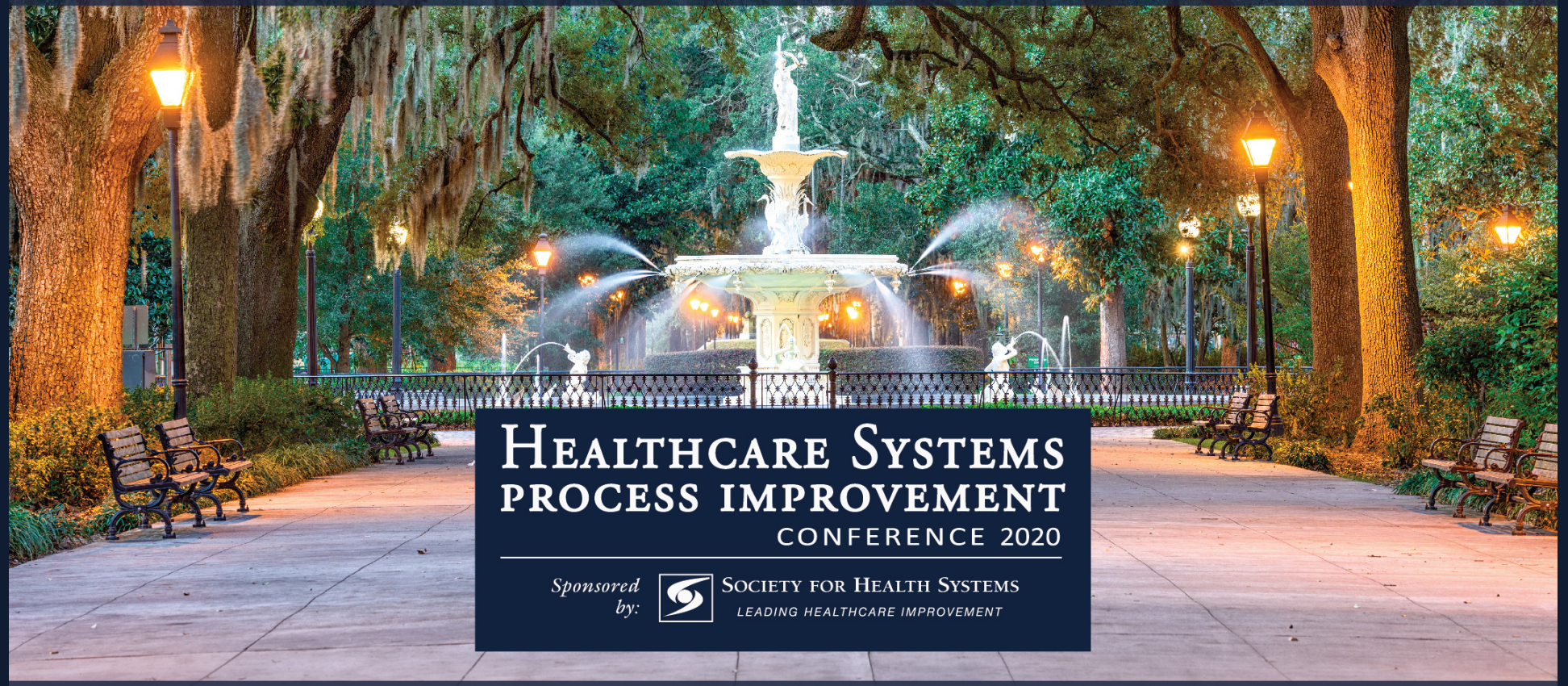


Simulating Access and Patient Flow for a Cardiovascular ICU

Luke Liu, Prof. Amy Cohn, Dr. Hitinder Gurm

CHEPS

M | CHEPS

Rx

A prescription to address system complexity in healthcare

INNOVATING HEALTHCARE DELIVERY

FOSTERING LEARNING

BUILDING COMMUNITY

POSITIVE IMPACT THROUGH...

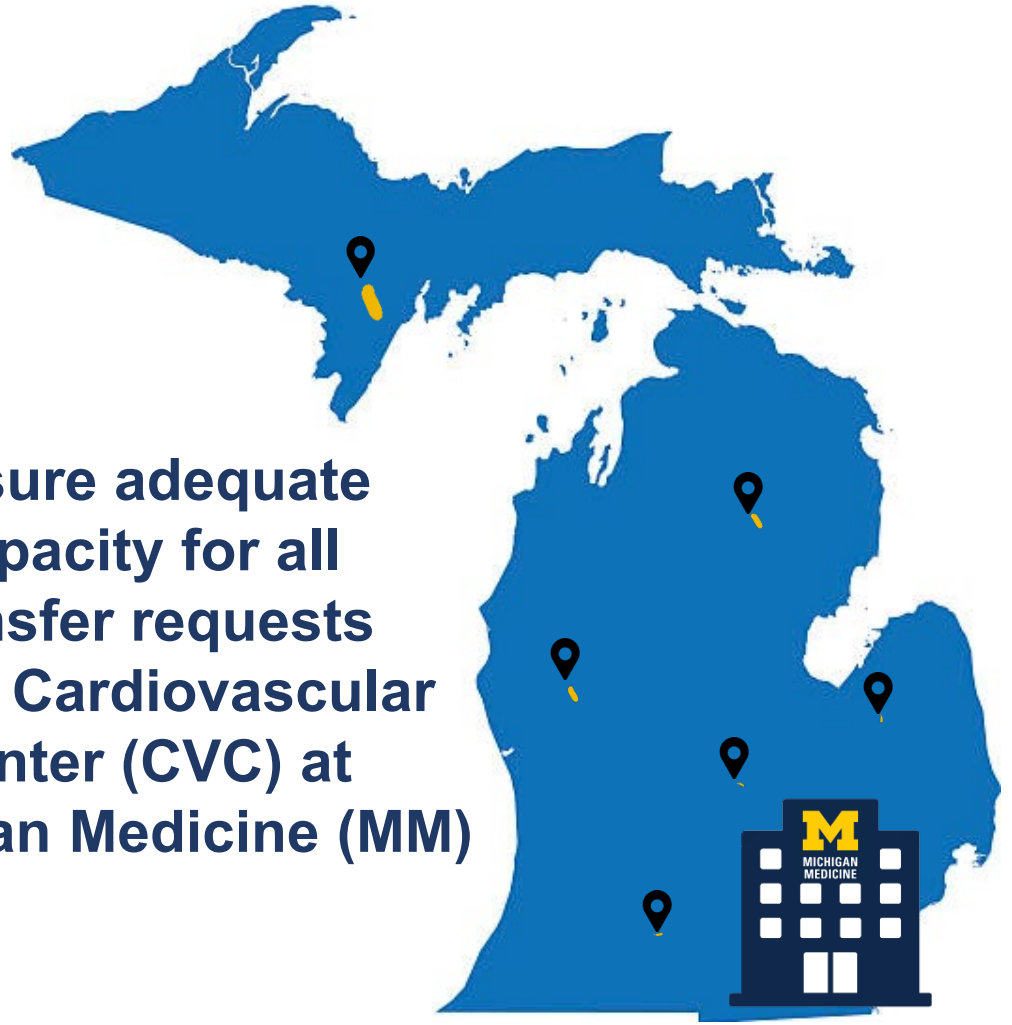
Research
Education
Implementation
Outreach
Dissemination

OUTLINE

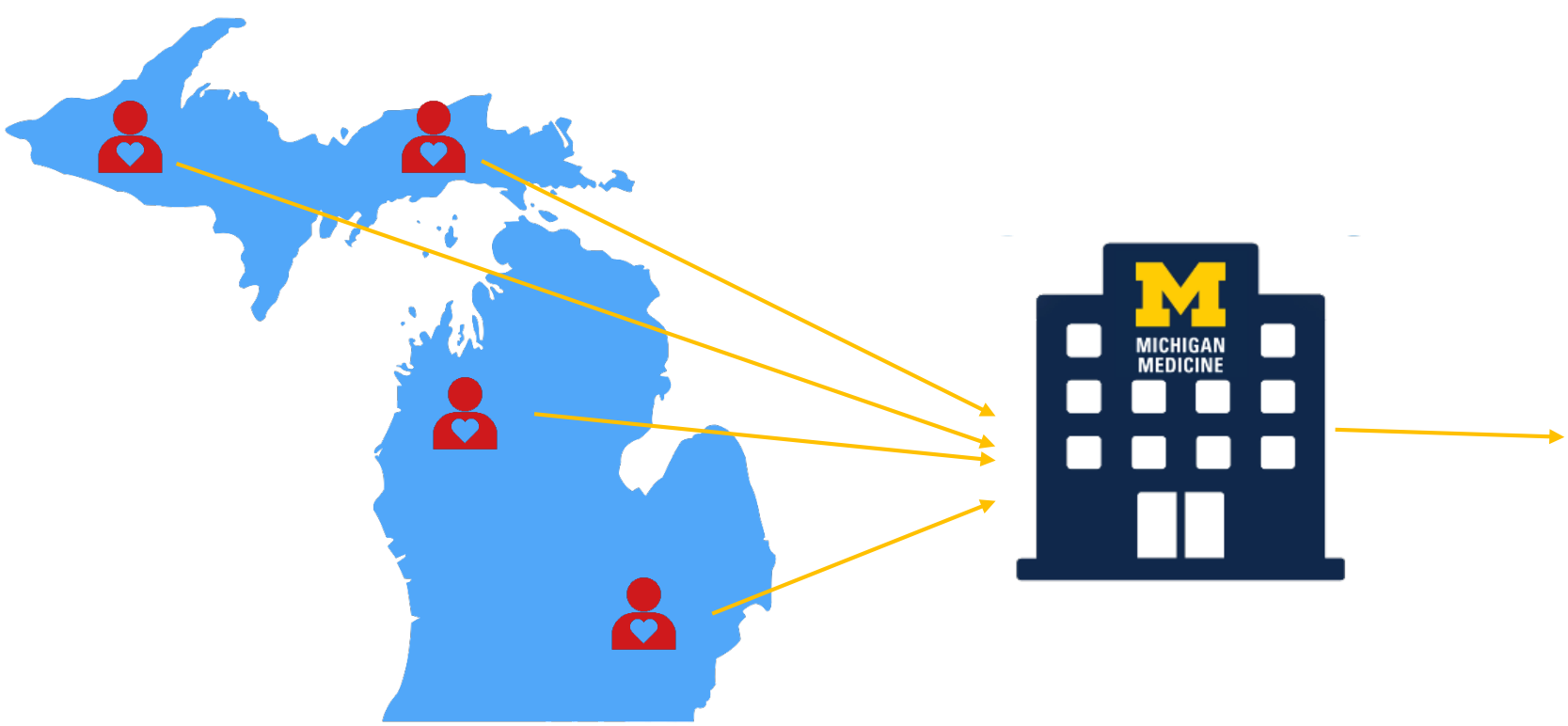
- Research Motivation
- Introduction
- Problem Statement
- Simulation Framework
- Analyses
- Future Research

RESEARCH MOTIVATION

Ensure adequate capacity for all transfer requests to the Cardiovascular Center (CVC) at Michigan Medicine (MM)



INITIAL RESEARCH QUESTION



Patient Needs

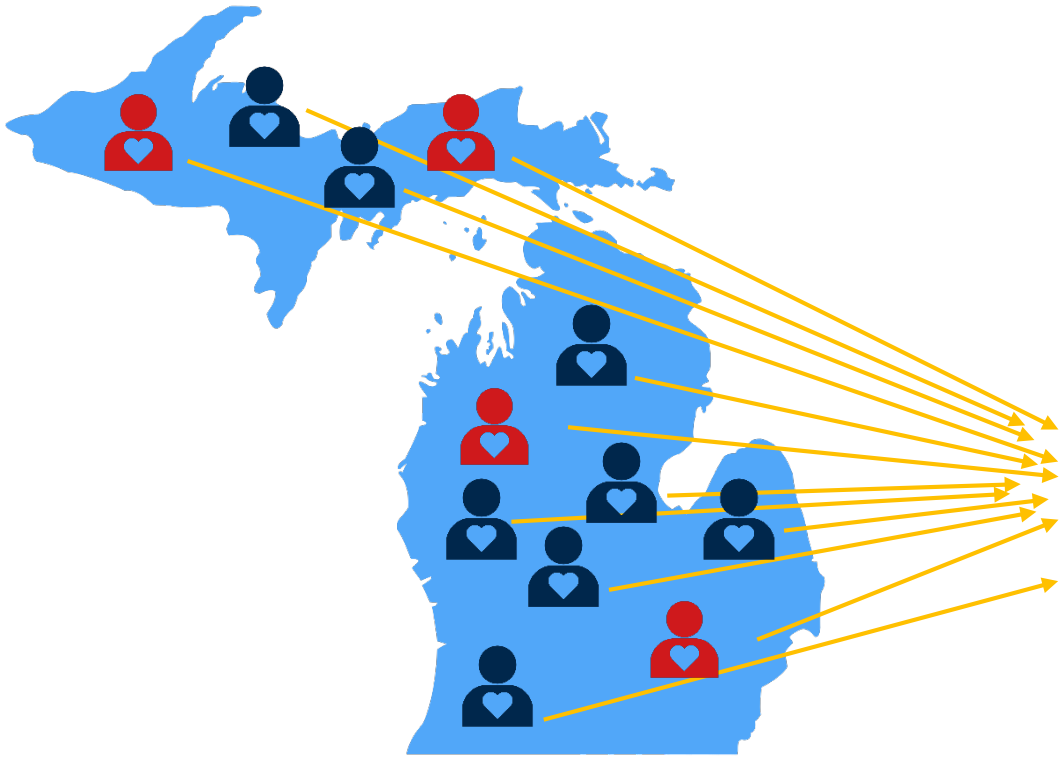
= Aortic Dissection Patients

INITIAL RESEARCH QUESTION

It's a lot more complicated than that…

= Aortic Dissection Patients

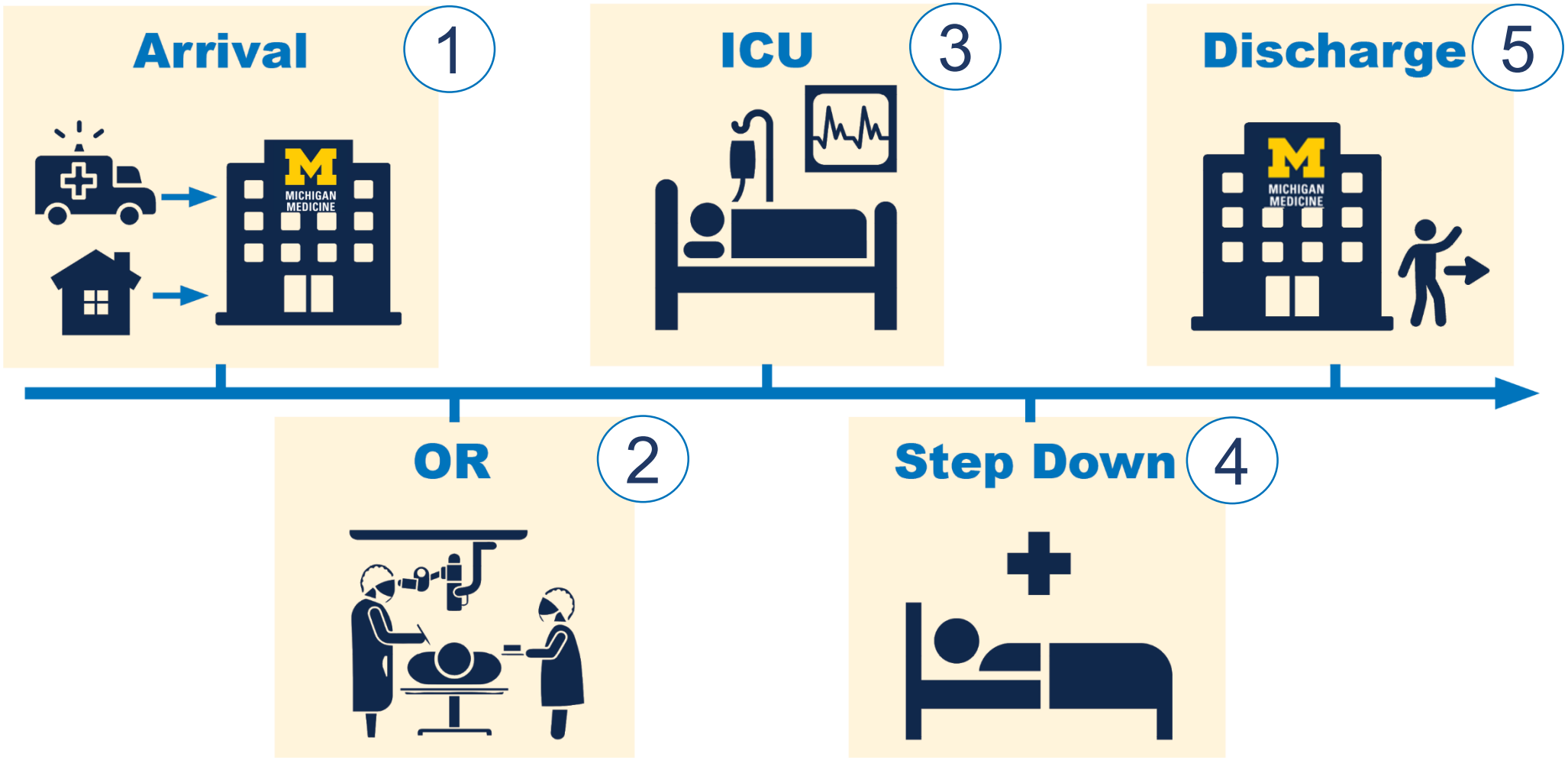
THE BIGGER PICTURE



= Aortic Dissection Patients

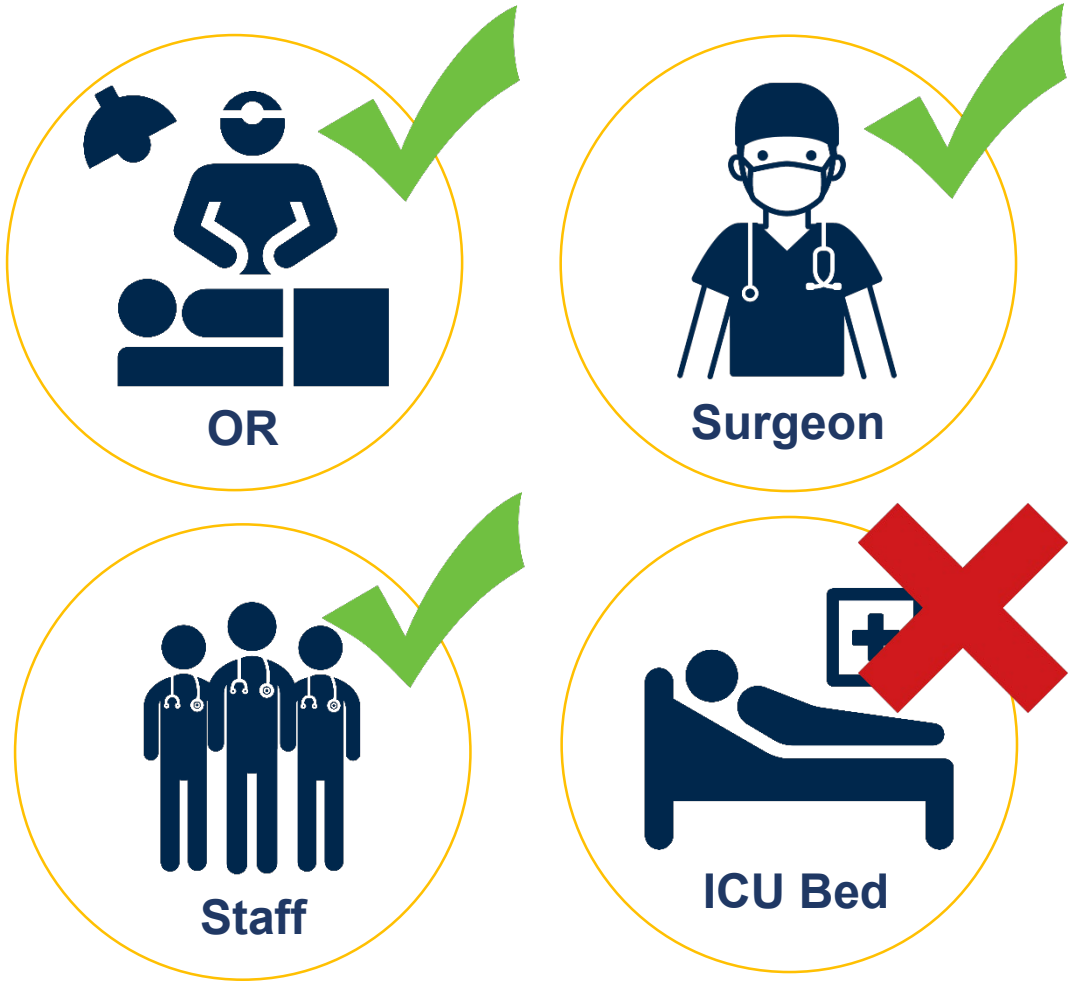
= All Other Cardiac Patient Types

PATIENT FLOW IN CARDIOVASCULAR SURGERY

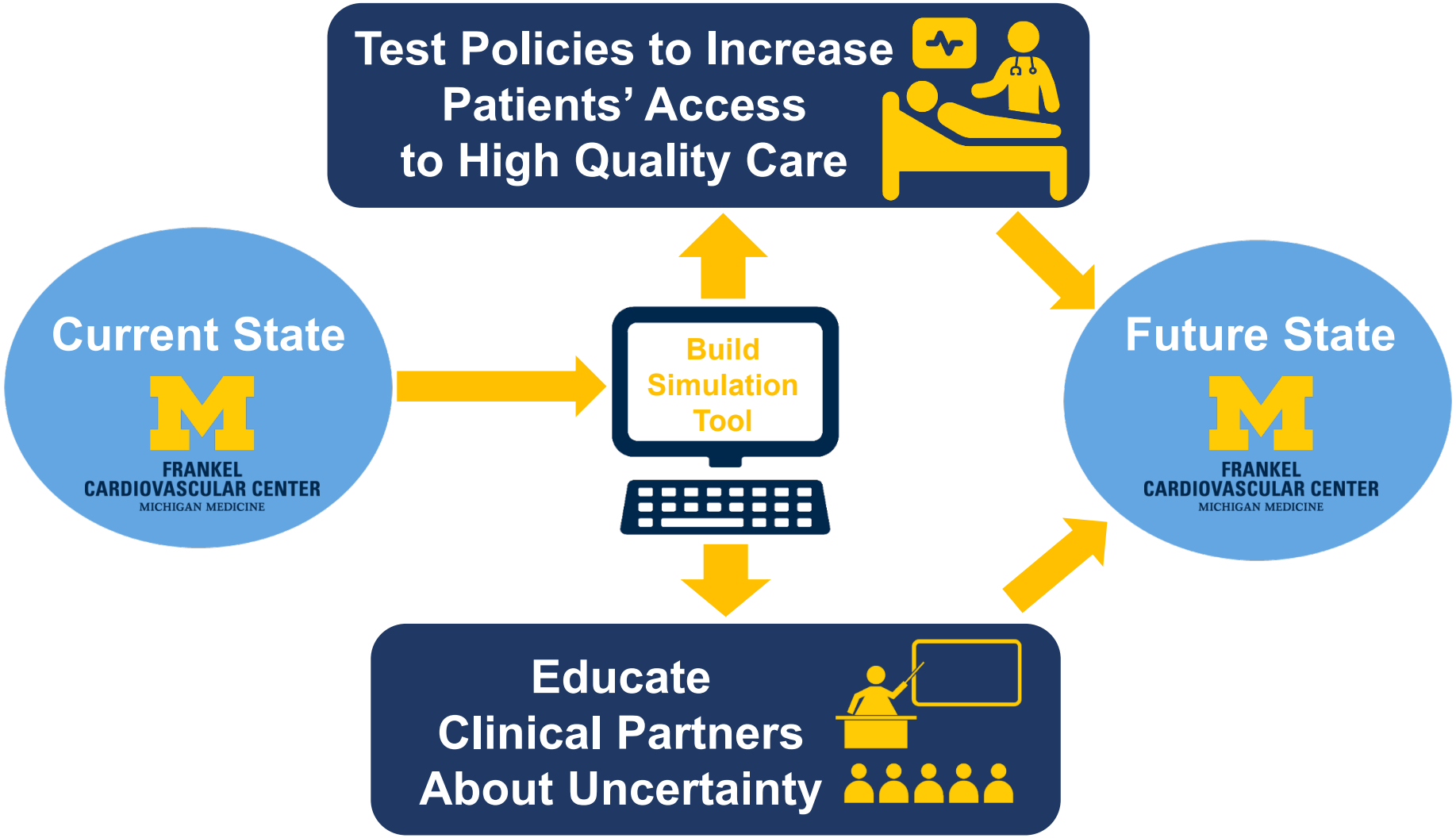


TRANSFER REQUESTS

Preliminary analysis conducted by the CVC staff showed that the most common reason for patient deferral when requesting transfer to Michigan Medicine is attributed to unavailable ICU beds.



APPROACH TO IMPROVING ICU UTILIZATION



SIMULATION FRAMEWORK

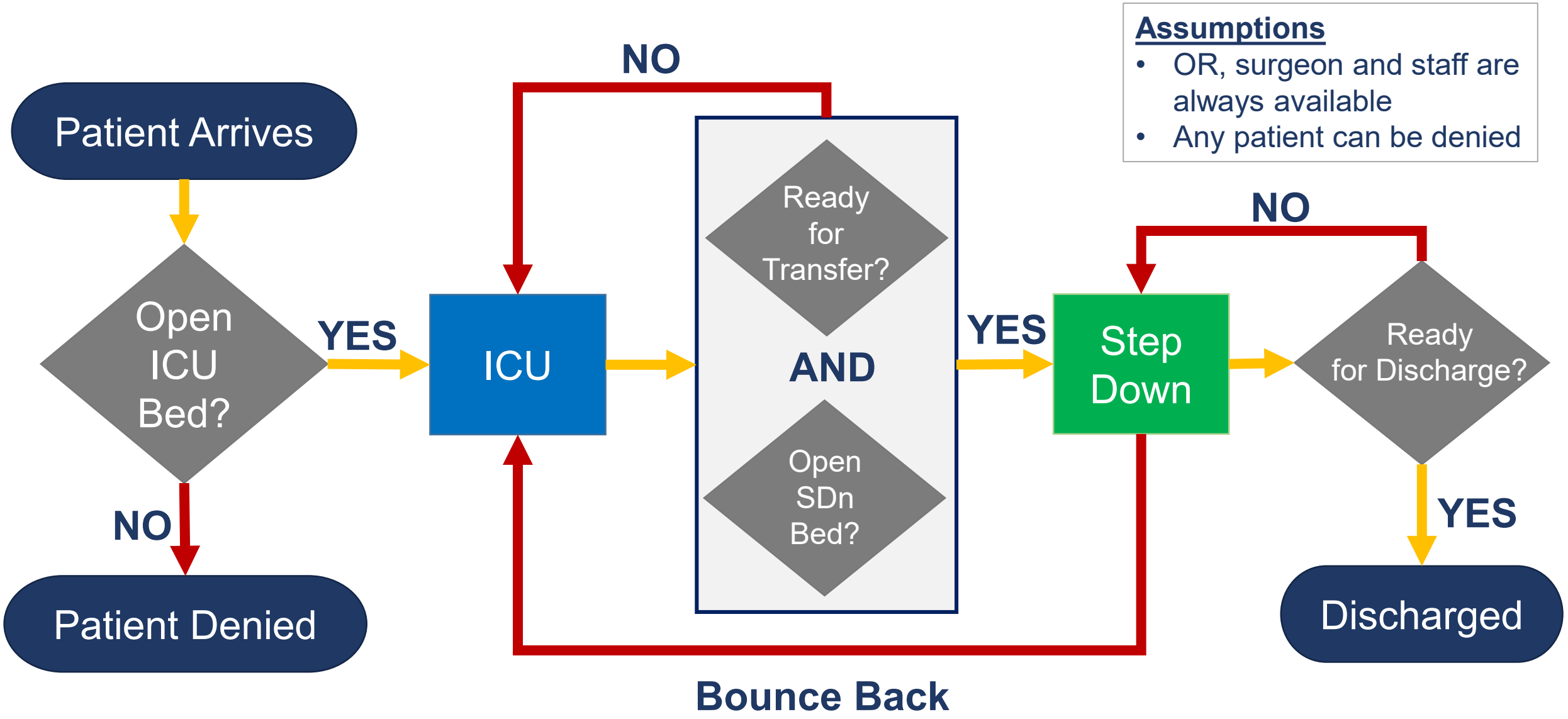
FIXED INPUTS

- Bed Count per Unit
- Time Horizon
- Number of Replications

VARIABLE INPUTS

- Patient Arrival Rate
- Length of Stay in ICU and Step Down (SDn) units
- Bounce Back Probability

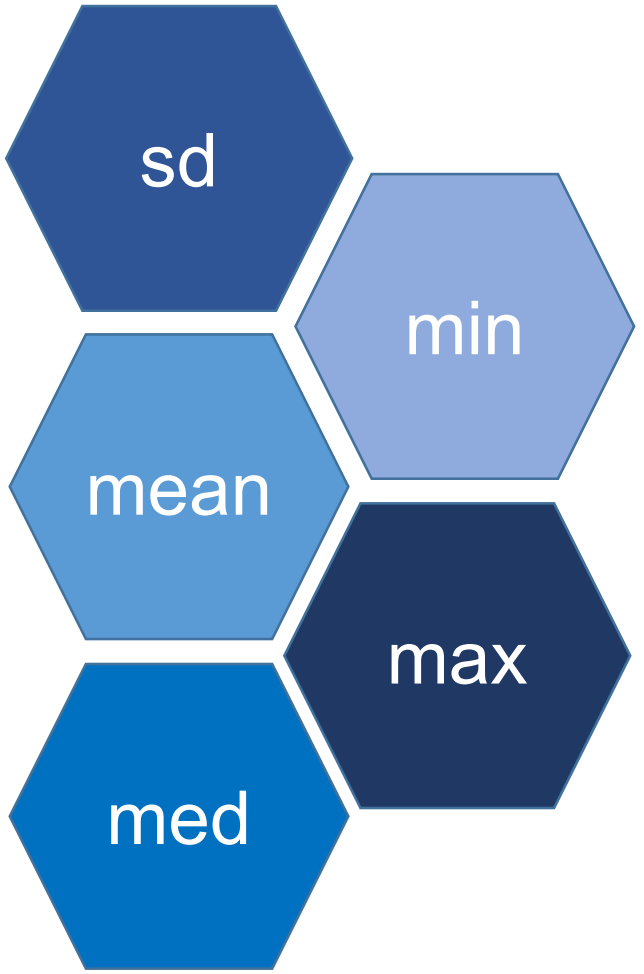
SIMULATION FRAMEWORK



SIMULATION FRAMEWORK

METRICS

Number of…	
Patient Arrivals	
Accepted Patients	
Denied Patients	
ICU	**Step Down (SDn)**
• Patient LOS • Unnecessary days in an ICU bed (SDn status) • Bed Utilization	• Patient LOS • Unnecessary days in a SDn bed (ICU status) • Bed Utilization



ANALYSES

1

SDn Variation

- Change number of shared SDn beds

2

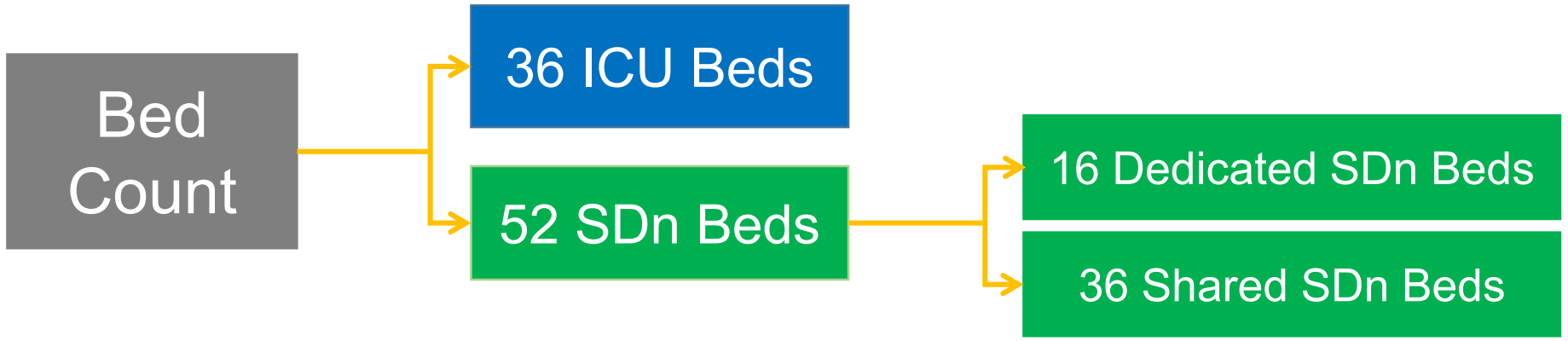
Bounce Back Rate

- Change the rate of bounce back incrementally

BASE CASE PARAMETERS

- 1 Patient Type
- Arrival Rate = 0.33 patient/hr
- Time Horizon = 1 Year
- Replications = 1,000

- Bernoulli trial for transfer and discharge from respective units
  - $P_{\text{ICU Transfer}} = 0.25$
  - $P_{\text{SDn Discharge}} = 0.25$



ANALYSIS 1: SDN VARIATION

Allocated Step Down Beds	28	32	36	40
Annual Patient Arrival	2879	2875	2878	2877
Patients Denied	**8.1%**	**5.8%**	**4.8%**	**4.5%**
ICU Average LOS ICU Status	3.45 days	3.44 days	3.44 days	3.44 days
ICU Average LOS SDn Status	**0.34 days**	**0.14 days**	**0.04 days**	**0.01 days**
SDn Average LOS	3.70 days	3.78 days	3.82 days	3.83 days
SDn Bed Utilization	94.23%	88.98%	82.06%	74.73 %

- Time Horizon = 1 Year
- Replications = 1,000
- 36 ICU Beds
- 16 Dedicated SDn Beds

ANALYSIS 2: BOUNCE BACK

Bounce Back Rate Increments

Bounce Back Rate	0%	5%	10%	15%
Annual Patient Arrival	2875	2871	2873	2872
Patients Denied	**5.8%**	**13%**	**22%**	**31%**
ICU Average LOS ICU Status	3.44 days	3.85 days	4.09 days	4.39 days
ICU Average LOS SDn Status	**0.14 days**	**0.31 days**	**0.68 days**	**1.15 days**
SDn Average LOS	3.78 days	4.19 days	4.43 days	4.45 days
SDn Average LOS ICU Status	**0 days**	**0.15 days**	**0.45 days**	**0.76 days**
ICU Bed Utilization	78.88%	85.95%	89.53%	92.02%

- Time Horizon = 1 Year
- Replications = 1,000
- 36 ICU Beds
- 32 SDn Beds

ANALYSES TAKEAWAYS

Analysis 1: SDn Variation

- The unnecessary ICU bed days decreases as SDn beds are added to a certain point
- Trade-offs will be necessary

Analysis 2: Bounce Back

- Small rates of bounce back impact utilization and flow
- Patient information would allow us to more accurately predict bounce back rates

FUTURE RESEARCH

- Expanding the tool
  - Adding more patient types
  - Adding patient predictors of bounce back

- Conducting Analysis
  - More data!
  - Explore smoothing elective surgery

ACKNOWLEDGEMENTS

Thank you to Ambika Agrawal, Amanda Moreno-Hernandez, Harini Pennathur, Hadi Saab, Ziqi Wang, Shuhao Zhou, and all prior CHEPS students who have contributed to this work!

Questions?

hubliu@umich.edu
cheps-contact@umich.edu

LITERATURE REVIEW

First Author	Reference	Year	Objective/Purpose
Levin, S.	[5]	2011	To test policies to reduce patient's length of stay (LOS) and increase patient throughput.
Marmor, Y.	[6]	2013	To predict minimum bed needs to achieve the high patient service level demanded for the cardiovascular ICU.
Levin, S.	[7]	2015	To estimate patients' wait time while integrating the effect of the transition process (i.e. wait time for a bed to become available) with queuing using embedded regression models.
Kolker, A.	[8]	2009	To establish a quantitative link between the daily load leveling of elective surgeries (i.e. elective schedule smoothing) and ICU diversion of multiple ICU units including cardio ICU.

REFERENCES

[1] Criado, Frank J. “Aortic Dissection: A 250-Year Perspective.” Ed. Joseph S. Coselli. Texas Heart Institute Journal 38.6 (2011): 694–700.

[2] Farber, Mark A, and Thaniyyah S Ahmad. “Aortic Dissection.” Merk Manual, Merck Sharp & Dohme Corp, March 2017.

[3] Birkmeyer JD, Siewers AE, Finlayson EV, Stukel TA, Lucas FL, Batista I, Welch HG, Wennberg DE (2002) Hospital volume and surgical mortality in the United States. N Engl J Med 346(15): 1128–1137

[4] Heidenreich, Paul A., et al. "Forecasting the future of cardiovascular disease in the United States: a policy statement from the American Heart Association." Circulation 123.8 (2011): 933-944

[5] Levin, Scott, et al. "Evaluating the effects of increasing surgical volume on emergency department patient access." BMJ quality & safety 20.2 (2011): 146-152.

[6] Marmor, Yariv N., et al. "Recovery bed planning in cardiovascular surgery: a simulation case study." Health care management science 16.4 (2013): 314-327.

[7] Levin, Scott, and Maxim Garifullin. "Simulating wait time in healthcare: accounting for transition process variability using survival analyses." 2015 Winter Simulation Conference (WSC). IEEE, 2015.

[8] Kolker, Alexander. "Process modeling of ICU patient flow: effect of daily load leveling of elective surgeries on ICU diversion." Journal of medical systems 33.1 (2009): 27.

[9] Halpern, Neil A., et al. "Trends in critical care beds and use among population groups and medicare and medicaid beneficiaries in the United States: 2000–2010." Critical care medicine 44.8 (2016): 1490.