University of Missouri Hospital (UH) #2

Maggie Dimler, Riley Arns,
Michael Stroud, and Reegan Spicer

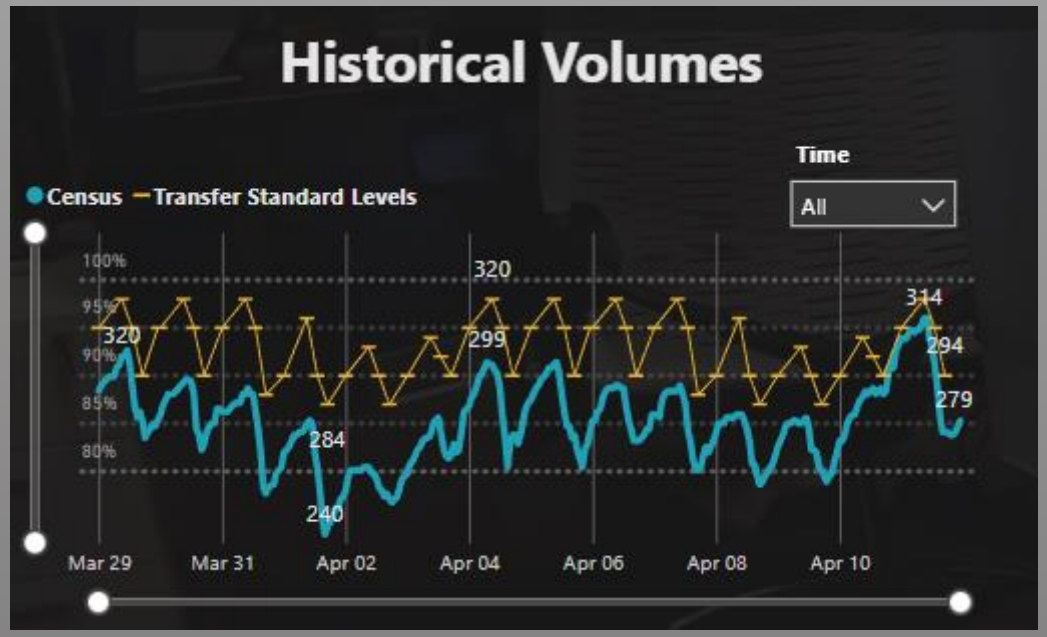
A Low-Cost Solution for High-Stakes Decisions: Simulation Software for Hypothesis Testing

- The healthcare industry is characterized by high costs, making it imperative for leaders to seek data-driven approaches for decision-making.
- Our simulation model presents a cost-effective option for testing expensive changes in the healthcare environment.
- Simulation software can help healthcare organizations make informed decisions with reduced risk and uncertainty.

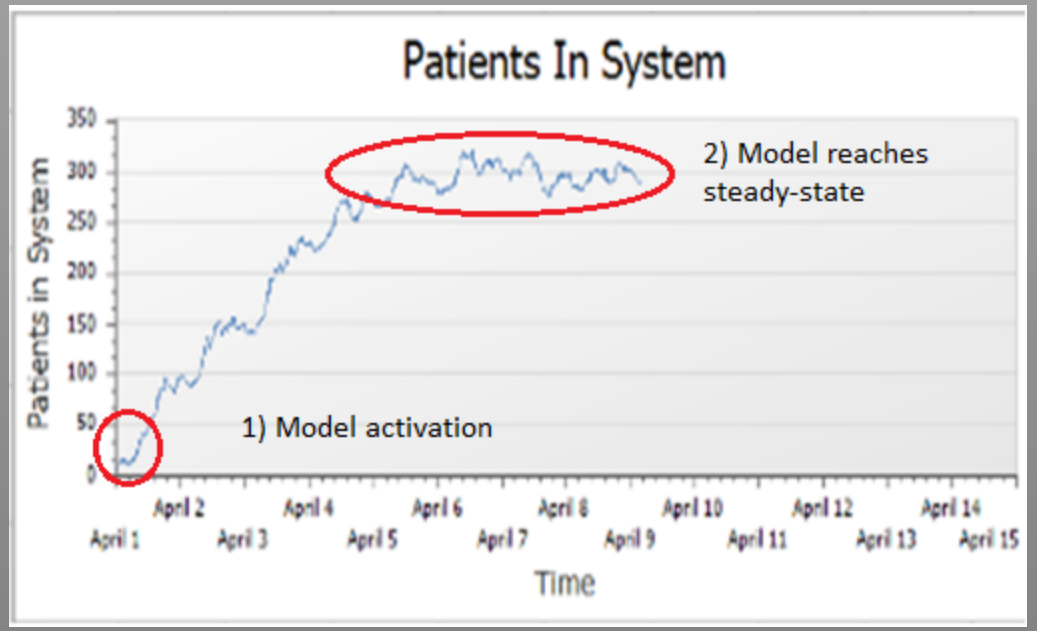
Project Objective

- To demonstrate how a patient flow model can support strategic planning by enabling executives to evaluate potential outcomes

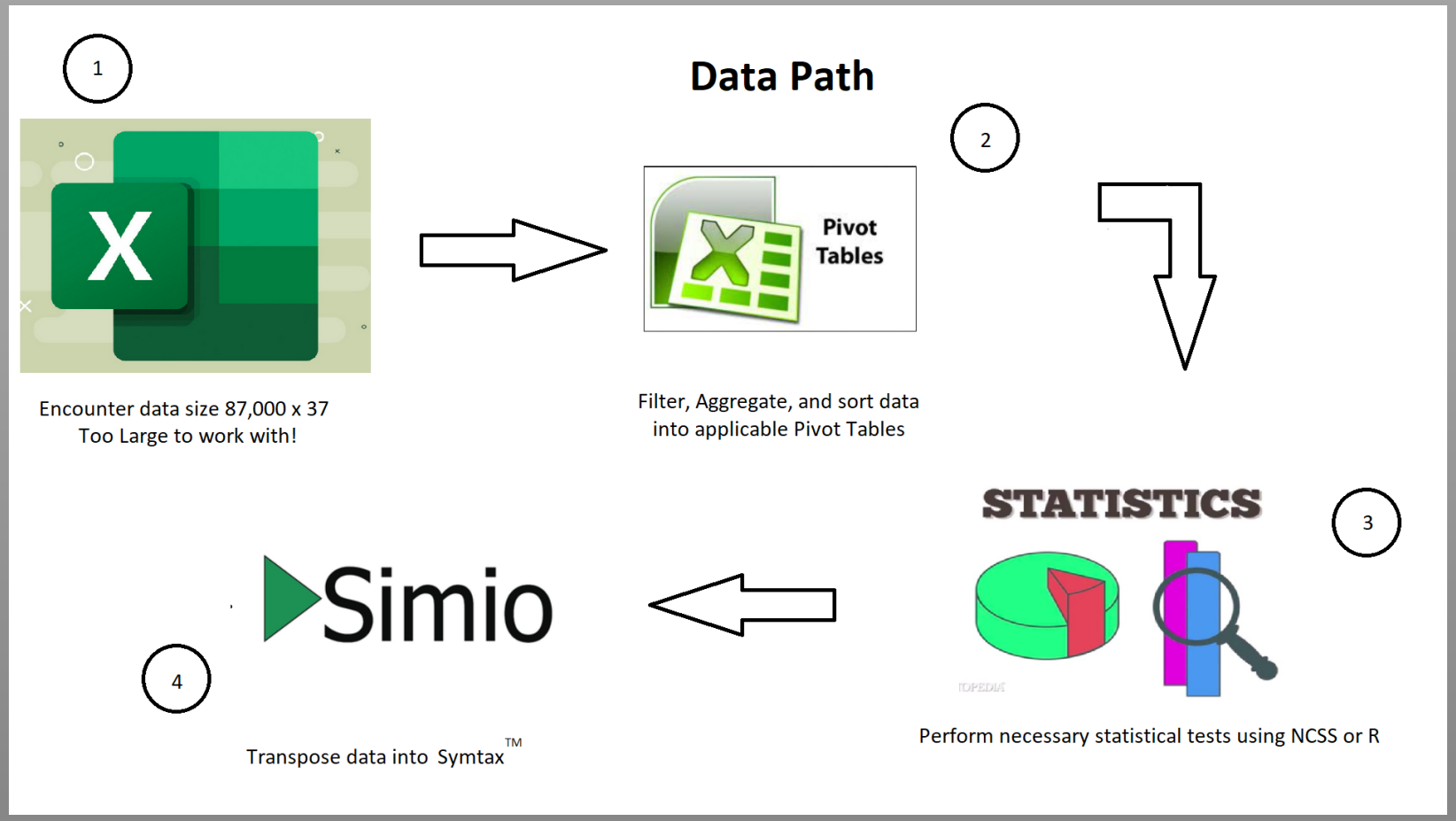
Real Hospital data



Modeling the data



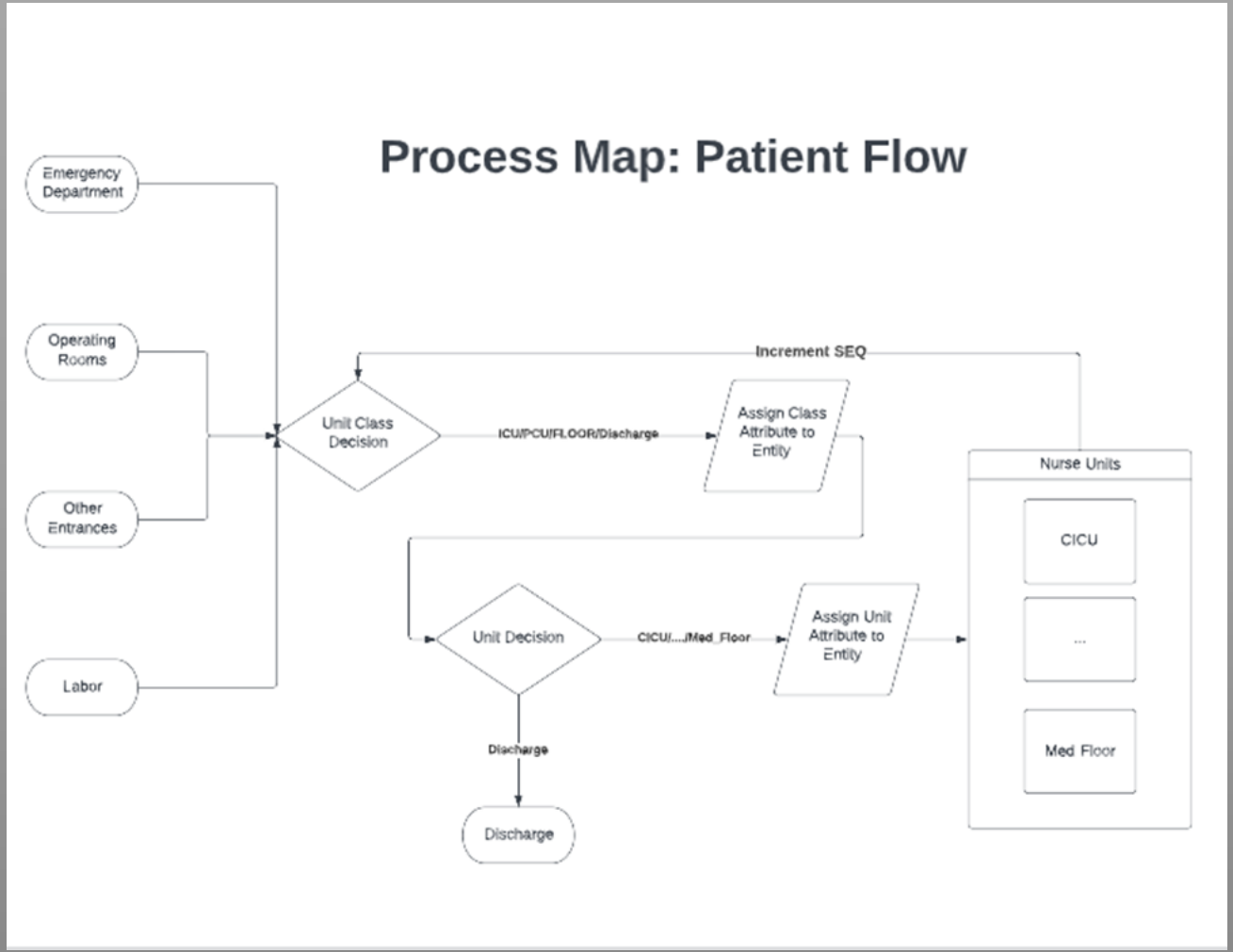
Our Simulation is Farm to Table



Building the Model!

Three main segments

- Arrival
- Routing
- Length of Stay

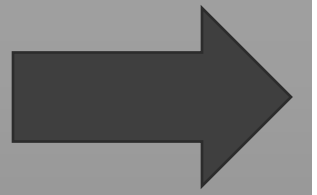


Building the Model: Routing Logic Formula

Two building block formulas

```
Math.If( cond1, value1, cond2, value2, … , elseValue )
```

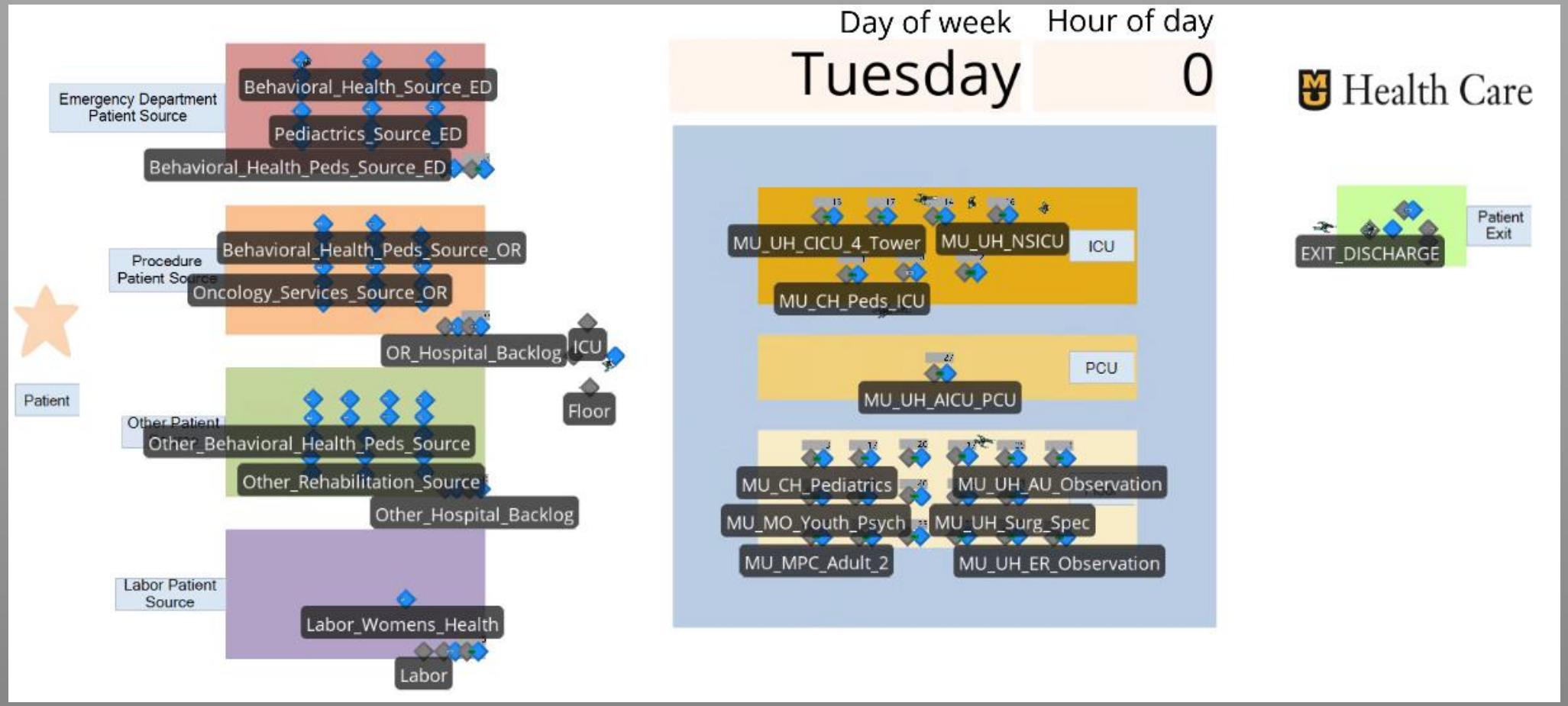
```
Random.Discrete( v1, c1, v2, c2, … )
```



```
Math.If[ModelEntity.SEQ==1,Math.If[ModelEntity.UNIT=="MU_CH_Pediatrics",Random.Discrete("EXIT_DISCHARGE",0.9425,"Floor",0.946,"ICU",1,"PCU",1),
ModelEntity.UNIT=="MU_MO_Youth_Psych",Random.Discrete("EXIT_DISCHARGE",1,"Floor",1,"ICU",1,"PCU",1),
ModelEntity.UNIT=="MU_MOI_Orthopaedics",Random.Discrete("EXIT_DISCHARGE",0.97774,"Floor",0.99205,"ICU",0.99523,"PCU",1),
ModelEntity.UNIT=="MU_MPC_Adult_1",Random.Discrete("EXIT_DISCHARGE",0.96825,"Floor",1,"ICU",1,"PCU",1),
ModelEntity.UNIT=="MU_MPC_Adult_2",Random.Discrete("EXIT_DISCHARGE",0.9845,"Floor",1,"ICU",1,"PCU",1),
ModelEntity.UNIT=="MU_UH_Cardiovascular",Random.Discrete("EXIT_DISCHARGE",0.82729,"Floor",0.90242,"ICU",0.98964,"PCU",1),
ModelEntity.UNIT=="MU_UH_ER_Observation",Random.Discrete("EXIT_DISCHARGE",0.82203,"Floor",0.98245,"ICU",0.99213,"PCU",1),
ModelEntity.UNIT=="MU_UH_Family_Medicine",Random.Discrete("EXIT_DISCHARGE",0.75273,"Floor",0.90027,"ICU",0.92486,"PCU",1),
ModelEntity.UNIT=="MU_UH_Integrated_Med",Random.Discrete("EXIT_DISCHARGE",0.94033,"Floor",0.96708,"ICU",0.97942,"PCU",1),
ModelEntity.UNIT=="MU_UH_Med_1",Random.Discrete("EXIT_DISCHARGE",0.75276,"Floor",0.91298,"ICU",0.94337,"PCU",1),
ModelEntity.UNIT=="MU_UH_Med_2",Random.Discrete("EXIT_DISCHARGE",0.74381,"Floor",0.90347,"ICU",0.94554,"PCU",1),
ModelEntity.UNIT=="MU_UH_Neuro_Science",Random.Discrete("EXIT_DISCHARGE",0.79076,"Floor",0.88023,"ICU",0.9798,"PCU",1),
ModelEntity.UNIT=="MU_UH_Obs_Short_Stay",Random.Discrete("EXIT_DISCHARGE",0.78984,"Floor",0.93023,"ICU",0.9621,"PCU",1),
ModelEntity.UNIT=="MU_UH_Oncology",Random.Discrete("EXIT_DISCHARGE",0.86888,"Floor",0.93357,"ICU",0.97378,"PCU",1),
ModelEntity.UNIT=="MU_UH_Surg_Spec",Random.Discrete("EXIT_DISCHARGE",0.83122,"Floor",0.95959,"ICU",0.98891,"PCU",1),
ModelEntity.UNIT=="MU_WCH_Maternal",Random.Discrete("EXIT_DISCHARGE",0.99708,"Floor",0.99883,"ICU",0.99942,"PCU",1),
ModelEntity.UNIT=="MU_UH_AU_Observation",Random.Discrete("EXIT_DISCHARGE",0.52327,"Floor",0.99964,"ICU",1,"PCU",1),
ModelEntity.UNIT=="MU_CH_Peds_ICU",Random.Discrete("EXIT_DISCHARGE",0.546,"Floor",0.996,"ICU",1,"PCU",1),
ModelEntity.UNIT=="MU_UH_CICU_4_Tower",Random.Discrete("EXIT_DISCHARGE",0.37719,"Floor",0.90643,"ICU",0.9576,"PCU",1),
ModelEntity.UNIT=="MU_UH_MICU3",Random.Discrete("EXIT_DISCHARGE",0.35645,"Floor",0.84355,"ICU",0.86774,"PCU",1),
ModelEntity.UNIT=="MU_UH_MICU5",Random.Discrete("EXIT_DISCHARGE",0.35785,"Floor",0.833,"ICU",0.85686,"PCU",1),
ModelEntity.UNIT=="MU_UH_NSICU",Random.Discrete("EXIT_DISCHARGE",0.34174,"Floor",0.95938,"ICU",0.97899,"PCU",1),
ModelEntity.UNIT=="MU_UH_SICU",Random.Discrete("EXIT_DISCHARGE",0.3208,"Floor",0.9292,"ICU",0.97124,"PCU",1),
ModelEntity.UNIT=="MU_WCH_NICU",Random.Discrete("EXIT_DISCHARGE",0.97674,"Floor",0.99225,"ICU",1,"PCU",1),
ModelEntity.UNIT=="MU_UH_AICU_PCU",Random.Discrete("EXIT_DISCHARGE",0.42058,"Floor",0.88357,"ICU",1,"PCU",1), "EXIT_DISCHARGE"),
ModelEntity.SEQ==2,Math.If[ModelEntity.UNIT=="MU_CH_Pediatrics",Random.Discrete("EXIT_DISCHARGE",0.976,"Floor",0.976,"ICU",1,"PCU",1),
ModelEntity.UNIT=="MU_MO_Youth_Psych",Random.Discrete("EXIT_DISCHARGE",1,"Floor",1,"ICU",1,"PCU",1),
ModelEntity.UNIT=="MU_MOI_Orthopaedics",Random.Discrete("EXIT_DISCHARGE",0.97284,"Floor",0.99012,"ICU",0.99259,"PCU",1),
ModelEntity.UNIT=="MU_MPC_Adult_1",Random.Discrete("EXIT_DISCHARGE",0.98435,"Floor",1,"ICU",1,"PCU",1),
ModelEntity.UNIT=="MU_MPC_Adult_2",Random.Discrete("EXIT_DISCHARGE",0.97987,"Floor",1,"ICU",1,"PCU",1),
ModelEntity.UNIT=="MU_UH_Cardiovascular",Random.Discrete("EXIT_DISCHARGE",0.82744,"Floor",0.92723,"ICU",0.99168,"PCU",1),
ModelEntity.UNIT=="MU_UH_ER_Observation",Random.Discrete("EXIT_DISCHARGE",1,"Floor",1,"ICU",1,"PCU",1),
ModelEntity.UNIT=="MU_UH_Family_Medicine",Random.Discrete("EXIT_DISCHARGE",0.80471,"Floor",0.91582,"ICU",0.94949,"PCU",1),
ModelEntity.UNIT=="MU_UH_Integrated_Med",Random.Discrete("EXIT_DISCHARGE",0.94783,"Floor",0.96957,"ICU",0.97391,"PCU",1),
ModelEntity.UNIT=="MU_UH_Med_1",Random.Discrete("EXIT_DISCHARGE",0.72956,"Floor",0.90356,"ICU",0.95388,"PCU",1),
ModelEntity.UNIT=="MU_UH_Med_2",Random.Discrete("EXIT_DISCHARGE",0.79644,"Floor",0.93639,"ICU",0.95165,"PCU",1),
ModelEntity.UNIT=="MU_UH_Neuro_Science",Random.Discrete("EXIT_DISCHARGE",0.78446,"Floor",0.89474,"ICU",0.97995,"PCU",1),
ModelEntity.UNIT=="MU_UH_Obs_Short_Stay",Random.Discrete("EXIT_DISCHARGE",0.77838,"Floor",0.91351,"ICU",0.95135,"PCU",1),
ModelEntity.UNIT=="MU_UH_Oncology",Random.Discrete("EXIT_DISCHARGE",0.8383,"Floor",0.94468,"ICU",0.98723,"PCU",1),
ModelEntity.UNIT=="MU_UH_Surg_Spec",Random.Discrete("EXIT_DISCHARGE",0.79268,"Floor",0.92988,"ICU",0.9939,"PCU",1),
ModelEntity.UNIT=="MU_WCH_Maternal",Random.Discrete("EXIT_DISCHARGE",1,"Floor",1,"ICU",1,"PCU",1),
ModelEntity.UNIT=="MU_UH_AU_Observation",Random.Discrete("EXIT_DISCHARGE",0.2381,"Floor",1,"ICU",1,"PCU",1),
ModelEntity.UNIT=="MU_CH_Peds_ICU",Random.Discrete("EXIT_DISCHARGE",0.25455,"Floor",0.99091,"ICU",1,"PCU",1),
ModelEntity.UNIT=="MU_UH_CICU_4_Tower",Random.Discrete("EXIT_DISCHARGE",0.32164,"Floor",0.87719,"ICU",0.97076,"PCU",1),
ModelEntity.UNIT=="MU_UH_MICU3",Random.Discrete("EXIT_DISCHARGE",0.27206,"Floor",0.78676,"ICU",0.82353,"PCU",1),
ModelEntity.UNIT=="MU_UH_MICU5",Random.Discrete("EXIT_DISCHARGE",0.31193,"Floor",0.77064,"ICU",0.77982,"PCU",1),
ModelEntity.UNIT=="MU_UH_NSICU",Random.Discrete("EXIT_DISCHARGE",0.36036,"Floor",0.88288,"ICU",0.94595,"PCU",1),
ModelEntity.UNIT=="MU_UH_SICU",Random.Discrete("EXIT_DISCHARGE",0.18367,"Floor",0.88776,"ICU",0.96939,"PCU",1),
ModelEntity.UNIT=="MU_WCH_NICU",Random.Discrete("EXIT_DISCHARGE",1,"Floor",1,"ICU",1,"PCU",1),
ModelEntity.UNIT=="MU_UH_AICU_PCU",Random.Discrete("EXIT_DISCHARGE",0.39388,"Floor",0.84898,"ICU",1,"PCU",1), "EXIT_DISCHARGE"),
ModelEntity.SEQ==3,Math.If[ModelEntity.UNIT=="MU_CH_Pediatrics",Random.Discrete("EXIT_DISCHARGE",0.9759,"Floor",0.9759,"ICU",1,"PCU",1),
ModelEntity.UNIT=="MU_MO_Youth_Psych",Random.Discrete("EXIT_DISCHARGE",1,"Floor",1,"ICU",1,"PCU",1),
ModelEntity.UNIT=="MU_MOI_Orthopaedics",Random.Discrete("EXIT_DISCHARGE",0.89189,"Floor",0.98198,"ICU",0.98198,"PCU",1),
ModelEntity.UNIT=="MU_MPC_Adult_1",Random.Discrete("EXIT_DISCHARGE",1,"Floor",1,"ICU",1,"PCU",1),
ModelEntity.UNIT=="MU_MPC_Adult_2",Random.Discrete("EXIT_DISCHARGE",1,"Floor",1,"ICU",1,"PCU",1),
ModelEntity.UNIT=="MU_UH_Cardiovascular",Random.Discrete("EXIT_DISCHARGE",0.73109,"Floor",0.87395,"ICU",0.98319,"PCU",1),
ModelEntity.UNIT=="MU_UH_Family_Medicine",Random.Discrete("EXIT_DISCHARGE",0.71963,"Floor",0.8785,"ICU",0.93458,"PCU",1),
ModelEntity.UNIT=="MU_UH_Integrated_Med",Random.Discrete("EXIT_DISCHARGE",0.83333,"Floor",0.93056,"ICU",0.95833,"PCU",1),
ModelEntity.UNIT=="MU_UH_Med_1",Random.Discrete("EXIT_DISCHARGE",0.70861,"Floor",0.92715,"ICU",0.96689,"PCU",1),
ModelEntity.UNIT=="MU_UH_Med_2",Random.Discrete("EXIT_DISCHARGE",0.73504,"Floor",0.86325,"ICU",0.89744,"PCU",1),
ModelEntity.UNIT=="MU_UH_Neuro_Science",Random.Discrete("EXIT_DISCHARGE",0.71875,"Floor",0.84375,"ICU",0.98438,"PCU",1),
ModelEntity.UNIT=="MU_UH_Obs_Short_Stay",Random.Discrete("EXIT_DISCHARGE",0.75676,"Floor",0.89189,"ICU",0.97297,"PCU",1),
ModelEntity.UNIT=="MU_UH_Oncology",Random.Discrete("EXIT_DISCHARGE",0.80488,"Floor",0.90244,"ICU",0.93902,"PCU",1),
```

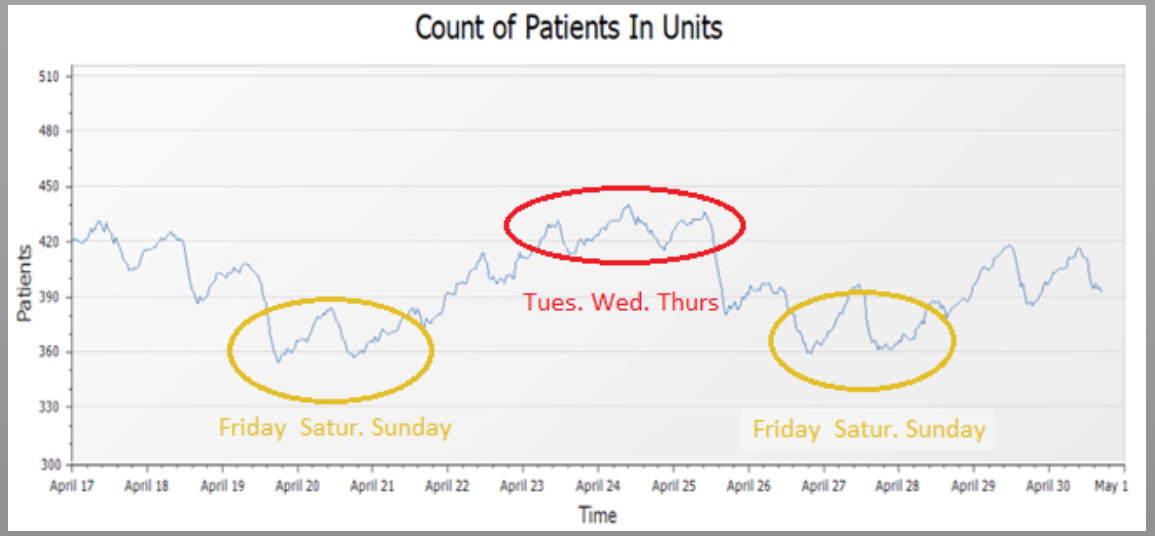
…

Video of Simulation



Qualitative Validation

- Qualitative analysis demonstrates the potential for simulating healthcare activates
- Daily and Weekly periodic cycles can be observed



Qualitative Validation

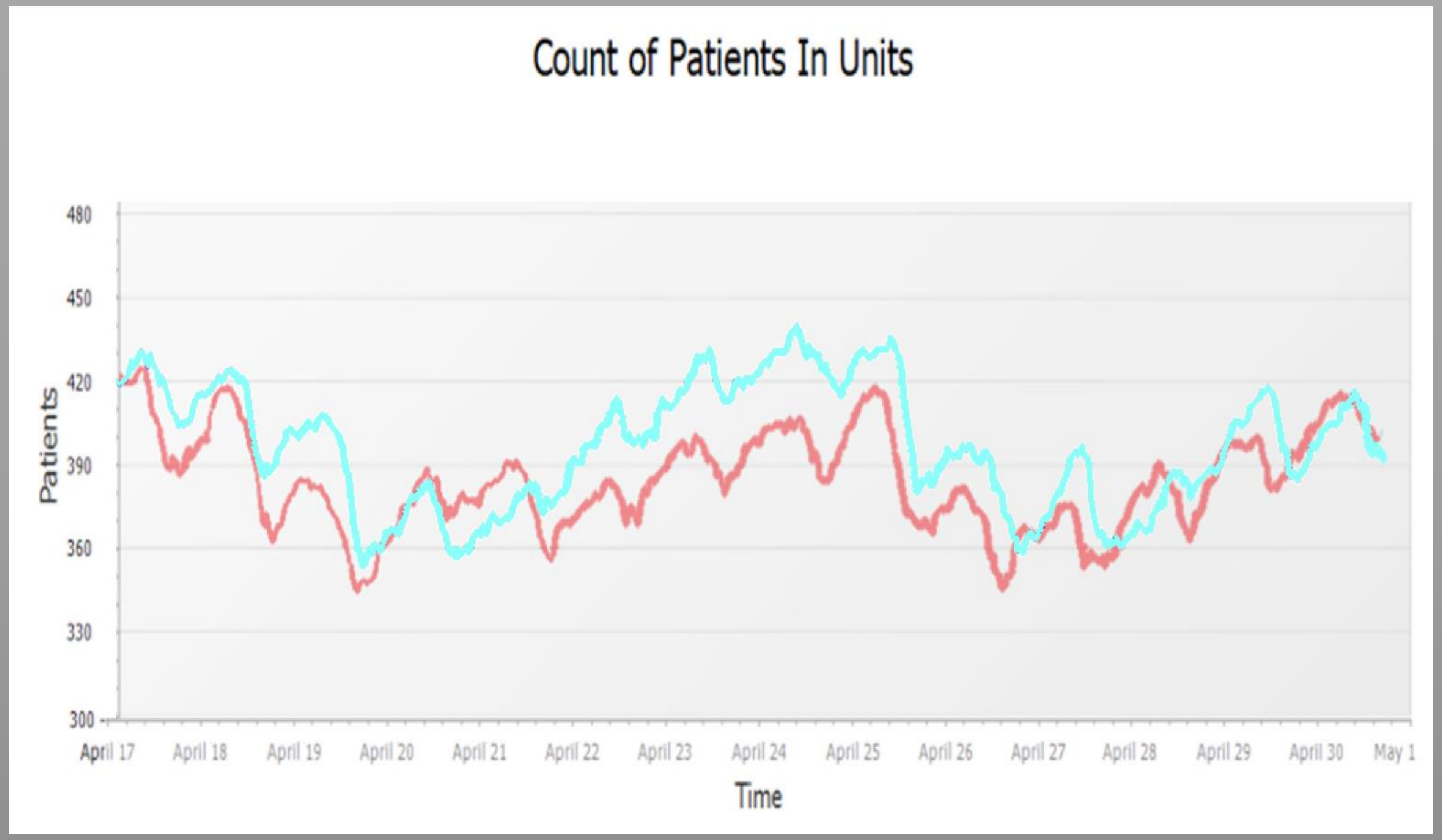
- With further modeling improvements, the simulation can accurately represent patient experiences in the NICU.
- Our simulation software model has the potential to provide valuable insights for decision-making

Using the Model

- The first step of our project was to build a model of patient flow
- The second step of our project was to show that the model can be used in providing insight.
- Three scenarios have been selected to showcase the model's usefulness.
- NOTE: The following scenarios were done with 1 replication, MUHC may or may not experience similar results

Hypothesis #1

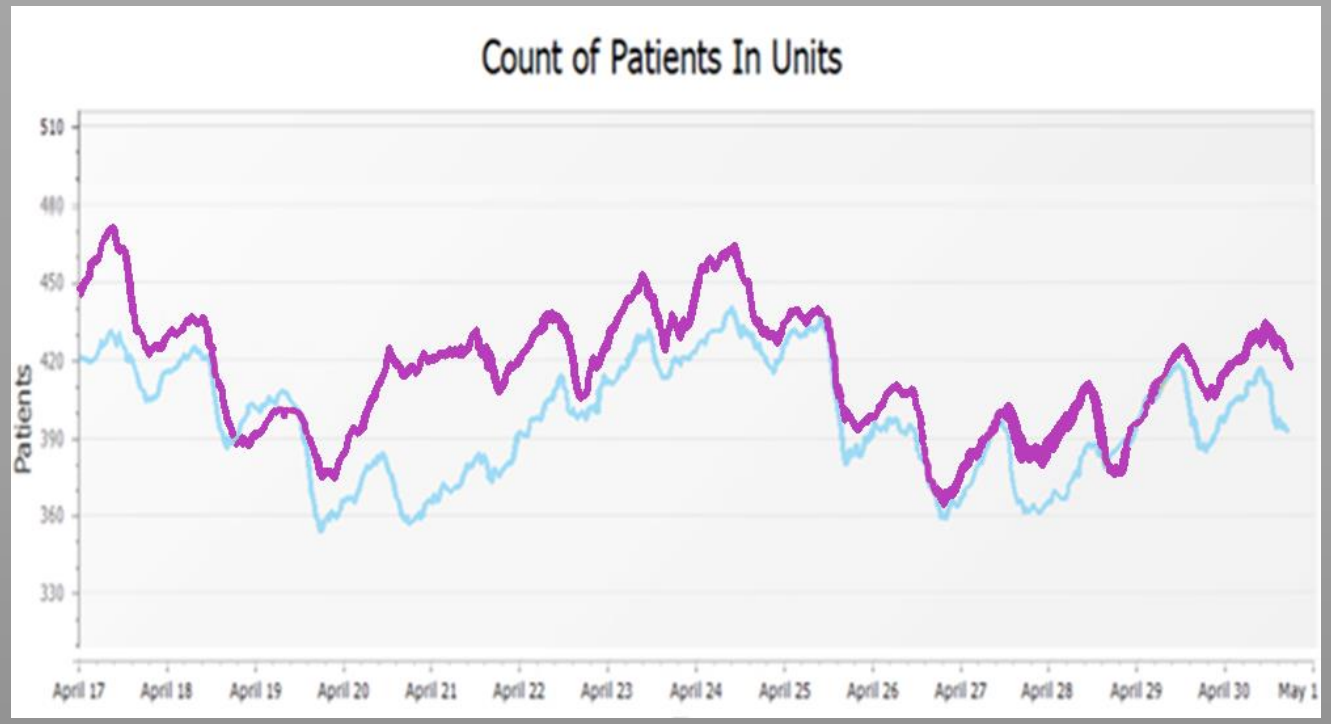
- What would happen if…
- Average discharge and transfer time moved from ~2:30 PM to 11:00 AM?
- Answer: Our model suggests a slight to negligible decrease in patients in units



Baseline in Blue
Hypothesis in Red

Hypothesis #2

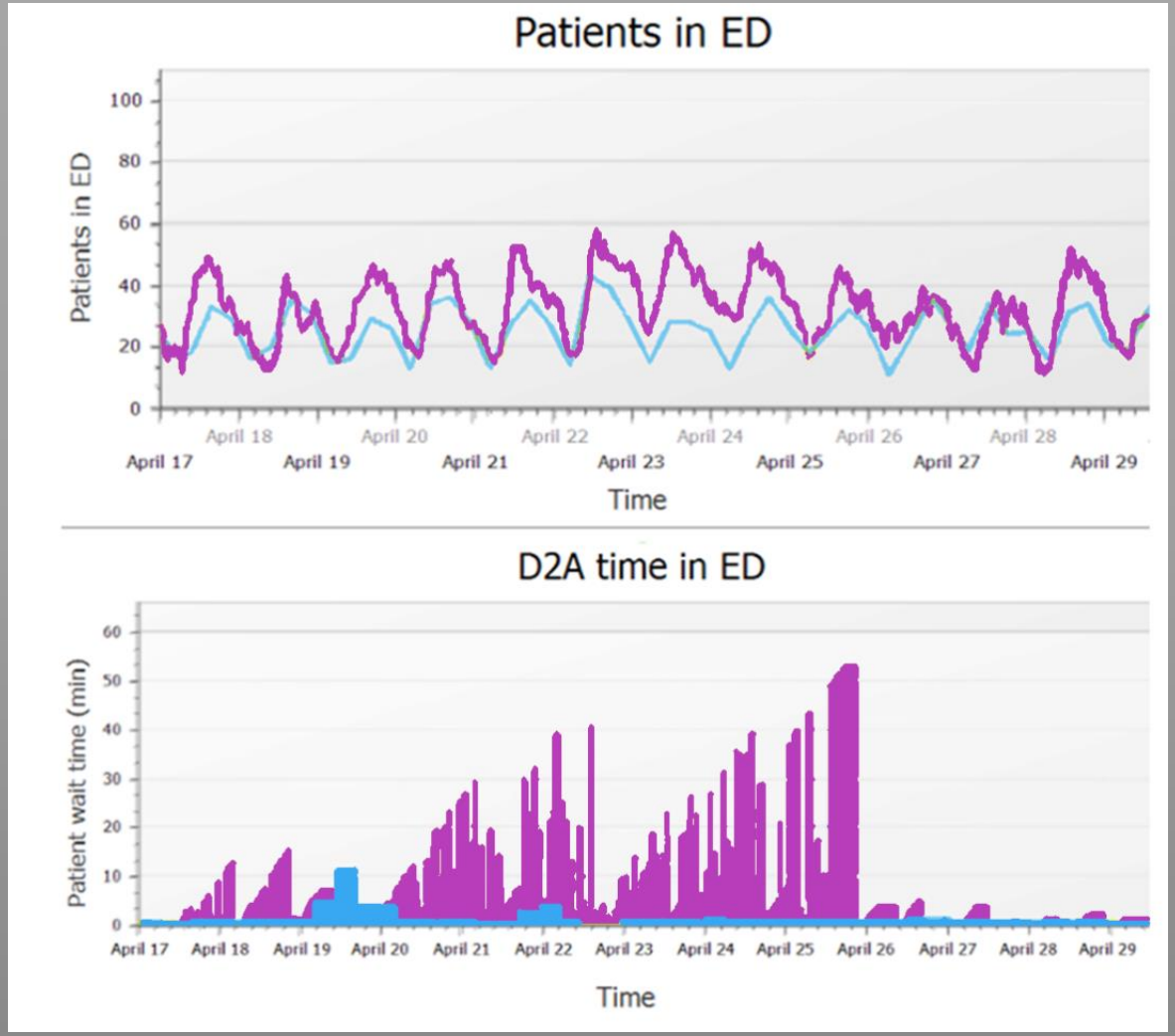
- What would happen if...
- Patient arrivals increased by 10% in all service lines?
- Answer: Our model suggests an increase in patients in units



Baseline in Blue
Hypothesis in Purple

Hypothesis #2 Continued: ER Impact

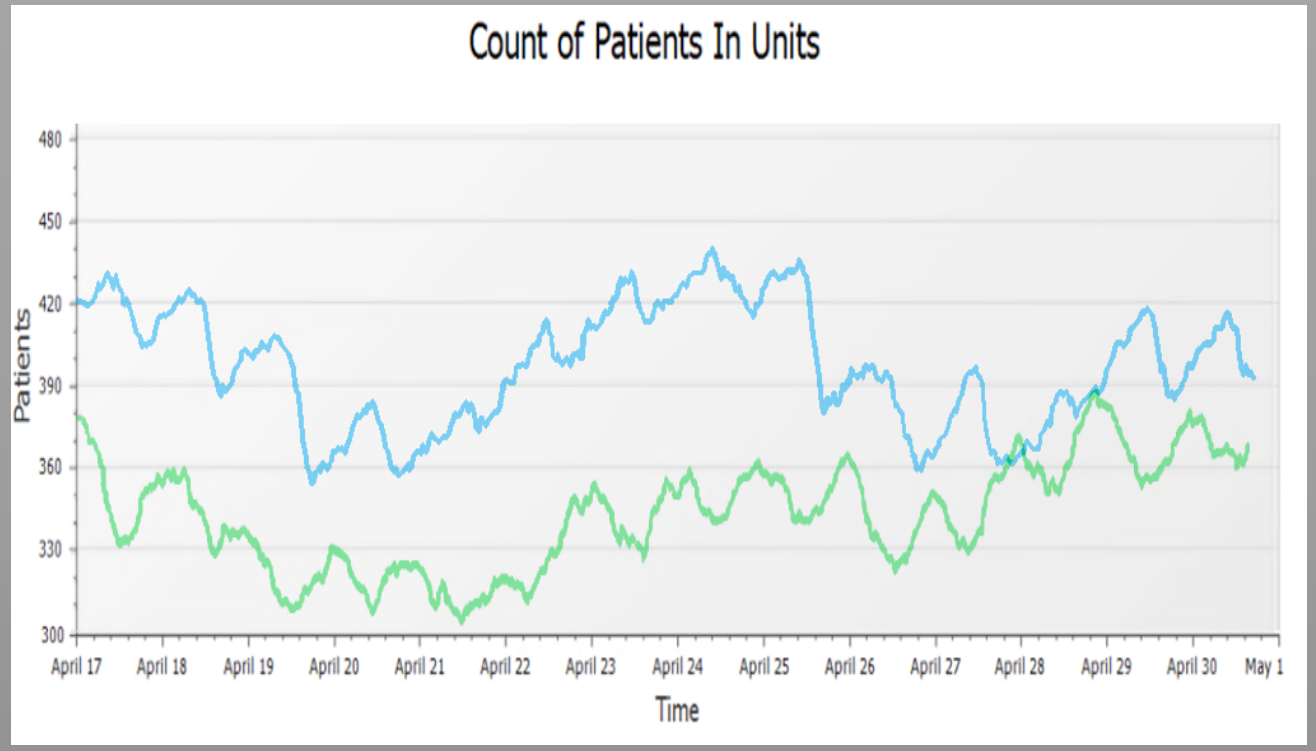
- As the hospital fills from the 10% increase in patient arrivals, patients wait in the ED until a bed has become available
- Leads to increased patients in ED and substantially increased decision to admit times.



Baseline in Blue
Hypothesis in Purple

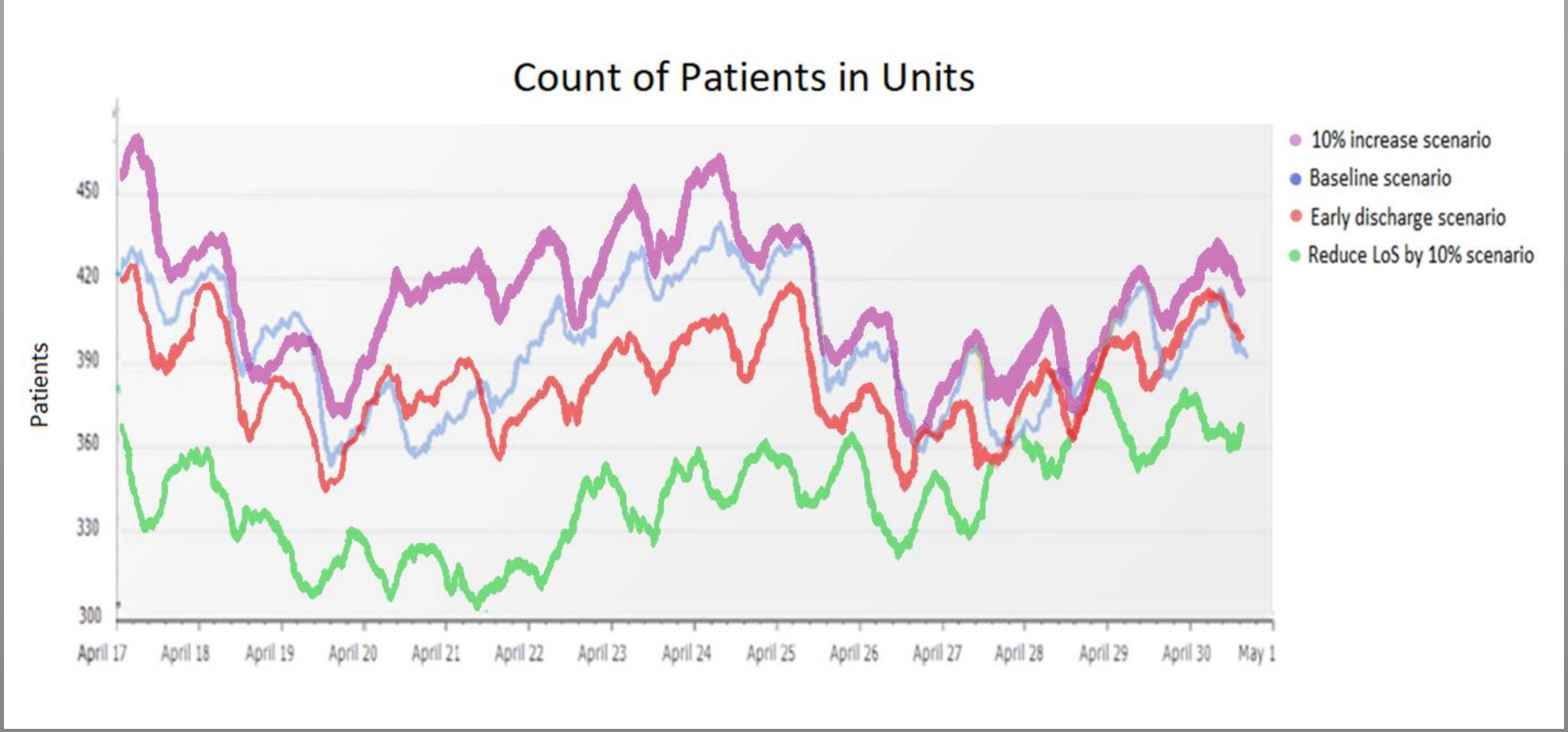
Hypothesis #3

- What would happen if...
- Patient Length of Stay decreased by 10%?
- Answer: Our model suggests a significant decrease in patients in units



Baseline in Blue
Hypothesis in green

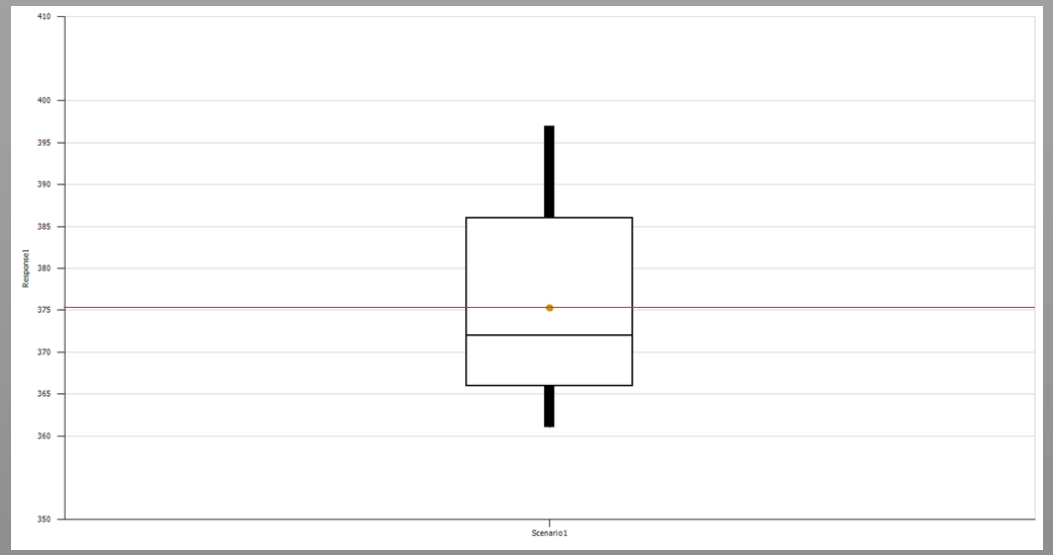
Results Graph



Experimentation Example

- Comparing the unaltered state to a scenario with increased demand and reduced length of stay, where is the **break-even** point?
- In the increased demand scenario, at what LoS reduction does the number of patients in units match the baseline scenario number of patients in units
- Five scenarios were replicated 10 times. Explored with the following LoS reductions
- Scenario 1) 0% reduction in LOS
- Scenario 2) 10% reduction in LOS
- Scenario 3) 20% reduction in LOS
- Scenario 4) 30% reduction in LOS
- Scenario 5) 40% reduction in LOS

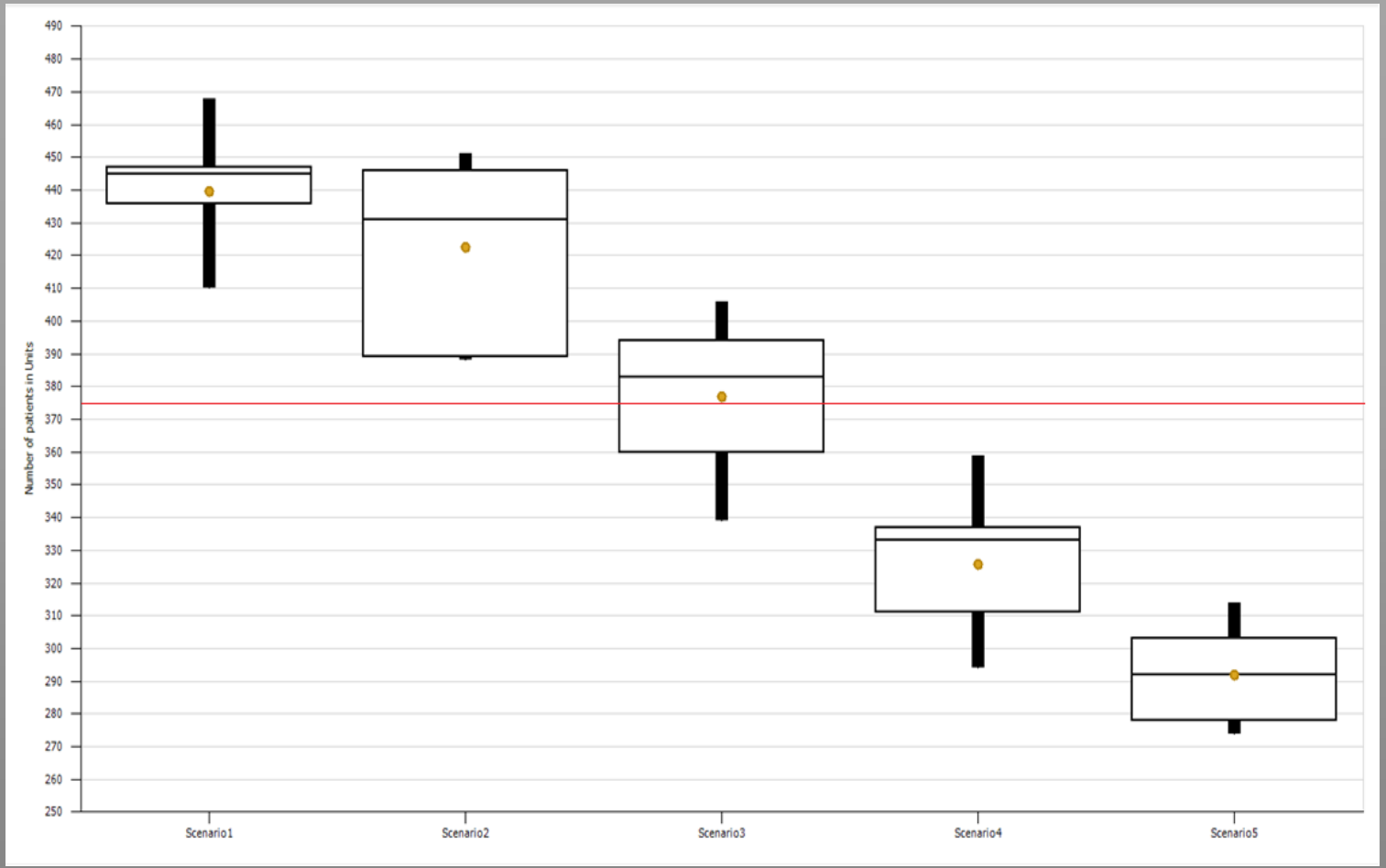
Baseline box plot



Mean: 375 Patients in units
IQR: 368 - 386

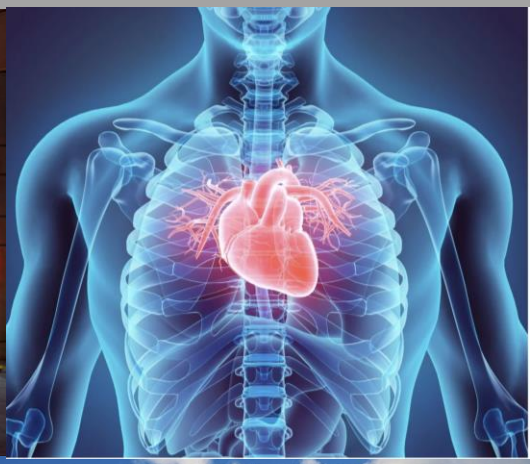
Experimentation Example Results

- Scenario 3 is the break-even point. This means a 20% reduction in length of stay counteracted the increase patient demand.
- This result is supported by Little's law



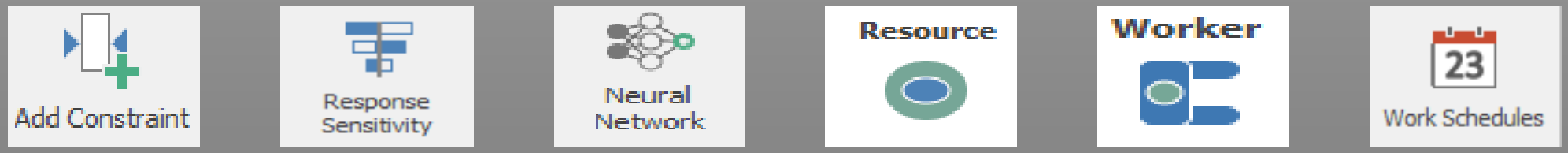
Testing Scenario Possibilities

- Service line specific demand increases in line with projected growth rates
  - Cardiovascular growth
- Increasing Emergency Department demand and/or capacity
  - Simulating Emergency department LWBS as a function of wait time
- Adding the new building to the model and future expansions



Recommendation of Continued Development

- Based on our findings, we recommend that the MUHC invest in the further development of a robust patient flow simulation tool to enhance decision-making processes.



Summary

Motivation:

- Simulation software can help healthcare organizations make informed decisions with reduced risk and uncertainty

Procedure:

- Build a simulation model of the hospital to test various hypothesis. Showcase the potential of simulation in data driven decisions

Future works:

- Further development and validation of simulation tools