic
revision date: Jan 29, 2024
hsye.org

About Tool

Estimates 1-30 day ahead bed demand for MedSurg, ICU, and ventilated patients given inputs about new suspected cases, lengths-of-stay, patient types, and current census.
For a more advanced tool (uses macros) that includes alternate new case assumptions, random simulation, and probability intervals please visit www.hsye.org/covid-19.

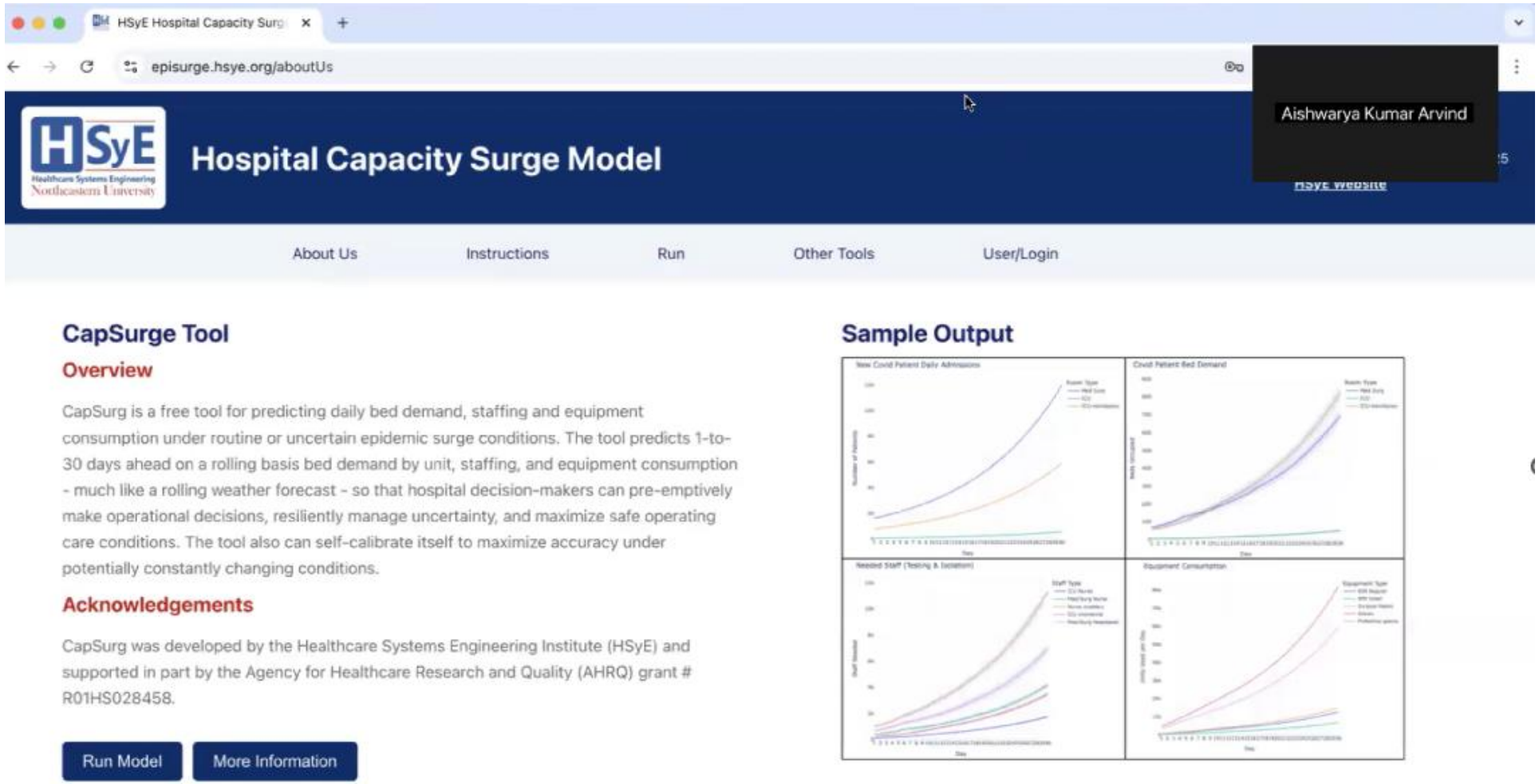


Improvements made

- Overall layout and navigation
- Start-up logic and accuracy
- Admissions curve fitting
- Accuracy (basic) optimization
- General debugging

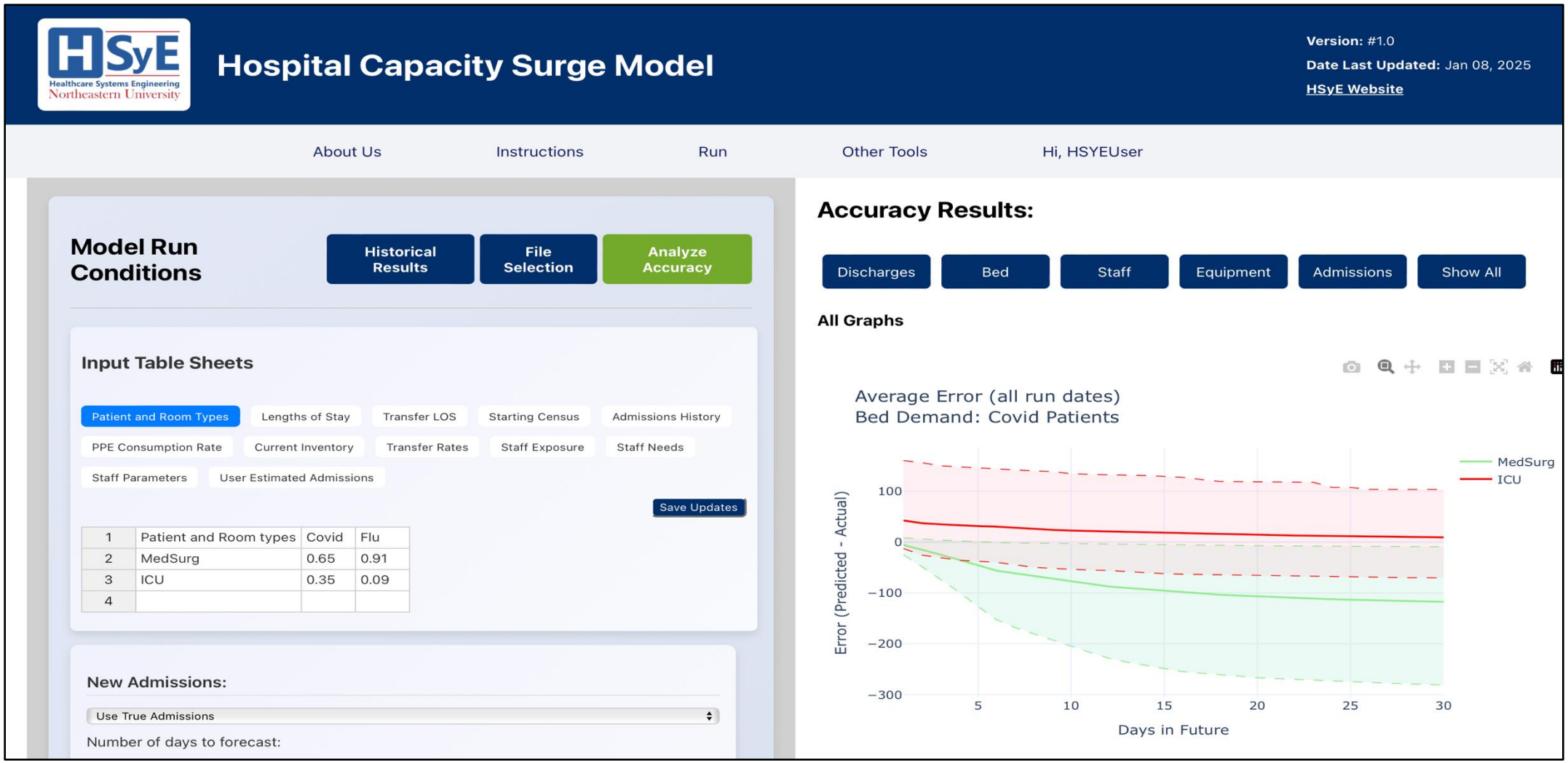
Online tool

[Click for video demo (5 min)]



Tool accuracy

[Click for video demo (5 min)]

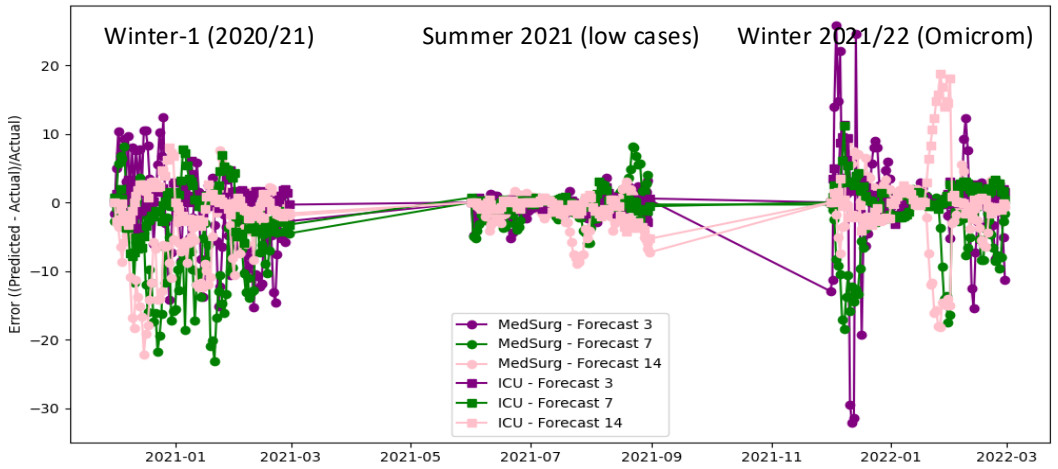


Accuracy results examples

Bed demand

Staff availability

Hospital 1 (large AMC)



Hospital 2 (small rural hospital)

Input benchmarks

Filters

Hospital Type: All

Date Range: 2020/01/01 – 2023/12/31

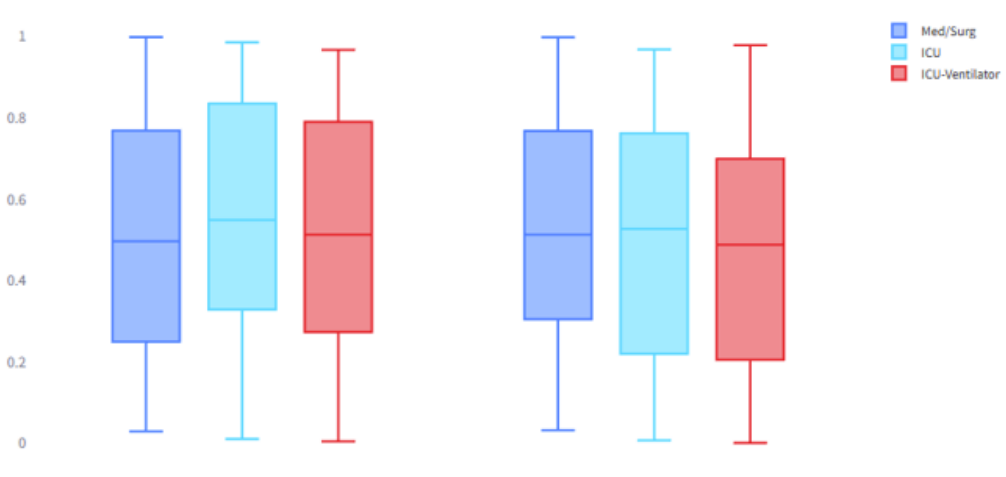
Input Type: User Input

Patient Type: All

Benchmarking Dashboard

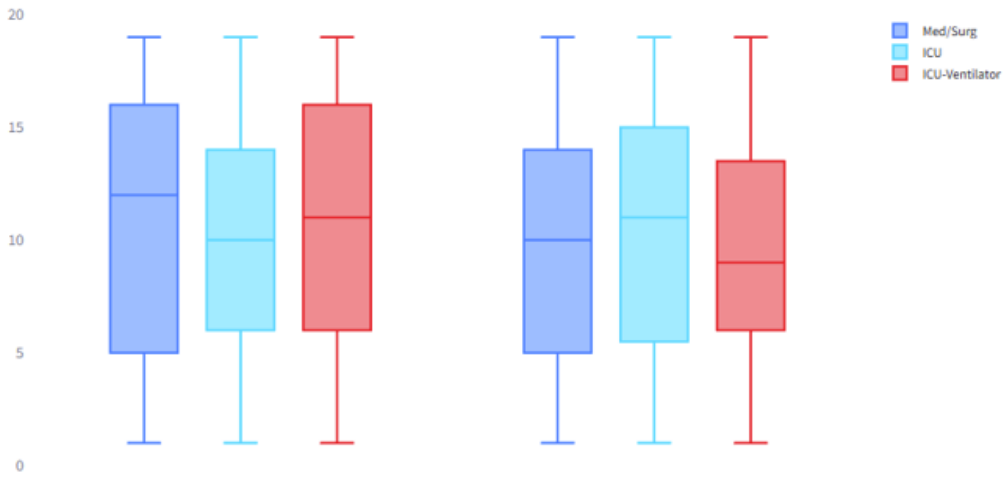
Beds | Staff | Equipment

Admission Percentages



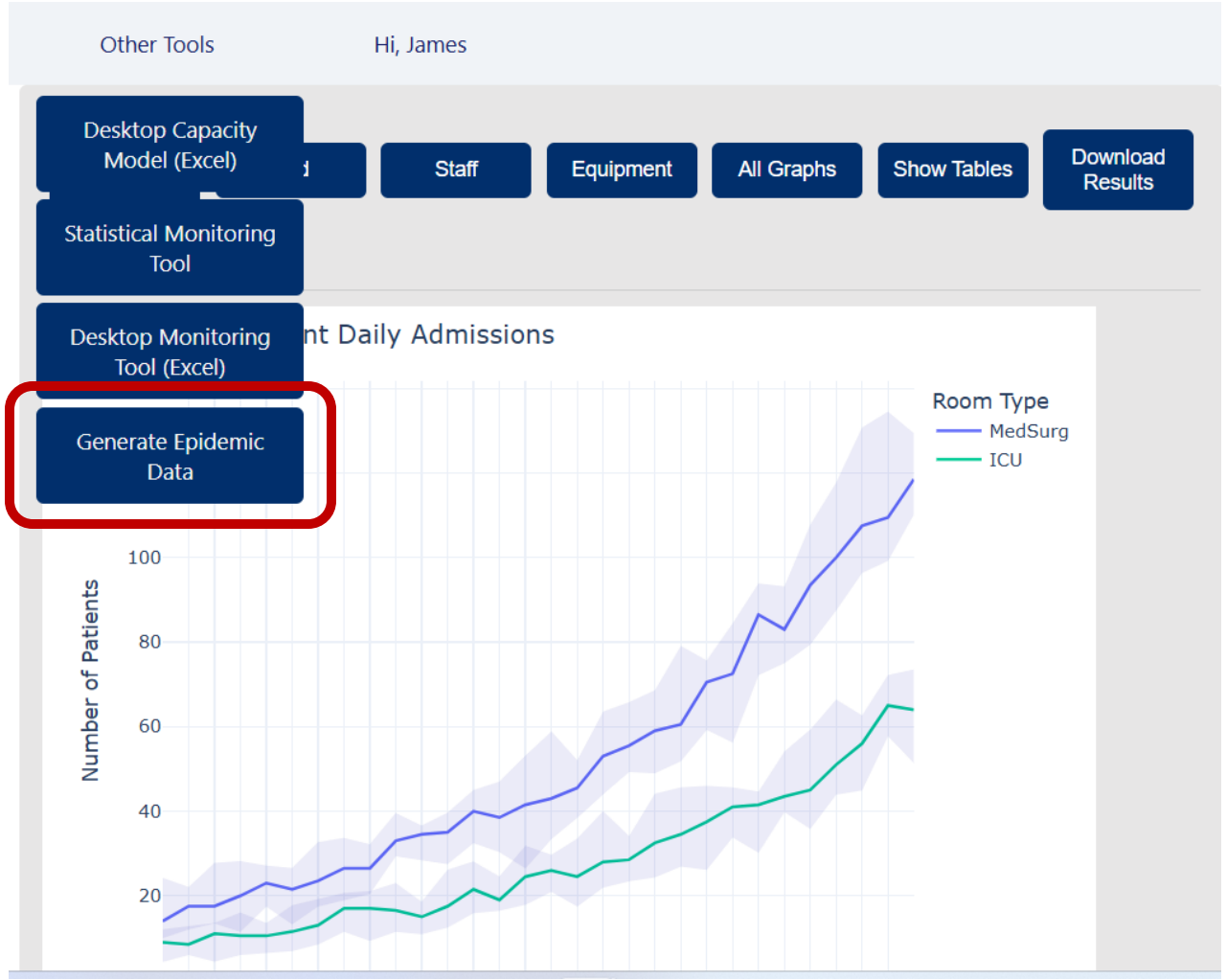
Patient Type	Med/Surg	ICU	ICU-Ventilator
Covid	mean: 0.50 std: 0.29	mean: 0.55 std: 0.29	mean: 0.51 std: 0.29
Non Covid	mean: 0.51 std: 0.26	mean: 0.50 std: 0.30	mean: 0.46 std: 0.29

Length of Stay



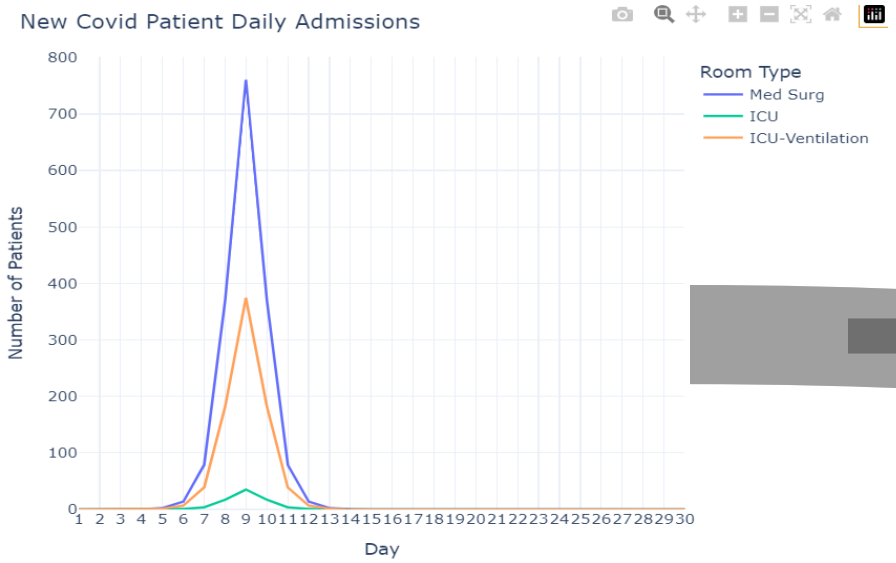
Patient Type	Med/Surg	ICU	ICU-Ventilator
Covid	mean: 10.76 std: 5.66	mean: 10.09 std: 5.28	mean: 10.43 std: 5.73
Non Covid	mean: 9.41 std: 5.36	mean: 10.67 std: 5.47	mean: 9.36 std: 4.98

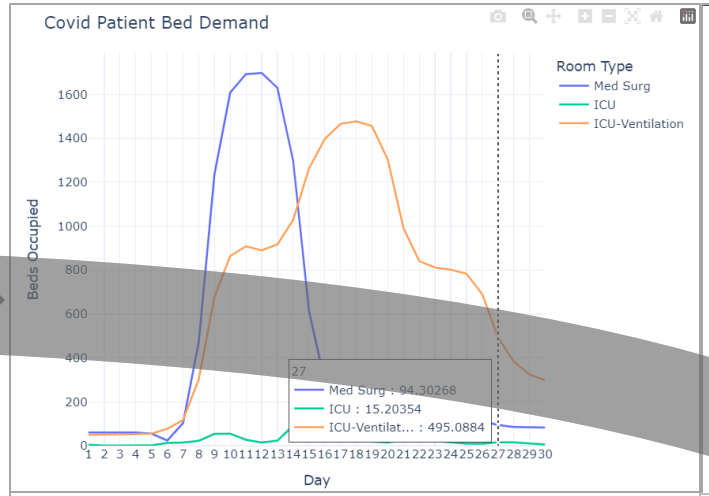
Epidemic simulator and data scenarios

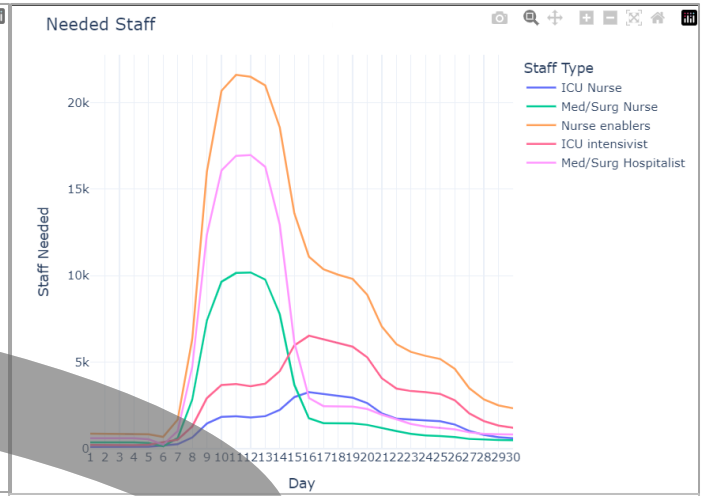


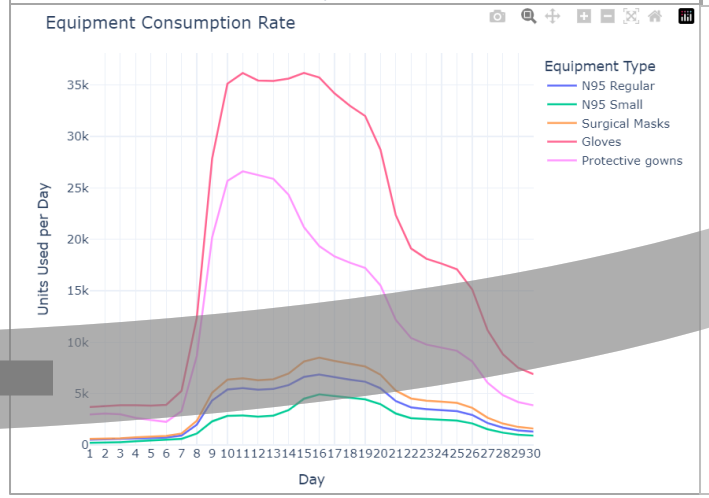
- Generic simulation program to generate any varied epidemic behaviors, waves, and severities of admissions, bed demand, equipment, and staff shortages
- Simulates tool use and impact under varied accuracy and decision-making behaviors
- Curated 11 hospital research data set for scenario analysis (obtaining more)
- Evaluates impact of types of pre-emptive actions on operational status and care quality (see next slide)

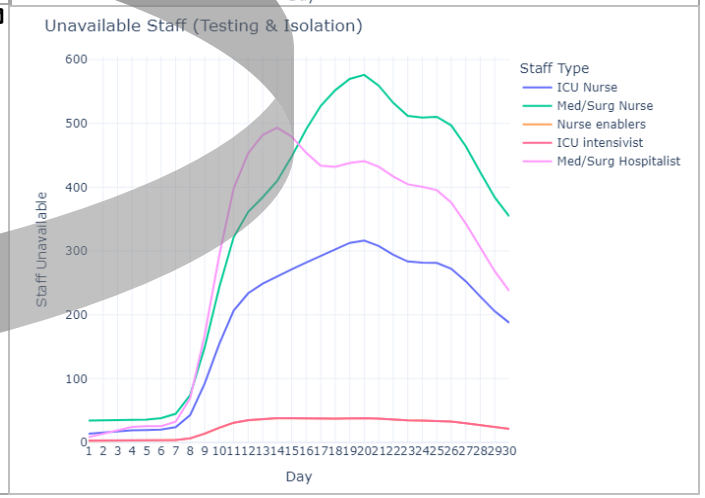
Results example - EpiSim

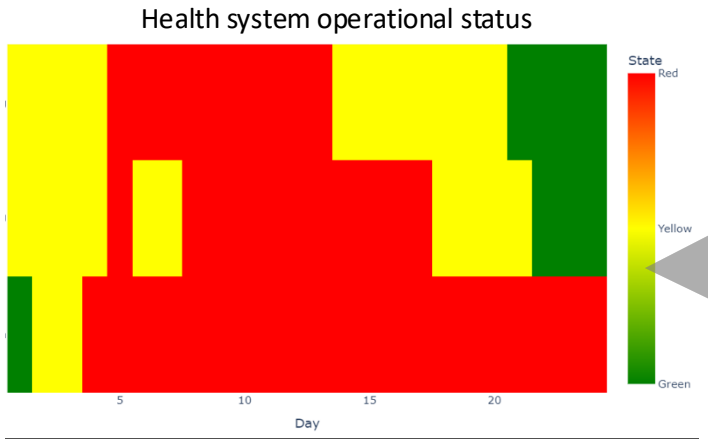




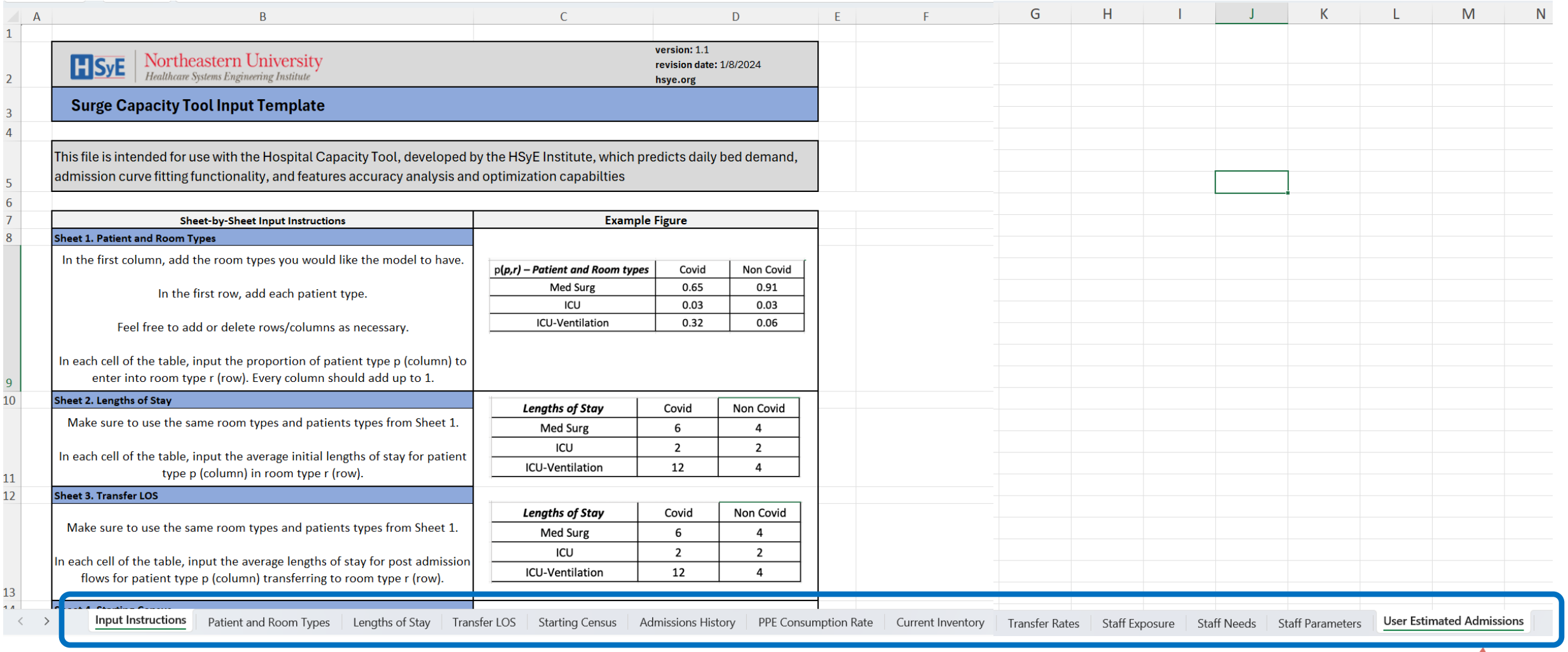








Input file A (to run online tool)



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version: 1.1
revision date: 1/8/2024
hsye.org

Surge Capacity Tool Input Template

This file is intended for use with the Hospital Capacity Tool, developed by the HSyE Institute, which predicts daily bed demand, admission curve fitting functionality, and features accuracy analysis and optimization capabilties

Sheet-by-Sheet Input Instructions	Example Figure
Sheet 1. Patient and Room Types In the first column, add the room types you would like the model to have. In the first row, add each patient type. Feel free to add or delete rows/columns as necessary. In each cell of the table, input the proportion of patient type p (column) to enter into room type r (row). Every column should add up to 1.	
Sheet 2. Lengths of Stay Make sure to use the same room types and patients types from Sheet 1. In each cell of the table, input the average initial lengths of stay for patient type p (column) in room type r (row).	
Sheet 3. Transfer LOS Make sure to use the same room types and patients types from Sheet 1. In each cell of the table, input the average lengths of stay for post admission flows for patient type p (column) transferring to room type r (row).	

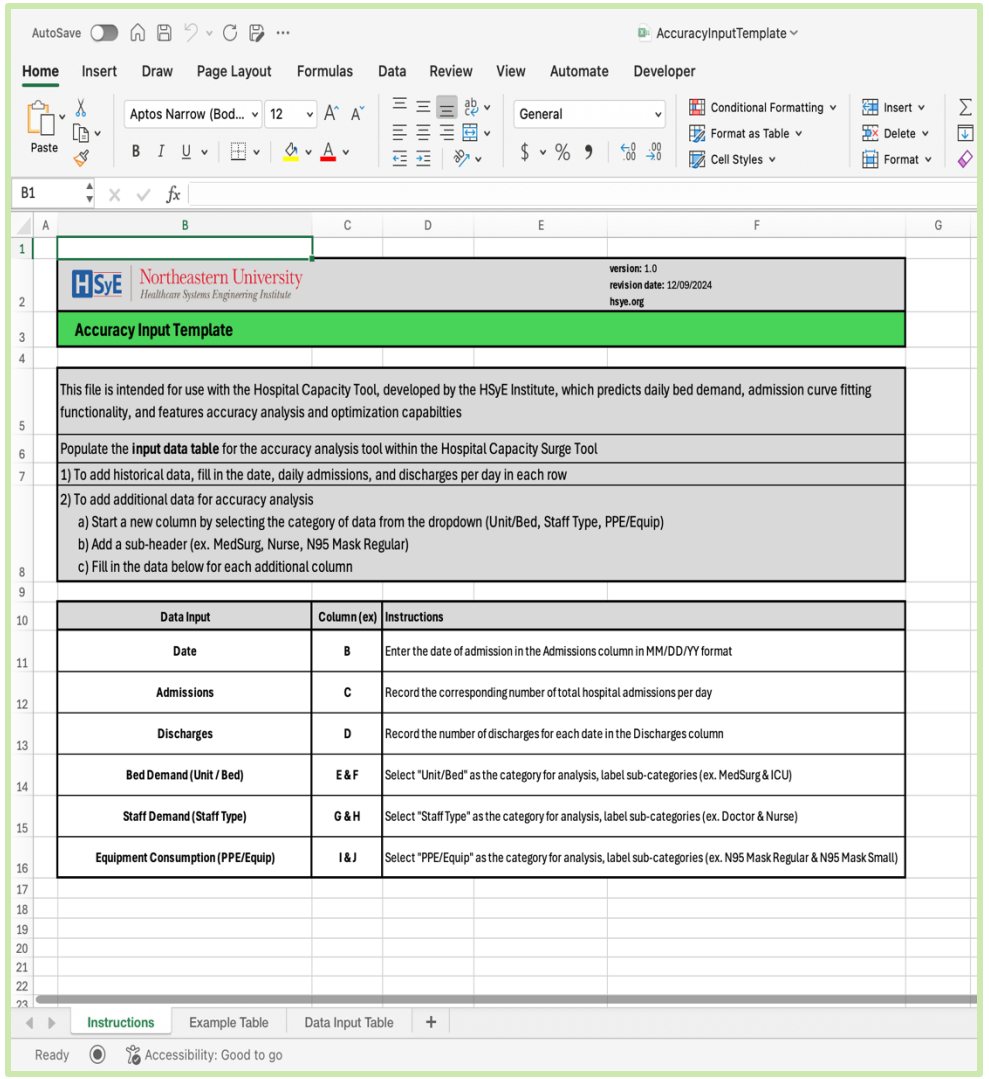
p(p,r) – Patient and Room types	Covid	Non Covid
Med Surg	0.65	0.91
ICU	0.03	0.03
ICU-Ventilation	0.32	0.06

Lengths of Stay	Covid	Non Covid
Med Surg	6	4
ICU	2	2
ICU-Ventilation	12	4

Lengths of Stay	Covid	Non Covid
Med Surg	6	4
ICU	2	2
ICU-Ventilation	12	4

Input Instructions | Patient and Room Types | Lengths of Stay | Transfer LOS | Starting Census | Admissions History | PPE Consumption Rate | Current Inventory | Transfer Rates | Staff Exposure | Staff Needs | Staff Parameters | User Estimated Admissions

Input file B (for accuracy analysis)



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Accuracy Input Template

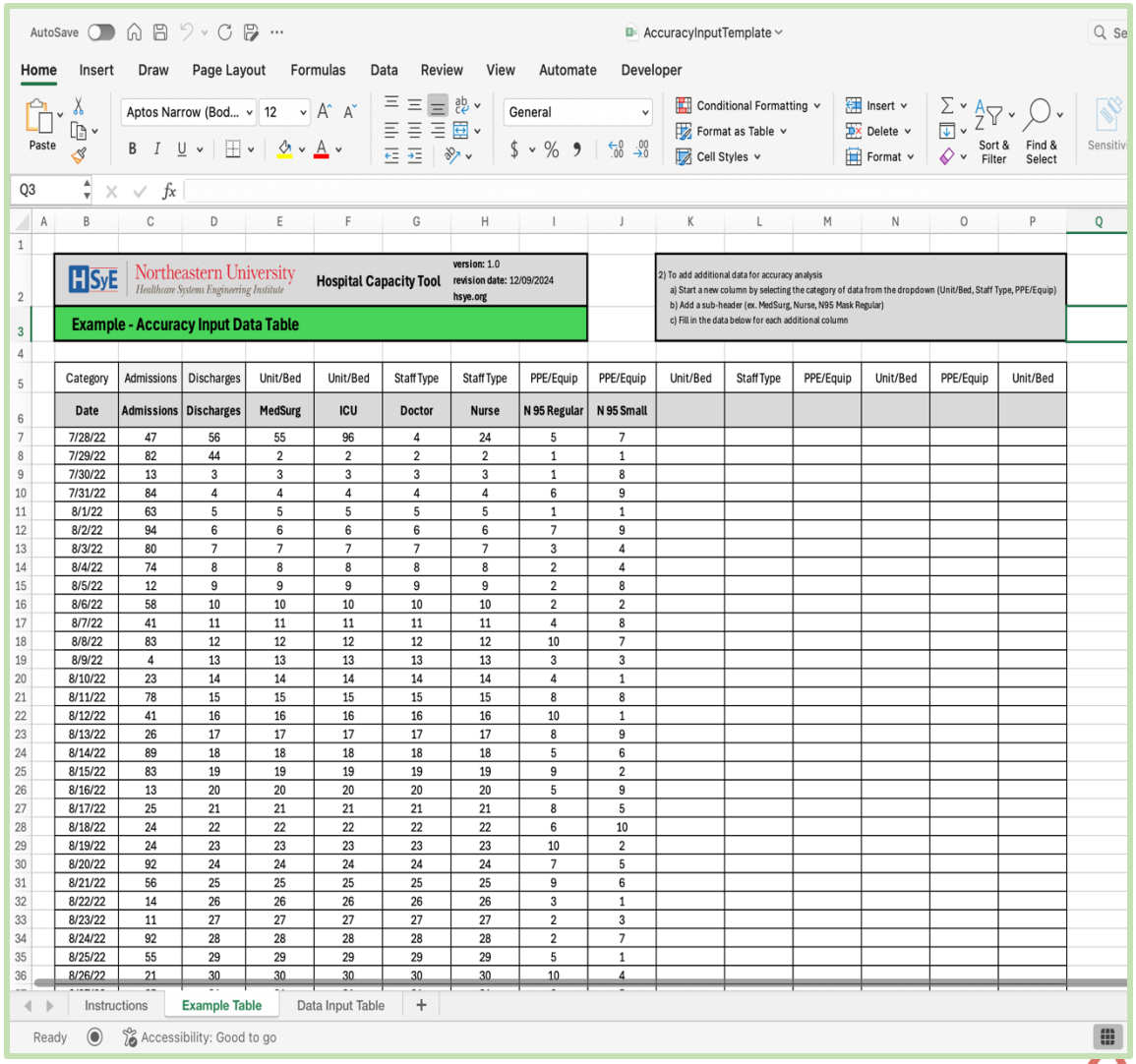
This file is intended for use with the Hospital Capacity Tool, developed by the HSyE Institute, which predicts daily bed demand, admission curve fitting functionality, and features accuracy analysis and optimization capabilities

Populate the **input data table** for the accuracy analysis tool within the Hospital Capacity Surge Tool

1) To add historical data, fill in the date, daily admissions, and discharges per day in each row

2) To add additional data for accuracy analysis
   a) Start a new column by selecting the category of data from the dropdown (Unit/Bed, Staff Type, PPE/Equip)
   b) Add a sub-header (ex. MedSurg, Nurse, N95 Mask Regular)
   c) Fill in the data below for each additional column

Data Input	Column (ex)	Instructions
Date	B	Enter the date of admission in the Admissions column in MM/DD/YY format
Admissions	C	Record the corresponding number of total hospital admissions per day
Discharges	D	Record the number of discharges for each date in the Discharges column
Bed Demand (Unit / Bed)	E & F	Select "Unit/Bed" as the category for analysis, label sub-categories (ex. MedSurg & ICU)
Staff Demand (Staff Type)	G & H	Select "Staff Type" as the category for analysis, label sub-categories (ex. Doctor & Nurse)
Equipment Consumption (PPE/Equip)	I & J	Select "PPE/Equip" as the category for analysis, label sub-categories (ex. N95 Mask Regular & N95 Mask Small)



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Hospital Capacity Tool

version: 1.0
revision date: 12/09/2024
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Example - Accuracy Input Data Table

2) To add additional data for accuracy analysis
a) Start a new column by selecting the category of data from the dropdown (Unit/Bed, Staff Type, PPE/Equip)
b) Add a sub-header (ex. MedSurg, Nurse, N95 Mask Regular)
c) Fill in the data below for each additional column

Category	Admissions	Discharges	Unit/Bed	Unit/Bed	Staff Type	Staff Type	PPE/Equip	PPE/Equip	Unit/Bed	Staff Type	PPE/Equip	Unit/Bed	PPE/Equip	Unit/Bed
Date	Admissions	Discharges	MedSurg	ICU	Doctor	Nurse	N 95 Regular	N 95 Small						
7/28/22	47	56	55	96	4	24	5	7						
7/29/22	82	44	2	2	2	2	1	1						
7/30/22	13	3	3	3	3	3	1	8						
7/31/22	84	4	4	4	4	4	6	9						
8/1/22	63	5	5	5	5	5	1	1						
8/2/22	94	6	6	6	6	6	7	9						
8/3/22	80	7	7	7	7	7	3	4						
8/4/22	74	8	8	8	8	8	2	4						
8/5/22	12	9	9	9	9	9	2	8						
8/6/22	58	10	10	10	10	10	2	2						
8/7/22	41	11	11	11	11	11	4	8						
8/8/22	83	12	12	12	12	12	10	7						
8/9/22	4	13	13	13	13	13	3	3						
8/10/22	23	14	14	14	14	14	4	1						
8/11/22	78	15	15	15	15	15	8	8						
8/12/22	41	16	16	16	16	16	10	1						
8/13/22	26	17	17	17	17	17	8	9						
8/14/22	89	18	18	18	18	18	5	6						
8/15/22	83	19	19	19	19	19	9	2						
8/16/22	13	20	20	20	20	20	5	9						
8/17/22	25	21	21	21	21	21	8	5						
8/18/22	24	22	22	22	22	22	6	10						
8/19/22	24	23	23	23	23	23	10	2						
8/20/22	92	24	24	24	24	24	7	5						
8/21/22	56	25	25	25	25	25	9	6						
8/22/22	14	26	26	26	26	26	3	1						
8/23/22	11	27	27	27	27	27	2	3						
8/24/22	92	28	28	28	28	28	2	7						
8/25/22	55	29	29	29	29	29	5	1						
8/26/22	21	30	30	30	30	30	10	4						

Input file C (for EpiSim)

Choose Mode:	Deterministic		Number of Replications	1		p_admitted	1
Choose Pattern:	Logistic						
		Patient Types					
Pattern Type	Parameter	Covid	Non Covid				
Doubling Days	Intercept	23	98				
	Days to Double	8	8				
Exponential	Intercept	3.684992212	4.547718536				
	Rate	-0.03994116	0.00638474				
Logistic	L	1.28E+03	4.59E+03				
	k	0.115124695	8.93E-02				
	x0	2.62E-19	8.17E+00				
Polynomial	Coefficients	-1.2043956, 38.97142857	0.60879121, 94.82857143				

Staffing Needs | Staffing Status | User Estimated Admissions | Research Conditions

Thresholds	Bed Demands		
	Med Surg	ICU	ICU-Ventilation
(Green) Under:	30	30	20
(Yellow) Between Green and:	70	80	50
(Red) Above:	70	80	50

Thresholds	Remaining Staff				
	ICU Nurse	Med/Surg Nurse	Nurse enablers	ICU intensivist	Med/Surg Hospitalist
(Green) Above:	90	180	148	89	106
(Yellow) Between Green and:	85	170	146	87	104
(Red) Under:	85	170	146	87	104

Logic improvements / debugging

- Exhaustively cross-checked Excel and online tool under range of conditions
- Deterministic vs simulation results cross-validation
- Admission fitting, hospital measures (beds, staff, equipment)
- Extreme “edge” cases
- Usability standard task, error finding
- Corrected multiple errors (rounding, start-up logic, curve fitting offsets, logistic growth logic, LOS > forecast period, others)
-
-

Usability improvements

Tool		How difficult or easy was completing the task?	How long did it take to complete exercise?	To what extent were you able to understand the results?	How mentally demanding was the task?	How hurried or rushed was the pace?	How hard did you work to accomplish task?	How successful were you in accomplishing what you were asked to do?	How frustrated, irritated, or stressed were you to complete ask?
		(1:Difficult 10: Easy)	Minutes	(1:Not 10: Completely)	(1:Not 10: Extremely)	(1:Not 10: Extremely)	(1:Not 10: Extremely)	(1: Perfect 10: Failure)	(1:Not 10: Extremely)
Excel Tool (n = 7)	Min	4	20	4	2	2	2	2	1
	Max	8.5	65	8.5	9	6	8	6	8
	Mean	**6**	**46.4**	**6.6**	**6.3**	**4.6**	**4.9**	**3.4**	**4.1**
Online Tool (n = 4)	Min	5.5	20	4	2	1	2	1	1
	Max	8.5	30	10	3	6	3	8	3
	Mean	**7.5**	**25**	**7.4**	**2.5**	**3**	**2.5**	**4.3**	**2.3**
Improved	% Better	25%	46%	12%	62%	35%	49%	(26%)	44%
	p	.0294	.0020	.2000	.0016	.1000	.0040	.7300	.0430

Usability examples

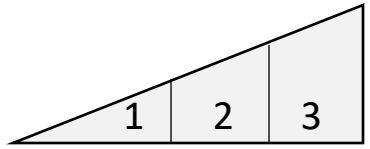
Excel Tool

	Challenges Identified	Improvements Identified and Made
1	**Layout and Navigation:** *Overwhelming interface, especially for first-time users.*	• Restructured interface to group results for better organization • Made color coding consistent • Standardized terminology
2	**Language and Instructions:** *Need for concise explanations*	• Changed text in pop-ups tom improve understanding and simplicity
3	**Interpretation of Results:** *Difficulty in reading model outputs*	• Simplified graphs with cleaner layouts • Reduced clutter and improved color contrast
4	**Visual Clarity:** *Charts and Titles*	• Aligned titles with consistent terminology, using larger texts • Standardized chart dimensions
5	**Run problems:** *Difficulty due to adjusting certain settings manually*	• Implemented feature that auto-checks necessary settings • Sheet lock restrictions for users

Online Tool

	Challenges Identified	Improvements Identified and Made
1	**Graph outputs:** *Difficult to read and interpret*	• Fewer significant digits for readability • Enhanced output table format
2	**Usability and navigation**: Clunky UI with design flaws	• Enhanced UI for better usability and clarity • Improved the scaling of objects to adapt across different screen sizes
3	**Bugs and Crashes:** *Tool crashes when switching between curve fit types*	• Fixed bug that caused a crash when switching curve fitting types • Corrected issues with input table edits
4	**Model Simulation:** *Inconsistencies with higher replications.*	• Fixed issues causing some simulation results to not display correctly • Refined graph updates and backend processes
5	**File Management and Upload Process**	• Added functionality to delete or archive unused files • Improved Excel input file so intuitive for users

Winter 2025 plans – Next steps



Aim 1 – Tool Technical

- Online tool – Benchmarking, optimization, auto-updating, auto accuracy, simulation, defaults
- Excel tool – Optimization, accuracy functions
- Expand EpiSim - Recurrent waves, system operational status, adaptive rules
- Analysis – Thorough impact, accuracy, and optimization analysis across multiple real and simulated conditions

Aim 2 – Tool Use and Usability

- Any/all outstanding 2024 action items
- Second round of usability analysis and address all identified needs (both tools)
- Complete survey and interviews of users/hospitals (use, impact, impressions)
- Smart-phone friendly and functional version of tool (or app)

Aim 3 – Tool Impact

- Hospital user group
- Empirical – (a) Prospective use, accuracy, and impact. (b) Retrospectively apply rule base to 2020-onwards data
- Simulation – System safety and adaptive rule base under varied conditions
- System science – Failure and resiliency analysis (FMEA, RAG)

More information

For more information:

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Participation opportunities:

1. Tool use survey: Take survey here
2. Provide general feedback (functionality, usability, etc) – email or zoom
3. Tool beta-testers (hospital user group)
4. Accuracy analysis (past or prospective data)