A Simulation Framework to Leverage Patient-Specific Data in Improving Cardiac Intensive Care Unit Utilization

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CHEPS

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A prescription to address system complexity in healthcare

INNOVATING HEALTHCARE DELIVERY

FOSTERING LEARNING

BUILDING COMMUNITY

POSITIVE IMPACT THROUGH...

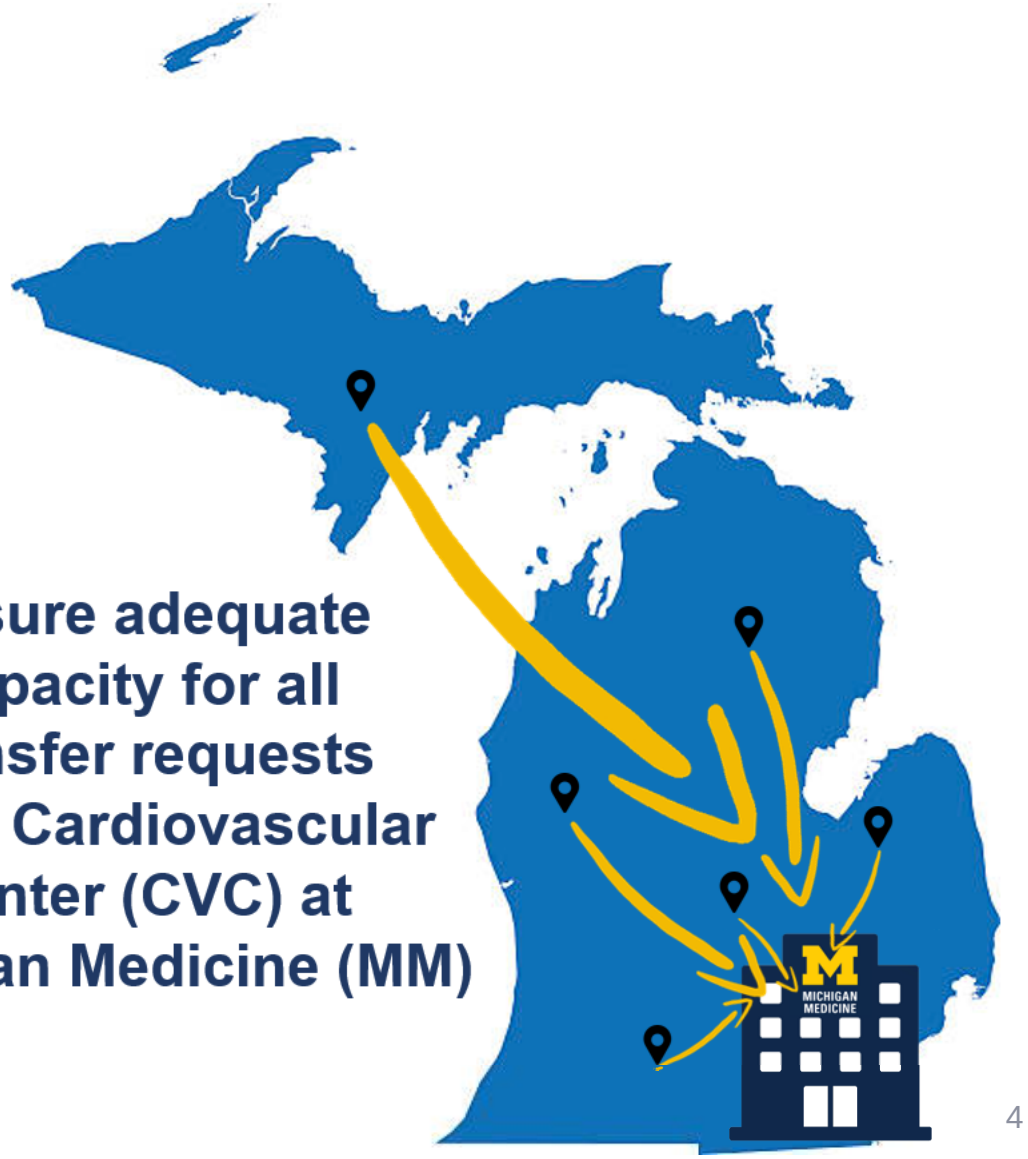
Research
Education
Implementation
Outreach
Dissemination

OUTLINE

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

RESEARCH MOTIVATION

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



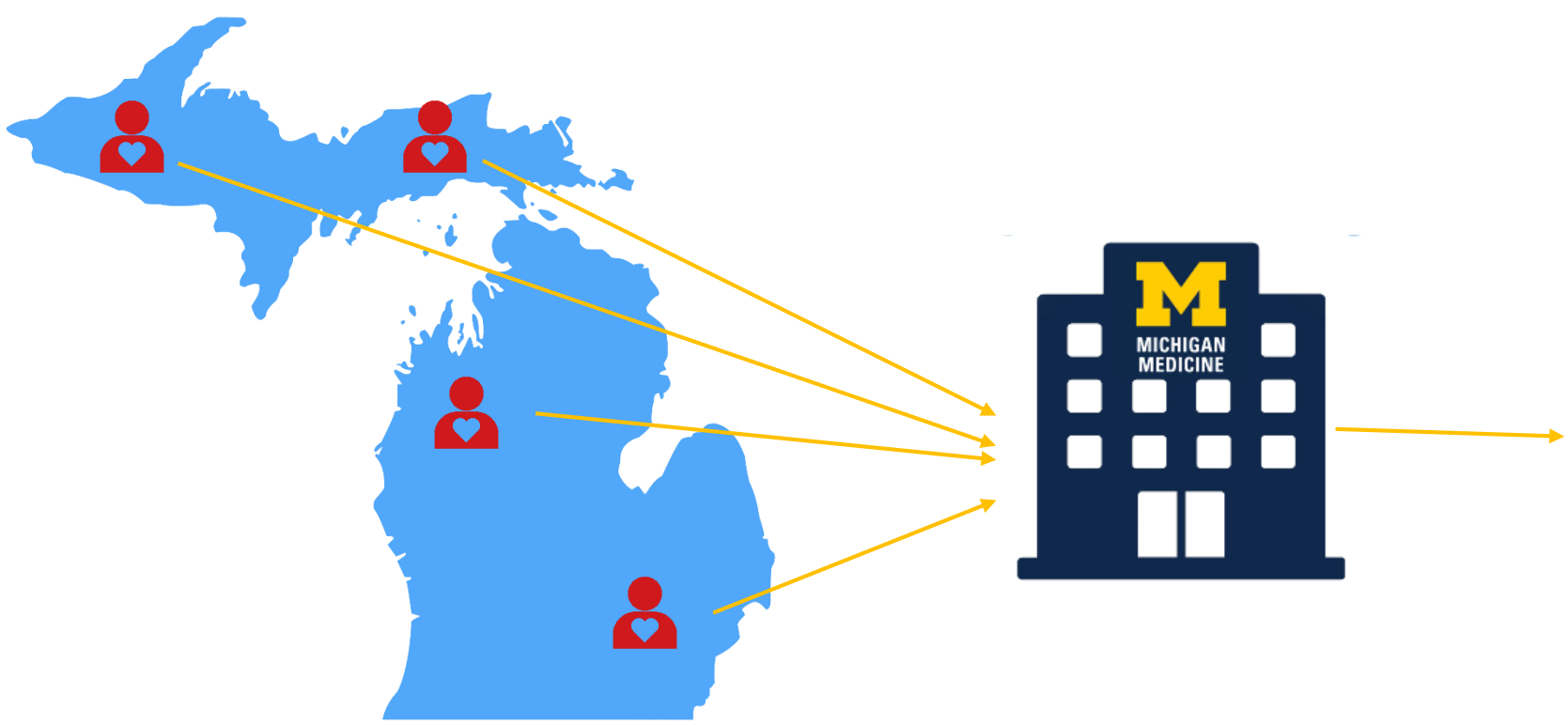
WHAT IS AN AORTIC DISSECTION?

Aortic dissection (AD) is an emergency cardiovascular condition affecting the aorta.

Mortality rate for AD increases 1% per hour [1]. Aortic dissections are rare, but when they occur, they are medical cardiovascular emergencies.

Cardiovascular disease is the leading cause of death in the US [3]. The most common surgeries in the United States (US) are cardiovascular [3].

INITIAL RESEARCH QUESTION



Patient Needs

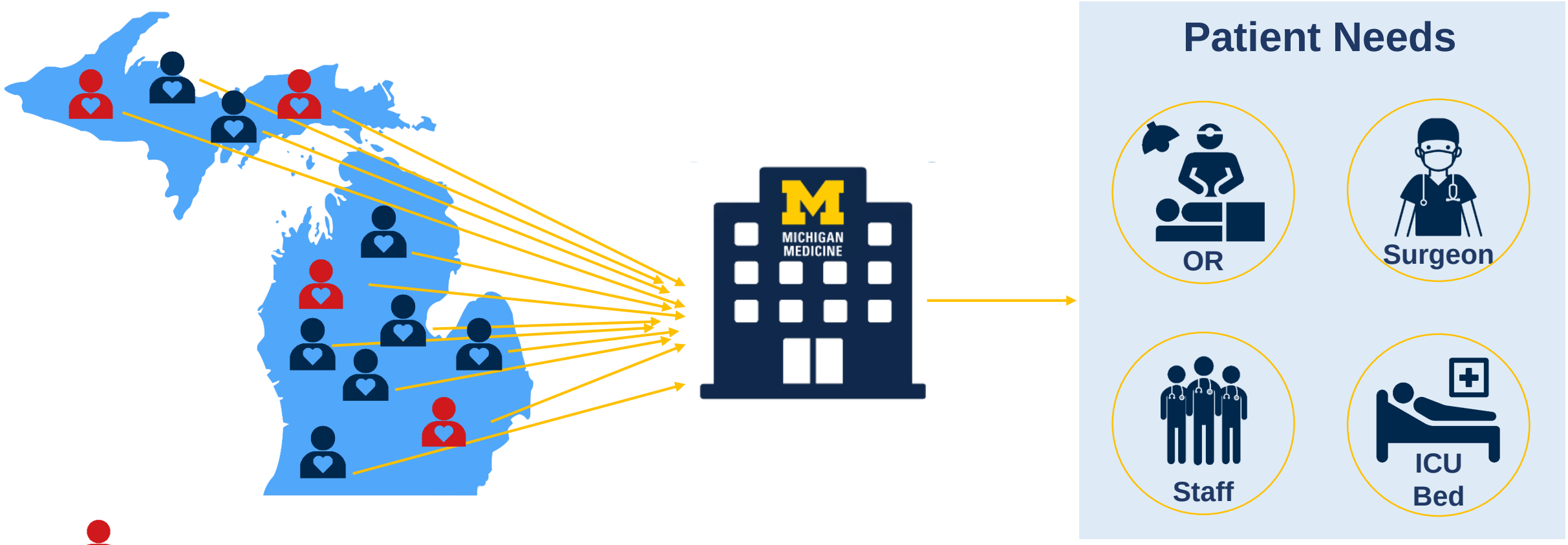
= Aortic Dissection Patients

INITIAL RESEARCH QUESTION

It's a lot more complicated than that…

= Aortic Dissection Patients

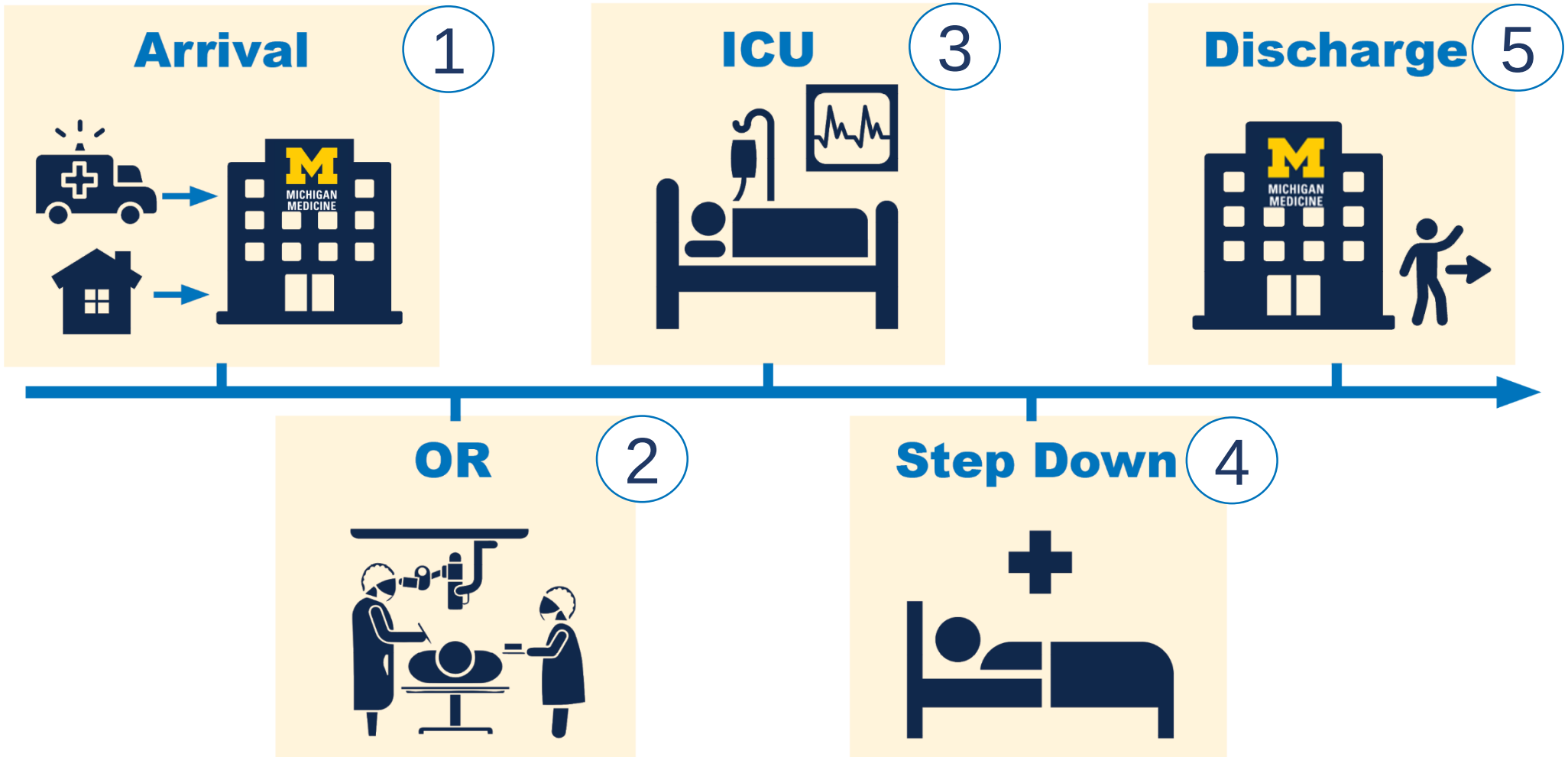
THE BIGGER PICTURE



= Aortic Dissection Patients

= All Other Cardiac Patient Types

PATIENT FLOW IN CARDIOVASCULAR SURGERY



HOW DO WE CLASSIFY PATIENTS?

Level 1
Arrival Type

Transfer from Another Facility

Transfer from UM ED

Scheduled Procedure

Level 2
Patient Type

Elective

Urgent

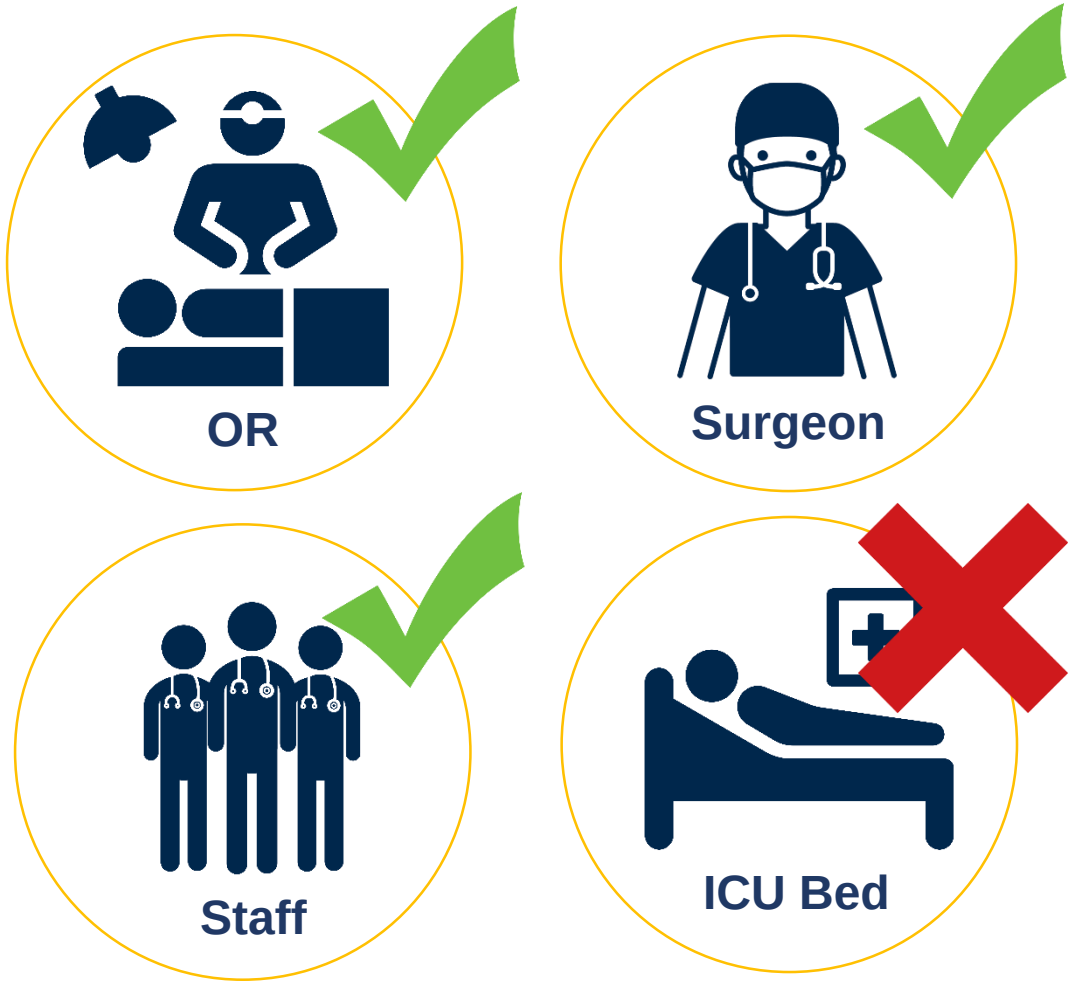
Emergent

Level 3
Patient Information

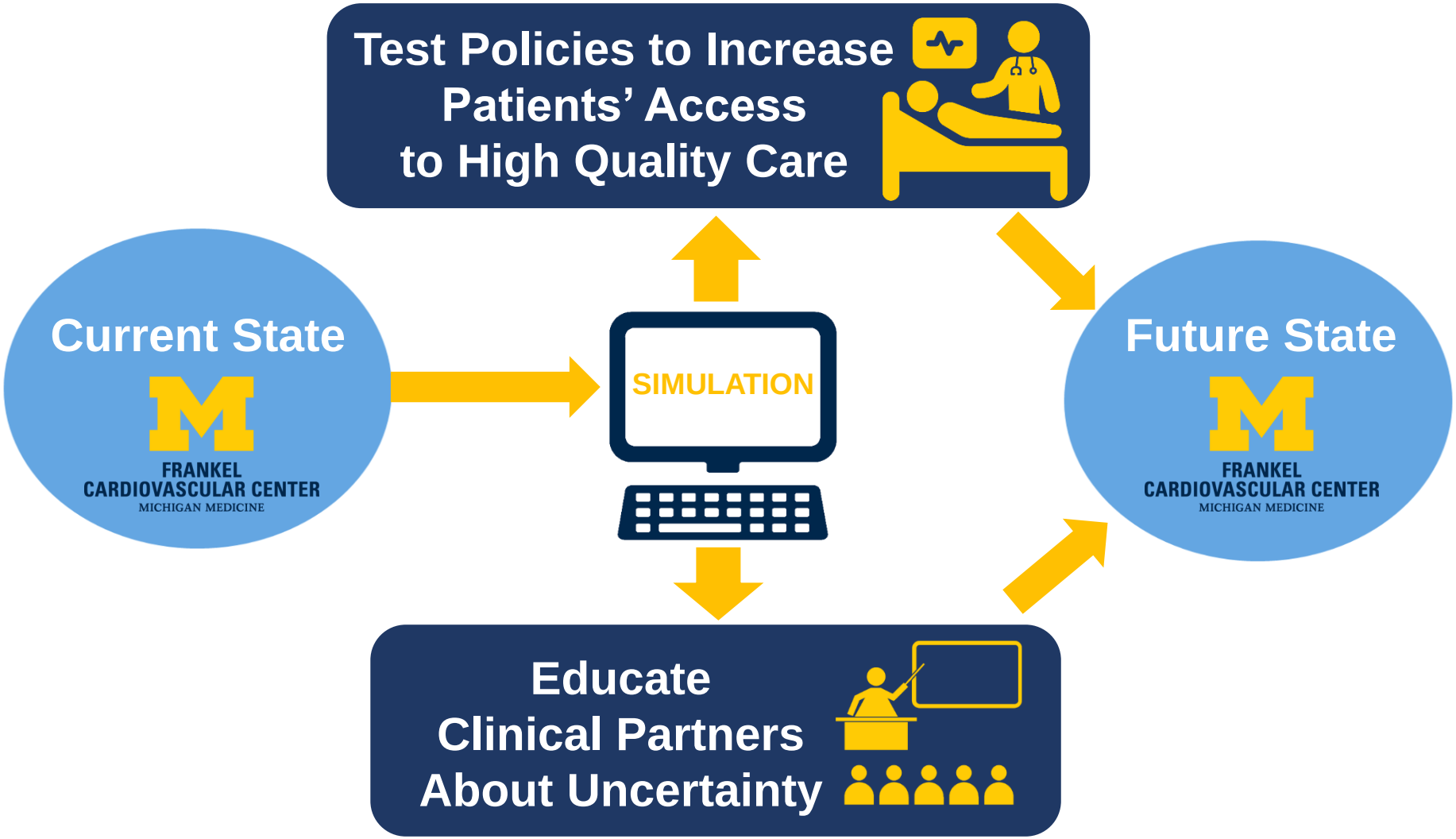
- AGE
- COMORBIDITY
- SEX
- BMI
- PRIOR Dx

TRANSFER REQUESTS

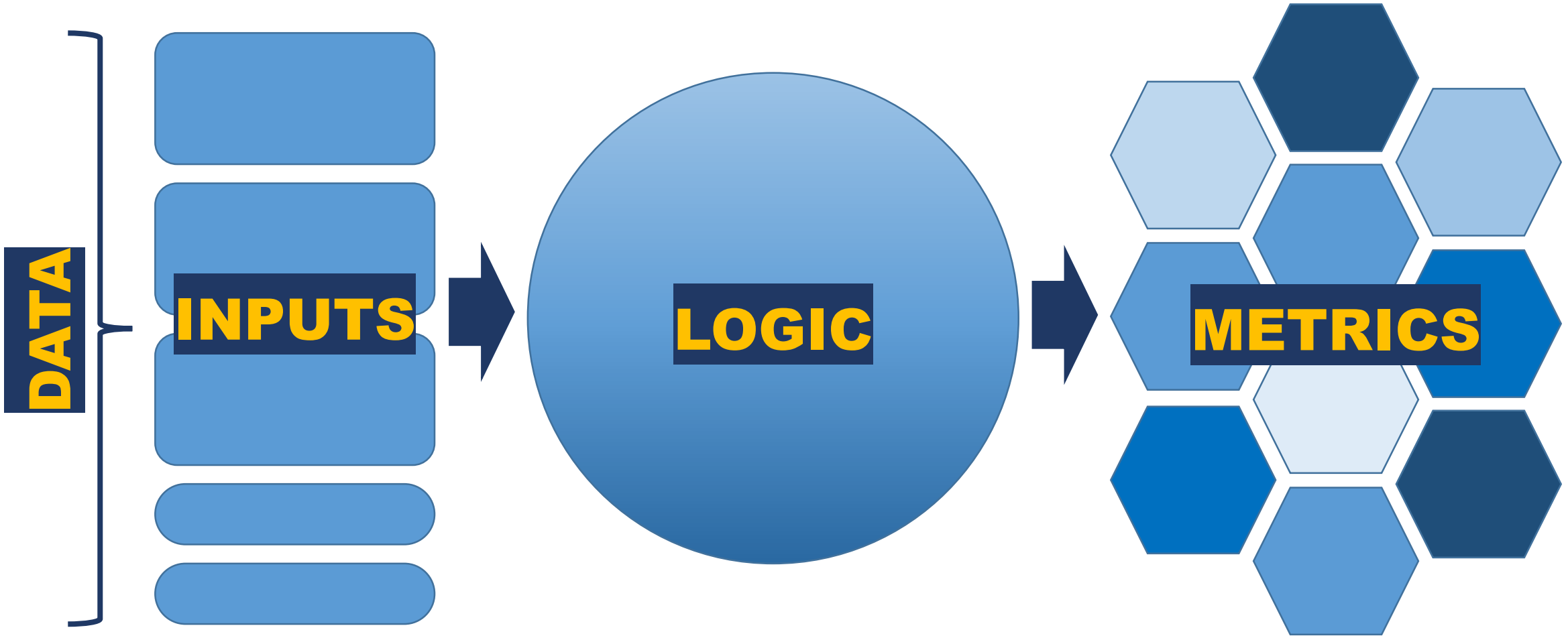
Preliminary analysis conducted by the CVC staff showed that the most common reason for patient deferral when requesting transfer to Michigan Medicine is attributed to unavailable ICU beds.



PROBLEM STATEMENT

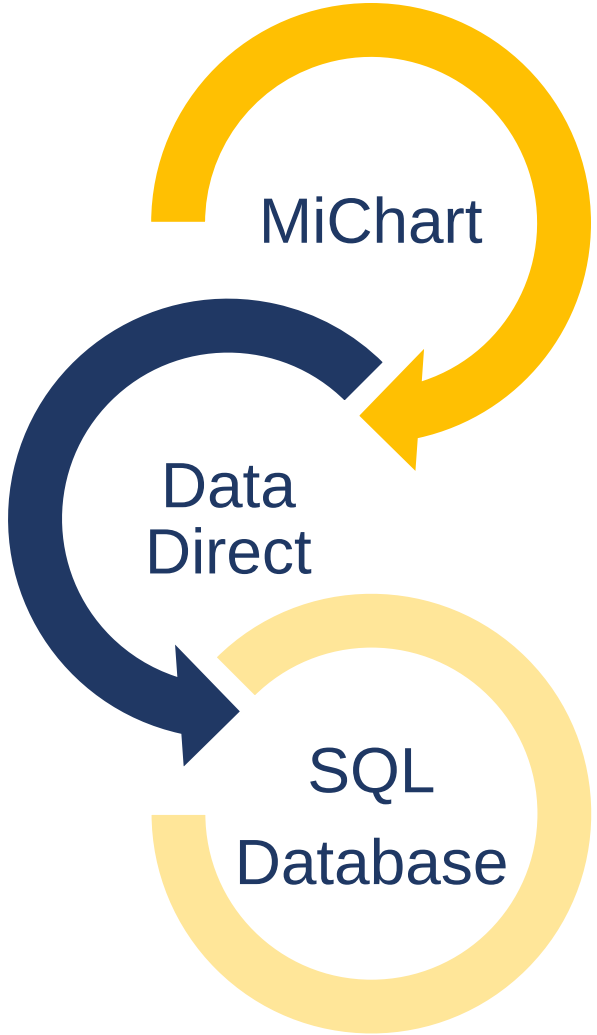


SIMULATION FRAMEWORK



DATA PRE-PROCESSING

- MiChart, a product of Epic, is Michigan Medicine's patient-centric electronic health record
- Data Direct enables access to clinical data
- SQL Database contains all patients that visited the CVC ICU between Jan 2016 and May 2019



SIMULATION FRAMEWORK

FIXED INPUTS

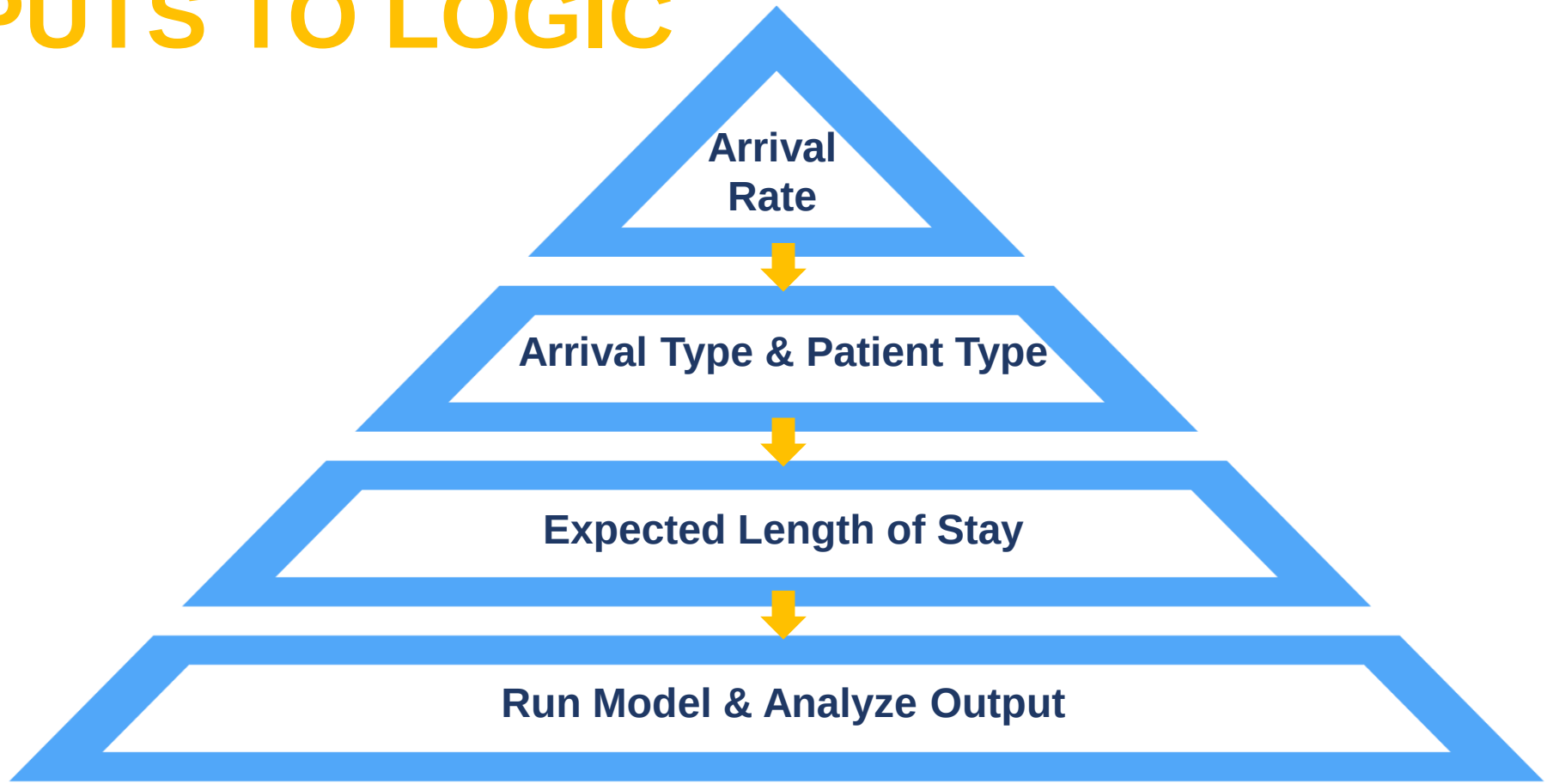
- Bed Count per Unit
- Time Horizon
- Replications

RANDOM INPUTS

- Patient Type
- Arrival Rate
- Service Time per Unit

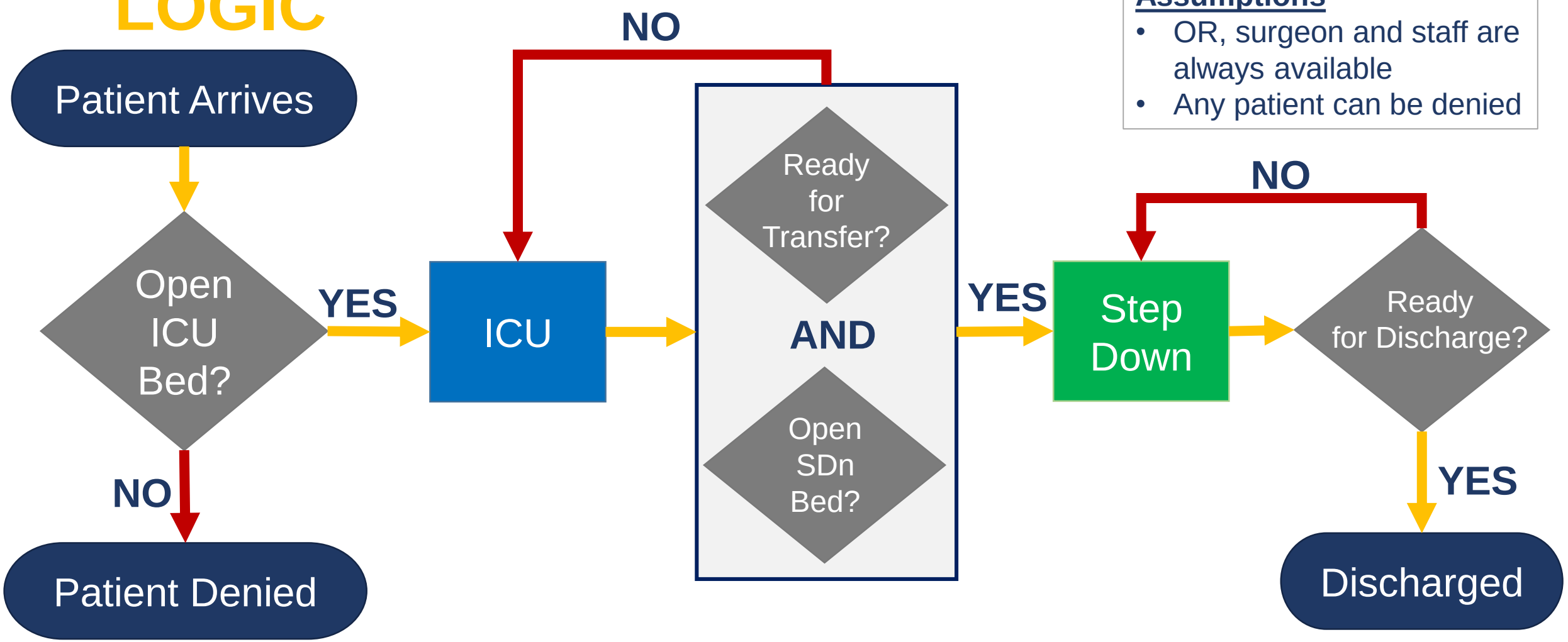
SIMULATION FRAMEWORK

INPUTS TO LOGIC



SIMULATION FRAMEWORK

LOGIC



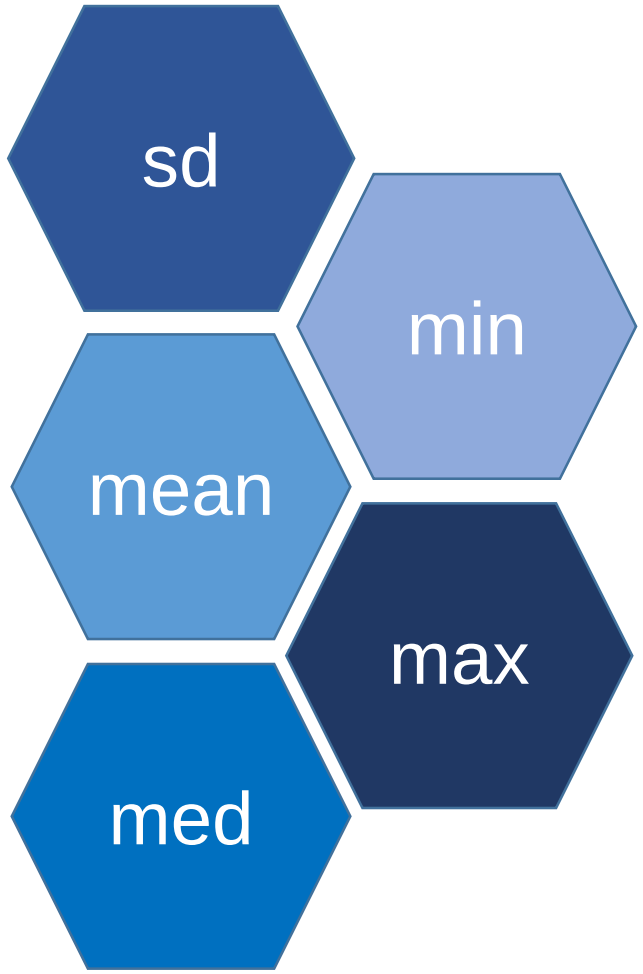
Assumptions

- OR, surgeon and staff are always available
- Any patient can be denied

SIMULATION FRAMEWORK

METRICS

Overall	
Patients Requesting Care (Patient Arrival)	
Accepted Patients	
Declined Patients	
ICU	**Stepdown (SDn)**
• Patient LOS • Unnecessary days in an ICU bed (SDn status) • Bed Utilization	• Patient LOS • Bed Utilization



ANALYSES

1

SDn Variation

- Change number of shared SDn beds

2

Arrival Rate

- Change the hourly patient admission rate

BASE CASE PARAMETERS

- 2 Patient Types:
  - Internal Transfers (Includes Elective Surgery)
  - Outside Transfers

- Internal Arrival Rate = 0.25 patient/hr
- Outside Arrival Rate = 0.06 patient/hr

- Time Horizon = 1 Year
- Replications = 1,000

BASE CASE PARAMENTERS

- Bernoulli trial for transfer and discharge from respective units

INTERNAL TRANSFER

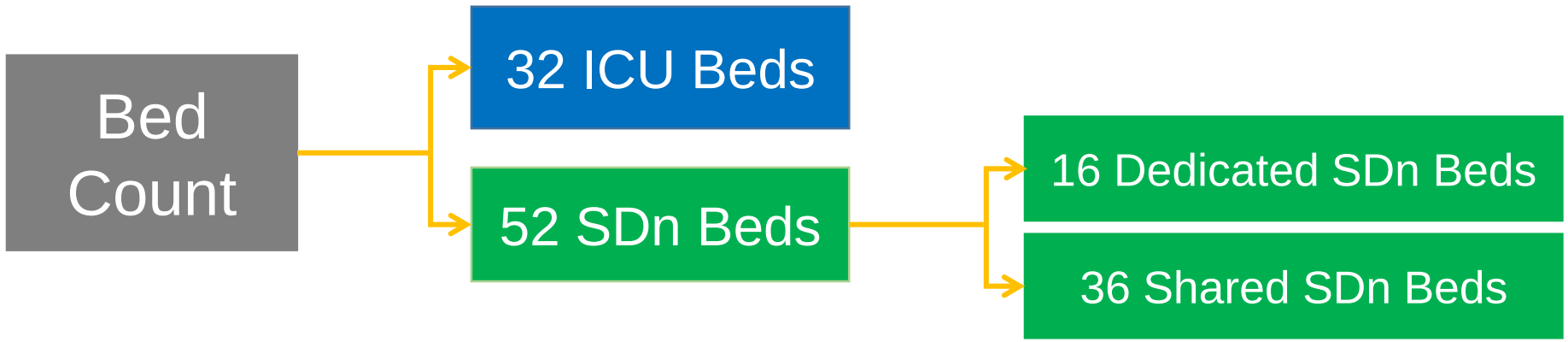
$P_{ICU\ Transfer\ 1} = 0.24$

$P_{SDn\ Discharge\ 1} = 0.25$

OUTSIDE TRANSFER

$P_{ICU\ Transfer\ 2} = 0.18$

$P_{SDn\ Discharge\ 2} = 0.25$



ANALYSIS 1: SDN VARIATION

Percentage of Shared Beds Available

Allocated Stepdown Beds	25	34	43	52
Patient Arrival	2718	2715	2717	2716
Outside Transfer Declined	**3%**	**2%**	**2%**	**2%**
Internal Transfer Bottleneck	**12%**	**9%**	**9%**	**9%**
ICU Average LOS Outside Transfer	4.93 days	4.93 days	4.93 days	4.95 days
ICU Avg LOS Internal Transfer	3.63 days	3.62 days	3.62 days	3.62 days
ICU Average LOS SDn status	**0.27 days**	**0.01 days**	**0 days**	**0 days**
SDn Average LOS	3.56 days	3.81 days	3.83 days	3.83 days

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

ANALYSIS 2: ARRIVAL RATE

Outside Transfer Arrival Rate Increments

Outside Transfer Arrival Rate	0.0602	0.0783	0.1017	0.1323	0.1719
Patient Arrival	2716	2875	3076	3345	3695
Outside Transfer Declined	**2%**	**4%**	**6%**	**9%**	**14%**
Internal Transfer Bottleneck	**9%**	**12%**	**15%**	**17%**	**20%**
ICU Average LOS Outside Transfer	4.95 days	4.95 days	4.98 days	4.98 days	5.02 days
ICU Avg LOS Internal Transfer	3.62 days	3.64 days	3.66 days	3.68 days	3.71 days
ICU Average LOS SDn status	**0 days**	**0 days**	**0 days**	**0 days**	**0 days**
SDn Average LOS	3.83 days	3.83 days	3.84 days	3.83 days	3.83 days

- Time Horizon = 1 Year
- Replications = 1,000
- 32 ICU Beds
- 52 SDn Beds
- Internal Transfer Arrival Rate = 0.25 patient/hr

ANALYSES TAKEAWAYS

Analysis 1: SDn Variation

- Outside transfer declined and internal transfer bottleneck remains constant regardless of the amount of dedicated SDn beds.

Analysis 2: Arrival Rate

- Increase in internal transfer bottleneck metric suggests evaluation of the internal patient flow prior to arrival at the ICU.

FUTURE RESEARCH

- Expanding the tool
  - Relaxing assumptions
  - Include Bounce Backs

- Conducting Analysis
  - More Data!!!
  - Collaborator goals: Explore smoothing elective surgery

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Questions?

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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.

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[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.

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