IISE ANNUAL Virtual CONFERENCE & EXPO 2020

Simulating Access And Patient Flow For A Cardiovascular ICU

Ziqi Wang, Prof. Amy Cohn, Dr. Hitinder Gurm

CHEPS

Rx

A prescription to address system complexity in healthcare

- INNOVATING HEALTHCARE DELIVERY
- FOSTERING LEARNING
- BUILDING COMMUNITY

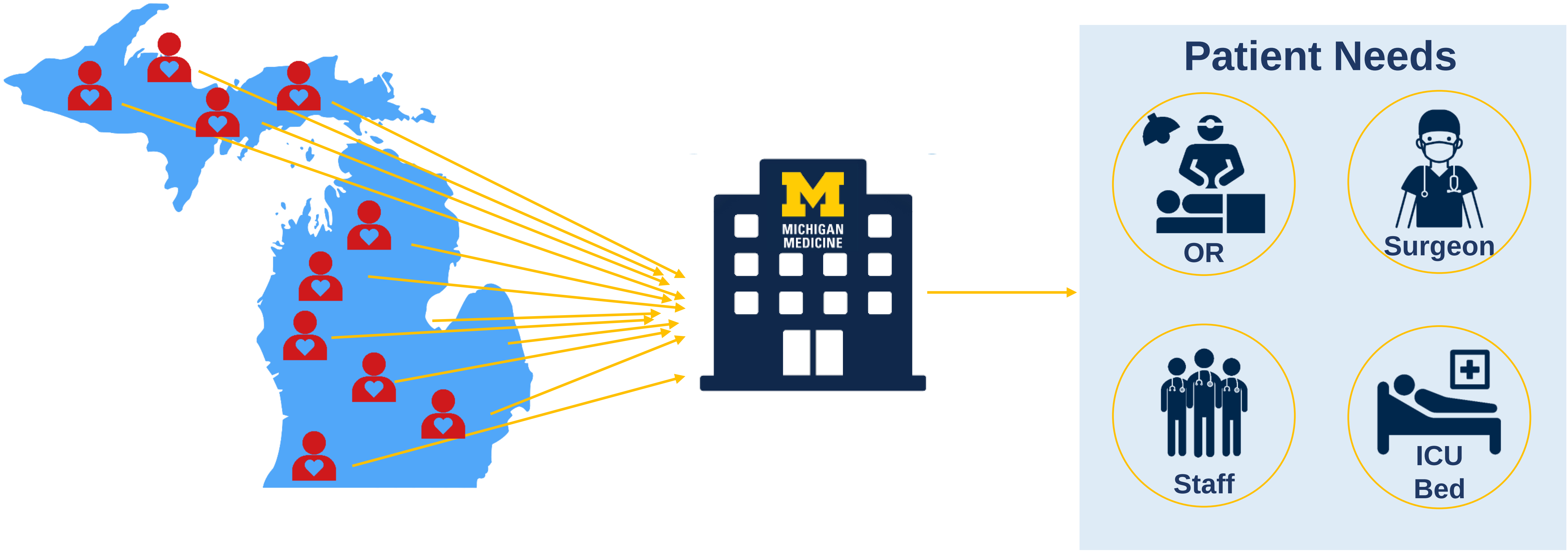
POSITIVE IMPACT THROUGH...

Research
Education
Implementation
Outreach
Dissemination

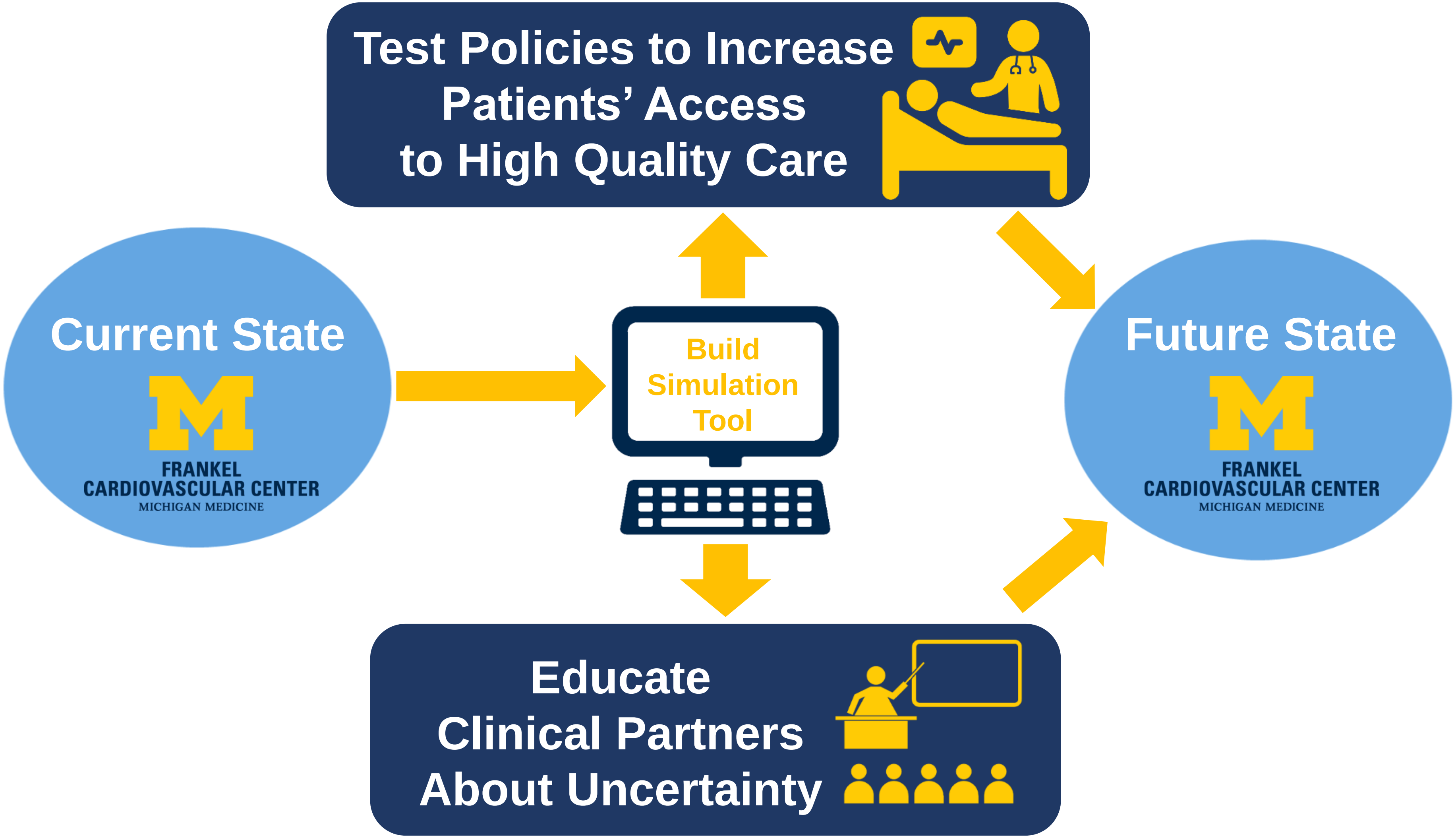
OUTLINE

- Background
- Simulation Framework
- Analyses
- Future Research

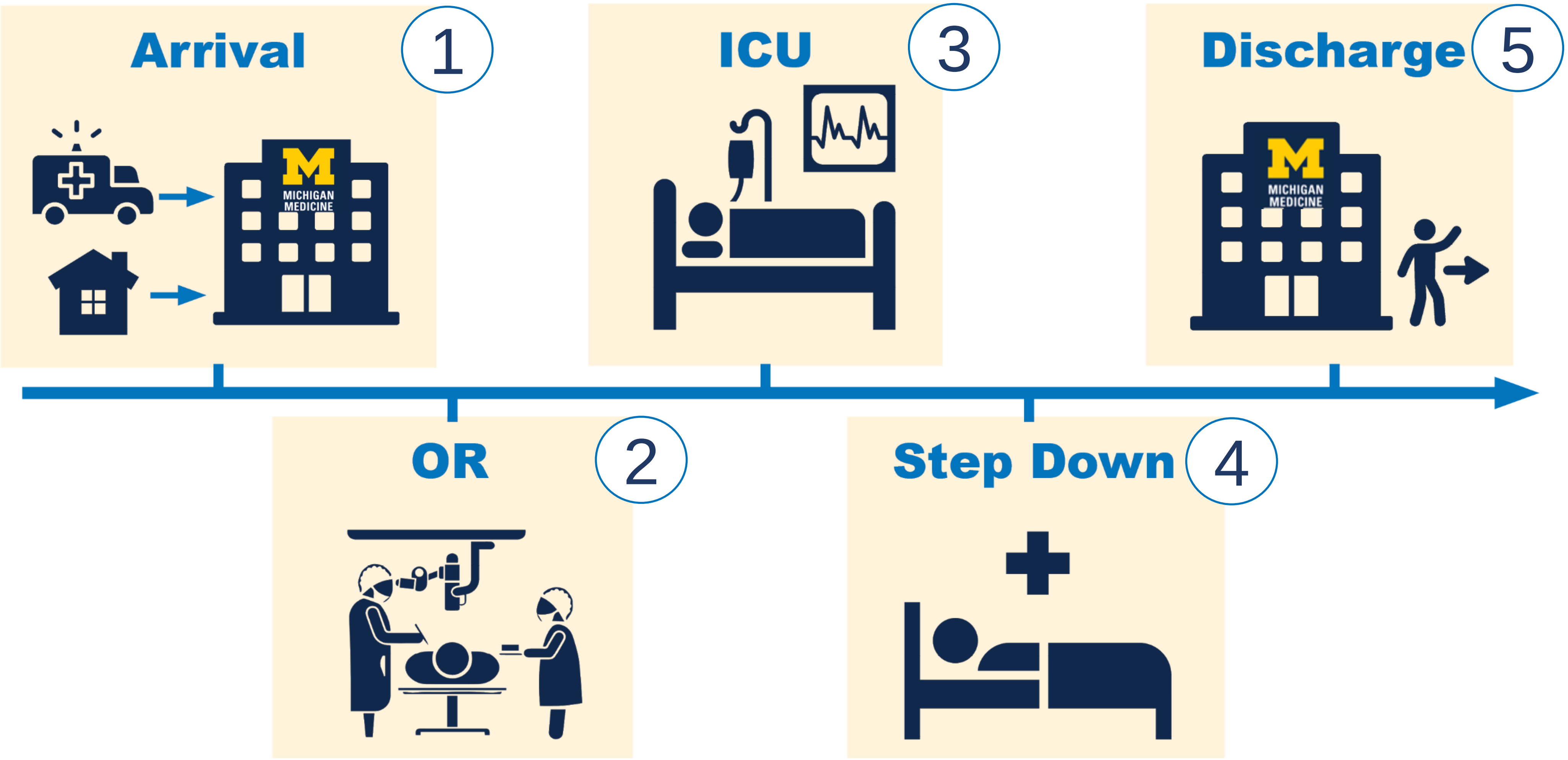
BACKGROUND



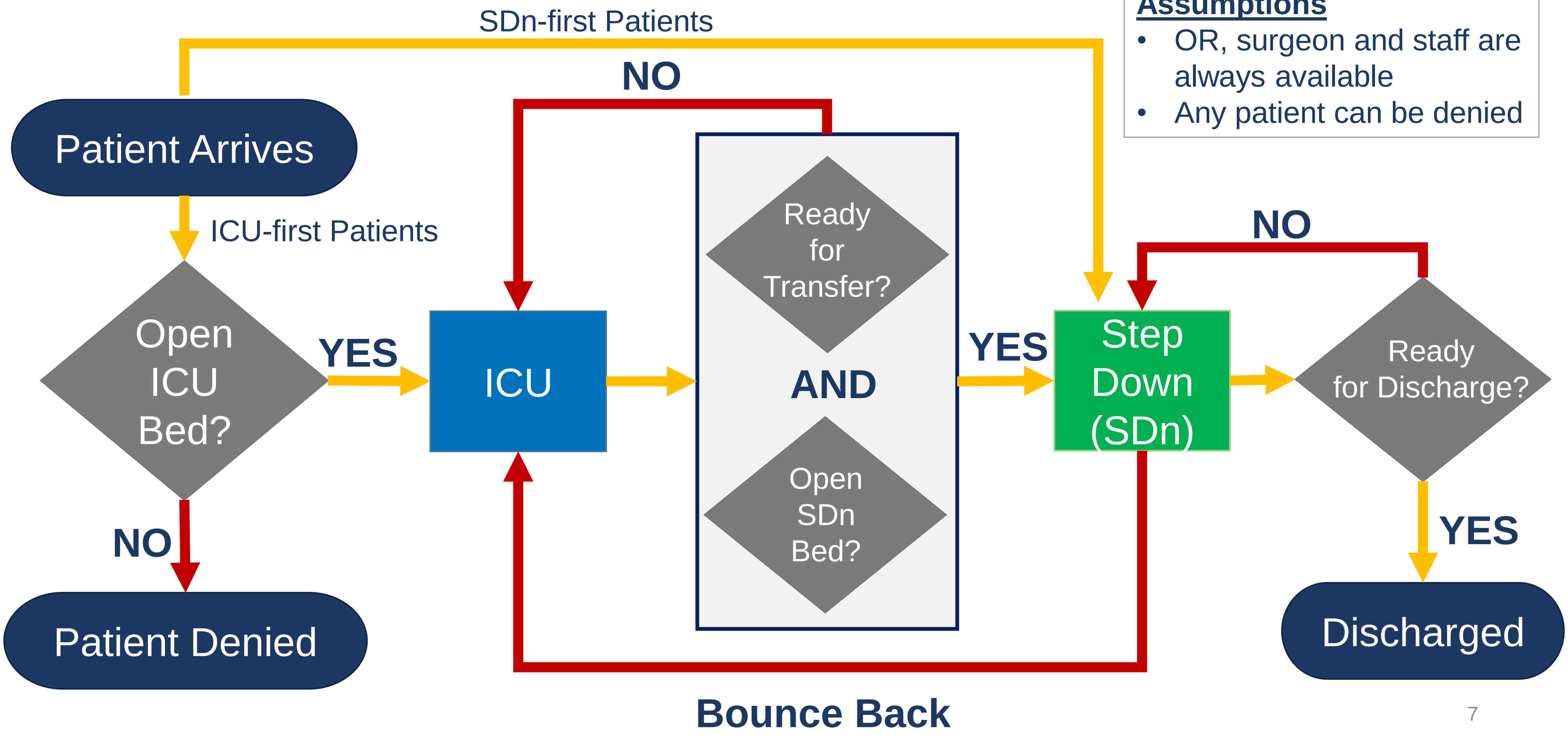
HOW SIMULATION CAN HELP



PATIENT FLOW



SIMULATION - FRAMEWORK



Assumptions

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

SIMULATION - INPUT

Fixed input:

- Bed count per unit
- Time horizon: 1 year
- Number of replications: 1000
- Bounce back probability: determined value calculated from electronic health record data

Variable input:

- Arrival rate: exponential distribution
- LOS in ICU and SDn: geometric distribution

SIMULATION - INPUT

Arrival rate: depends on day of week (different days of the week have different arrival rates)

LOS in ICU and SDn (ICU-first Patients):

- For patient X_i, we set $ICULOS_i^j$ to represent his LOS of $j\ th$ ICU visit
- We set $SDLOS_i^j$ to represent his LOS of $j\ th$ SDn visit
- Since the patient starts from ICU, whether he bounces back or not, he will visit ICU and SDn the same number of times
- N represents the number of patients
- M_i represents how many times patient i visits ICU/SDn.
- Then, we calculate:

$$ICULOS_1 = \frac{1}{N}\sum_{j=1}^{N} ICULOS_i^1\ , ICULOS_2 = \frac{1}{N * (\sum M_i)}\sum_{j=1}^{N}\sum_{i=2}^{M_i} ICULOS_i^j$$

$$SDLOS_1 = \frac{1}{N}\sum_{j=1}^{N} SDLOS_i^1\ , SDLOS_2 = \frac{1}{N * (\sum M_i)}\sum_{j=1}^{N}\sum_{i=2}^{M_i} SDLOS_i^j$$

- This means we separate patients’ first ICU/SDn stay and the all remaining ICU/SDn stays

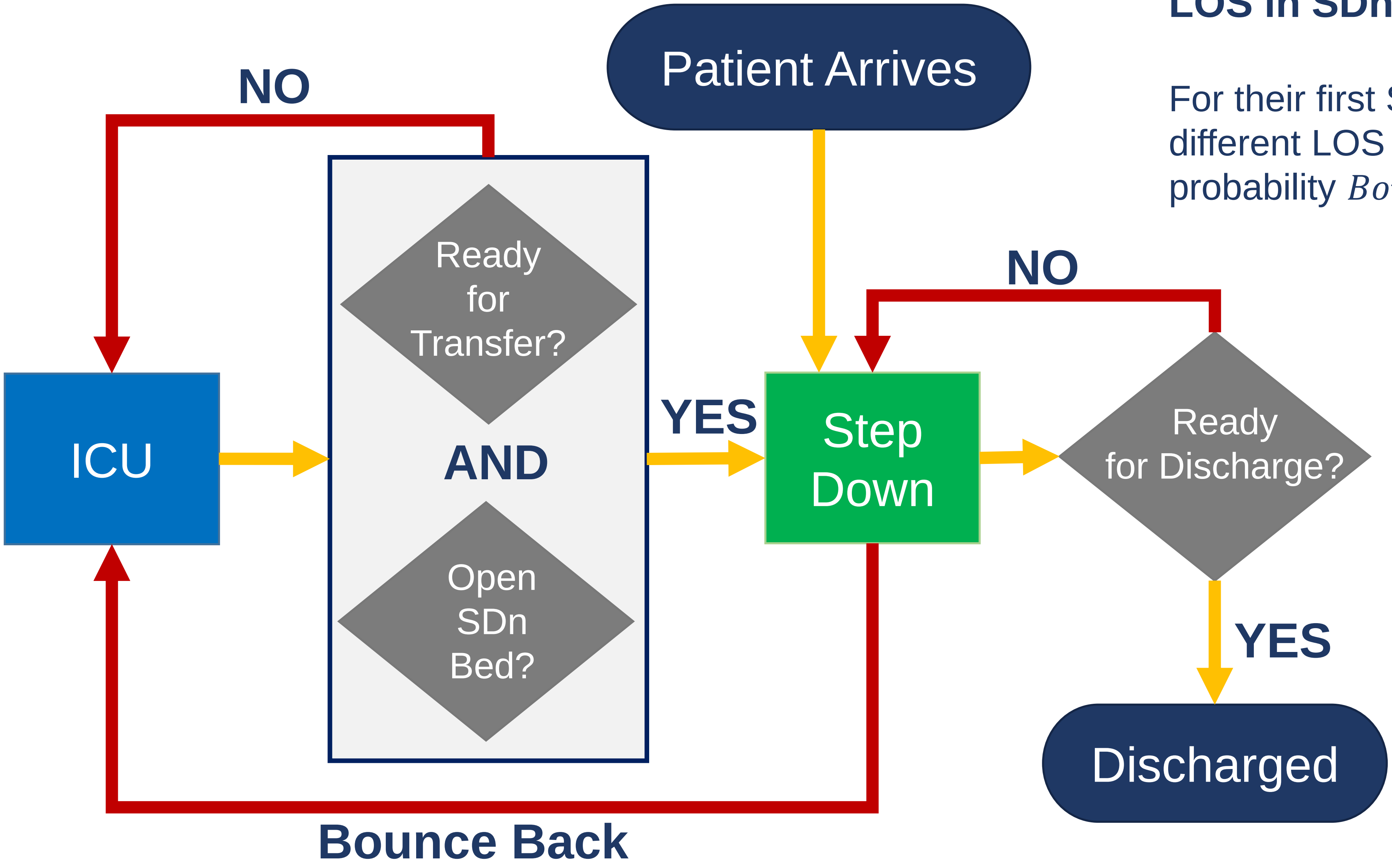
SIMULATION - INPUT

Bounce Back Probability

- 2 patient groups
  - LOS longer than median
  - LOS shorter than median
- Bounce Back probability used depends on LOS of the most recent ICU stay
  - $BounceBack_1$ for patients whose LOS of their most recent ICU visit is longer than the median
  - $BounceBack_2$ for patients whose LOS of their most recent ICU visit is below the median

$$BounceBack_1 > BounceBack_2$$

SIMULATION - INPUT

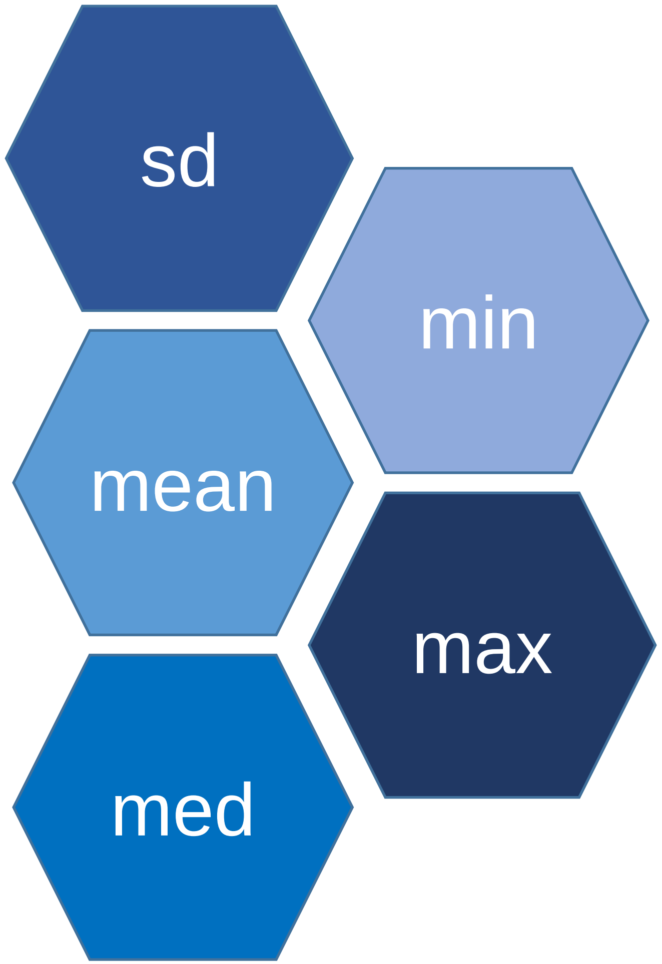


LOS in SDn: (SDn-first patients)

For their first SDn visit, they have different LOS LOS_{SD} and bounce back probability $BounceBack_{SD}$.

SIMULATION - METRICS

<table>
<tr><th colspan="2">Number of…</th></tr>
<tr><td colspan="2">Patient Arrivals</td></tr>
<tr><td colspan="2">Accepted Patients</td></tr>
<tr><td colspan="2">Denied Patients</td></tr>
<tr><th>ICU</th><th>Step Down (SDn)</th></tr>
<tr><td>• Patient LOS
• Unnecessary days in an ICU bed (SDn status)
• Bed Utilization</td><td>• Patient LOS
• Unnecessary days in a SDn bed (ICU status)
• Bed Utilization</td></tr>
</table>



ANALYSES

Analysis 1	Analysis 2	Analysis 3
How many beds we need in ICU	How many beds we need in SDn	How bounce back influences the denial rate

BASE CASE PARAMETERS

- 1 Patient Type
- Arrival Rate vs. Day of Week

Day of Week	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Arrival Rate (patients/hour)	0.237	0.281	0.245	0.231	0.243	0.090	0.080

- Time Horizon: 1 year
- Replications of simulation: 1000
- ICU-first patients (72.3%)

Parameters	$ICULOS_1$	$ICULOS_2$	$SDLOS_1$	$SDLOS_2$	$BounceBack_1$	$BounceBack_2$
Value	3.64 days	6.29 days	4.29 days	5.33 days	15.2%	10.8%

- SD-first patients (27.7%)

Parameters	LOS_{SD}	$BounceBack_{SD}$
Value	3.45 days	12.4%

ANALYSIS 1 – HOW MANY BEDS IN ICU

Set 1000 SDn beds to avoid bottleneck from ICU to SDn.

Allocated ICU Beds	28	30	32	34
Annual Patient Arrival	1784	1784	1785	1783
Patients Denied	**8.67%**	**7.12%**	**5.92%**	**4.91%**
ICU Average LOS ICU Status	3.94	4.02	3.98	4.01
ICU Average LOS SDn Status	**0**	**0**	**0**	**0**
SDn Average LOS	6.03	6.05	6.02	5.99
ICU Beds Utilization	**81.93%**	**80.92%**	**79.92%**	**78.81%**

Acceptable level of patients denied: 5%
Acceptable level of ICU beds utilization: 75%

ANALYSIS 2 – HOW MANY BEDS IN SDn

Set 34 ICU beds to avoid bottleneck from ICU to SDn.

Allocated SDn Beds	34	42	50	58	62
Annual Patient Arrival	1785	1781	1784	1786	1784
Patients Denied	**11.91%**	**8.54%**	**5.77%**	**5.13%**	**5.00%**
ICU Average LOS ICU Status	4.34	4.27	4.21	4.20	4.20
ICU Average LOS SDn Status	**0.54**	**0.44**	**0.37**	**0.36**	**0.36**
SDn Average LOS	5.81	5.93	5.98	5.99	6.00
SDn Beds Utilization	**79.84**	**73.08**	**61.73%**	**53.88%**	**50.56%**

Acceptable level of patients denied: 5%

ANALYSIS 3 – INFLUENCE OF BB

Set 34 ICU beds and 50 SDn beds.

BounceBack Probability 1	**10.8%**	**12.8%**	**14.8%**	**16.8%**
BounceBack Probability 2	**15.2%**	**17.2%**	**19.2%**	**21.2%**
Annual Patient Arrival	1784	1784	1785	1786
Patients Denied	**5.69%**	**7.48%**	**9.93%**	**13.41%**
ICU Average LOS ICU Status	4.21	4.26	4.31	4.39
ICU Average LOS SDn Status	**0.37**	**0.42**	**0.48**	**0.59**
SDn Average LOS	5.99	6.25	6.52	6.78
ICU Beds Utilization	**78.77%**	**79.92%**	**80.76%**	**81.44%**
SDn Beds Utilization	**61.77%**	**66.87%**	**72.69%**	**78.45%**

TAKEAWAYS

1. The benefits of adding ICU/SDn beds will plateau after a certain point as after this threshold, the marginal benefits of lowering the percentage of patients denied will be outweighed by the drawbacks of low bed utilization.

2. Even a small amount of uncertainty (change of bounce back probability) in the hospital system has a significant impact on patient flow.

FUTURE RESEARCH

1. Add elective surgery process to the model which may influence the arrival rate

2. Use the simulation to help make better decisions about accepting transfers and arranging elective surgeries

ACKNOWLEDGEMENTS

The Seth Bonder Foundation

PRECISION HEALTH
UNIVERSITY OF MICHIGAN

CHEPS
CENTER FOR HEALTHCARE ENGINEERING & PATIENT SAFETY

FRANKEL CARDIOVASCULAR CENTER
MICHIGAN MEDICINE

Thank you to Samir Agarwala, Imani Carson, Joshua Fink, Shamit Kikani, Luke Liu, Harini Pennathur, Hadi Saab, and all previous team members who contributed to this work.