An Integrated Agent-Based and Queueing Model for the Spread of Outpatient Infections

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Healthcare-Associated Infections

Inpatient

1. **They're common.**
   - 1.7 million per year
2. **They're costly.**
   - 99,000 deaths per year
   - $5B medical cost per year
3. **It's getting worse.**
   - 36% increase over last 20 years

R. Monina Klevens et al. Estimating Health Care-Associated Infections and Deaths in U.S. Hospitals, 2002. CDC Public Health Reports March-April 2007.

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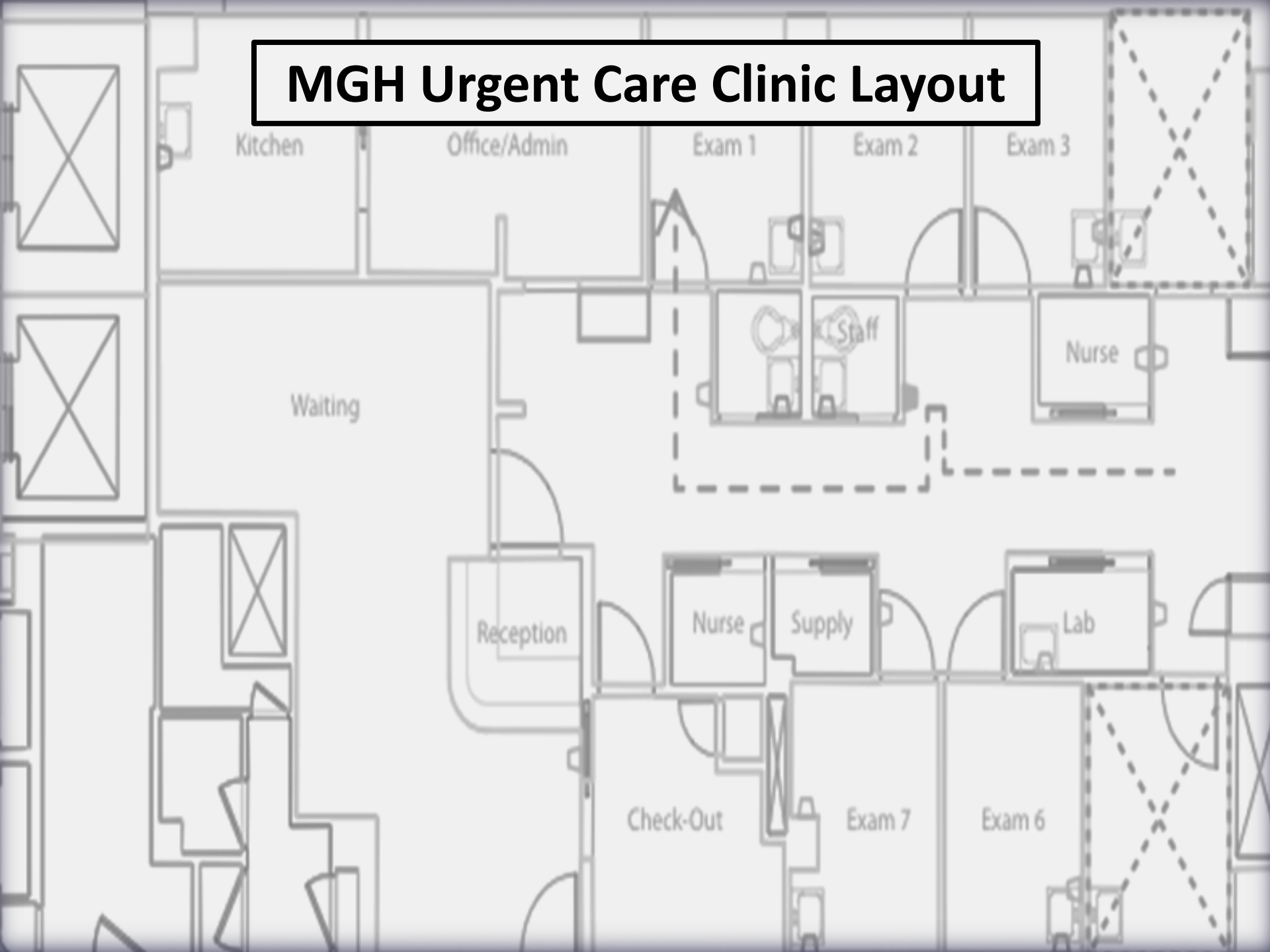
Outpatient

1. **How bad is it?**
2. **What factors contribute?**
3. **What policies are most effective?**


MASSACHUSETTS GENERAL HOSPITAL
MAIN ENTRANCE

MGH Urgent Care Clinic Layout



Healthcare-Associated Infections at MGH Urgent Care Clinic

Sponsor Objectives:

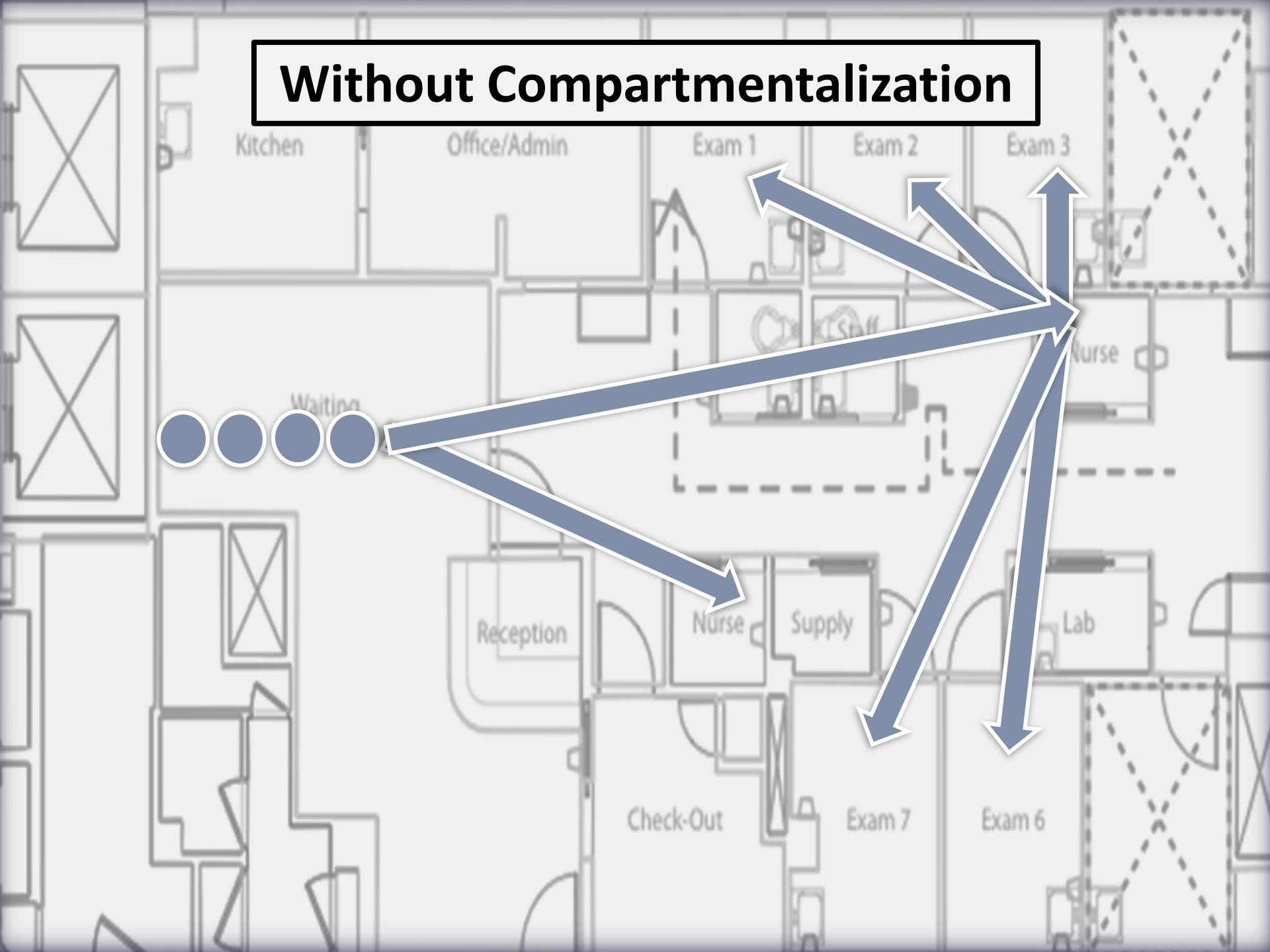
- Investigate ways to reduce the spread of infection in outpatient clinics
- Develop generalizable knowledge in addition to specific solutions

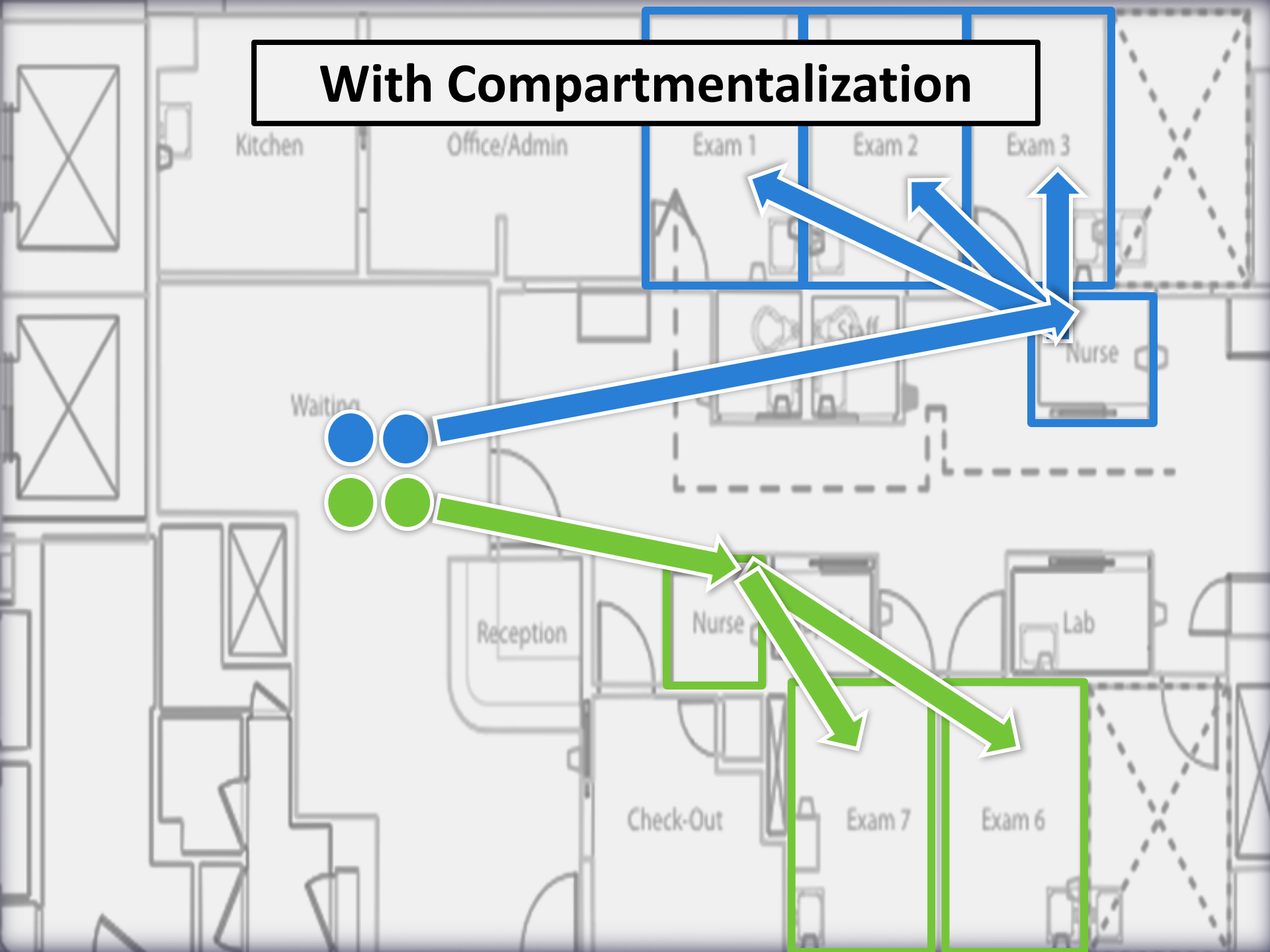
AIM Statement

Test potential methods for reducing infection transmission

with a focus on compartmentalization and hand sanitization

measured in terms of system-wide exposure and performance.


Without Compartmentalization
Kitchen
Office/Admin
Exam 1
Exam 2
Exam 3
Staff
Nurse
Waiting
Reception
Nurse
Supply
Lab
Check-Out
Exam 7
Exam 6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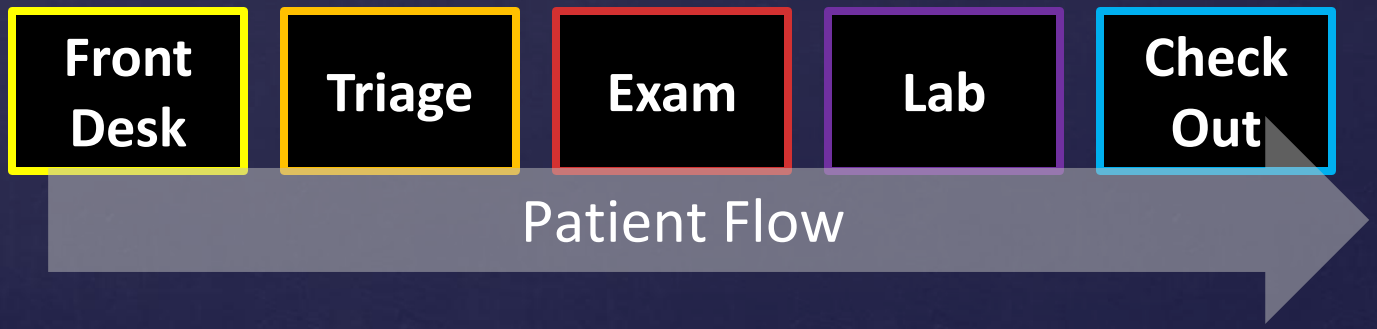
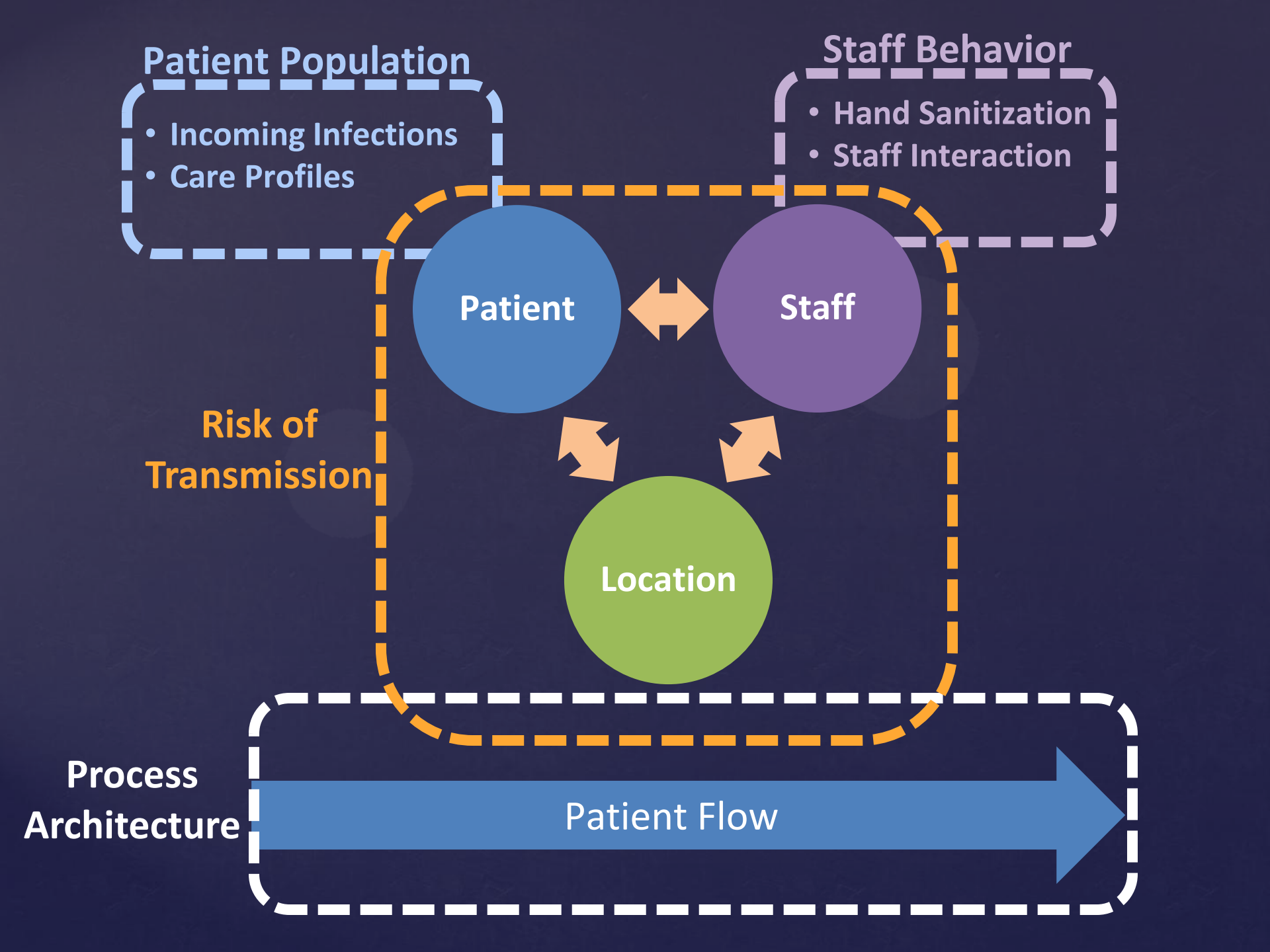
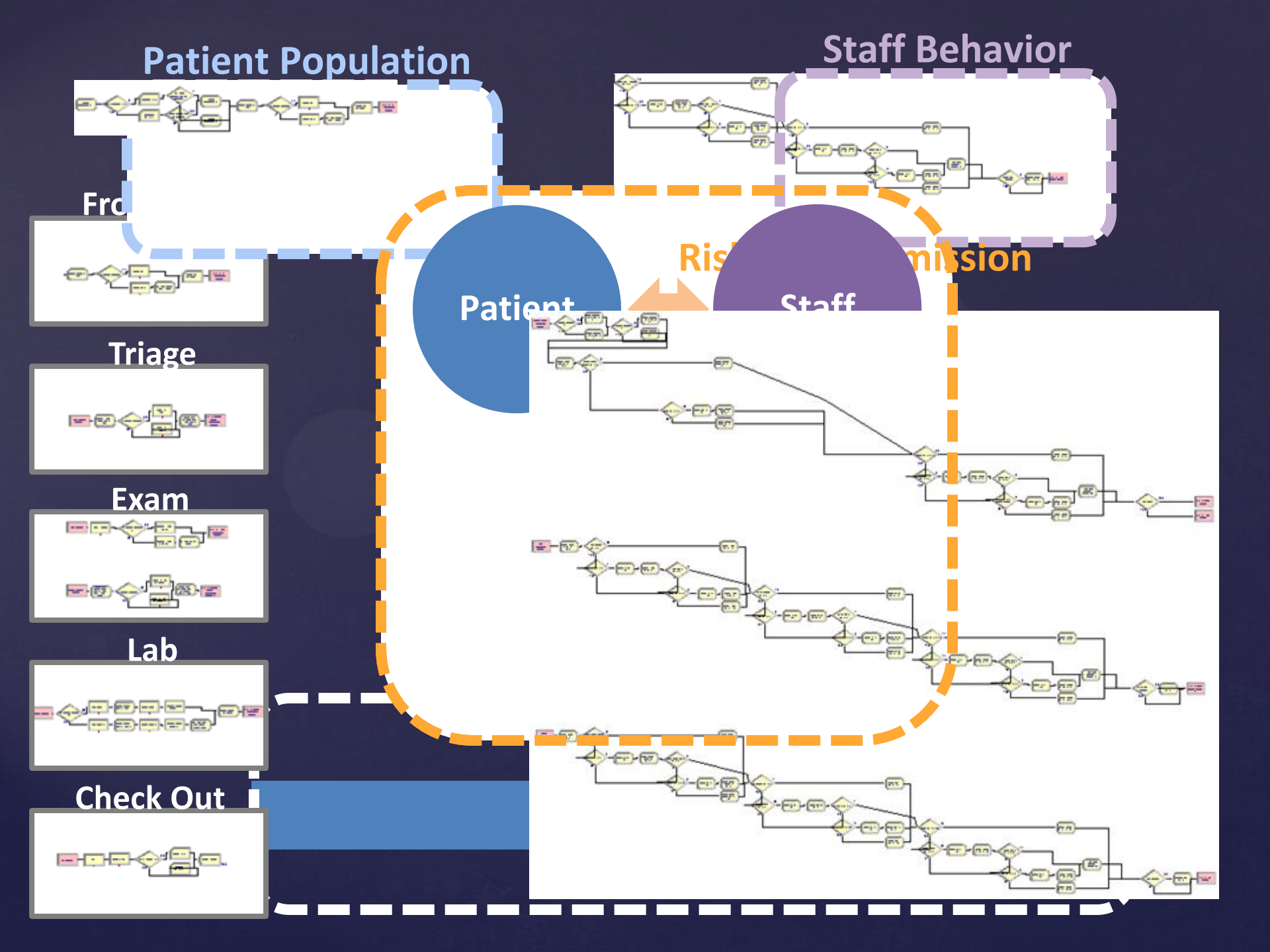
Five Opportunities for Compartmentalization

In terms of

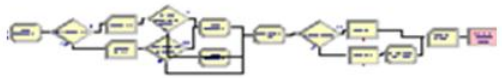
- Environment / Equipment
- Personnel



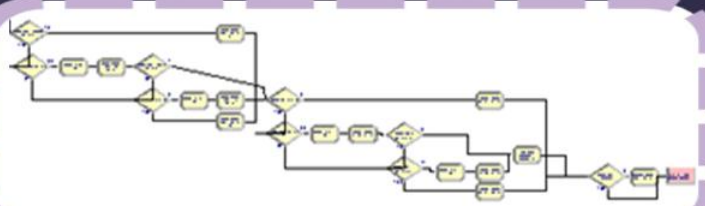

Patient Population
• Incoming Infections
• Care Profiles
Staff Behavior
• Hand Sanitization
• Staff Interaction
Patient
Staff
Location
Risk of Transmission
Process Architecture
Patient Flow


Patient Population
Staff Behavior
Fro
Triage
Exam
Lab
Check Out
Patient
Staff

Patient Population



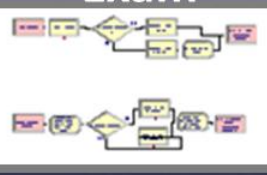
Staff Behavior



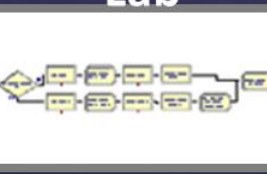
Front Desk

Triage

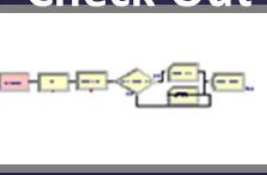
Exam



Lab



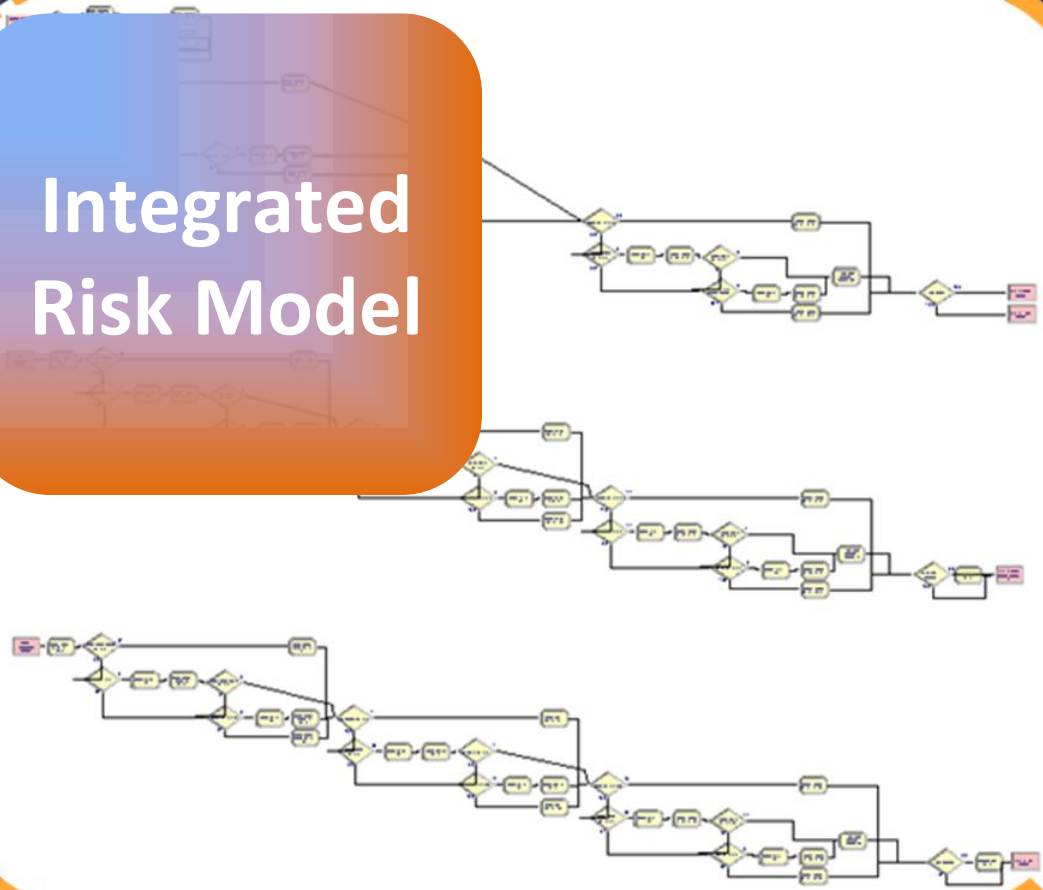
Check Out



Patient Flow

Risk of Transmission

Integrated Risk Model



Model and Experimentation

Experimental Variables

- Compartmentalization
- Hand Sanitization Rates
- Resource Reduction

Sensitivity Variables

- Incoming Incidence Rates
- Cross Contamination Rates
- Initial Utilization Levels

System Metrics

- Infection Exposures
- System Performance
- Feasibility

Experimental Results

Comparing Improvement Policies

Compartmentalization

11 values

types of compartmentalization

Hand Sanitization

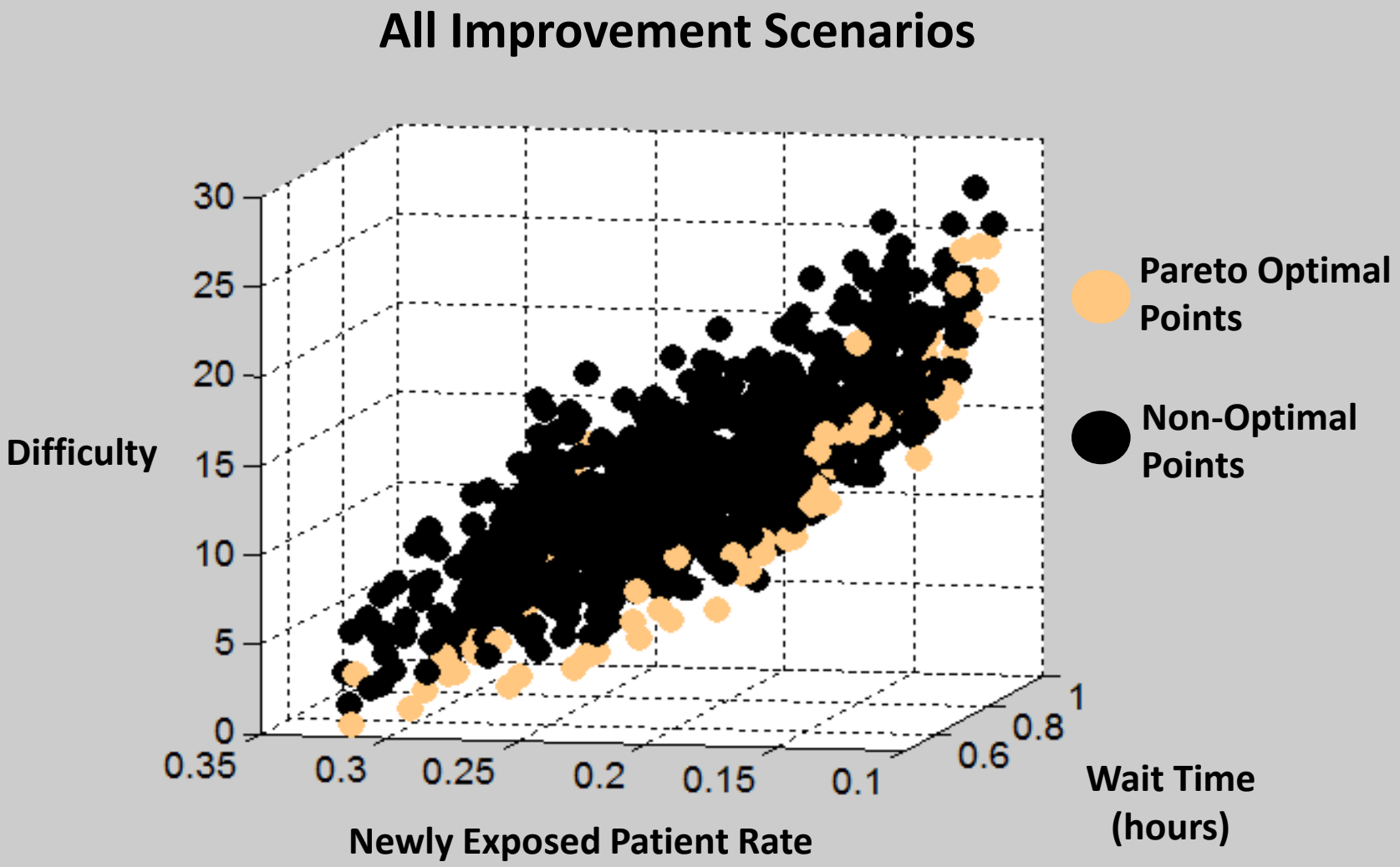
3^4 values

low, med, high for 4 staff types

891 Combinations

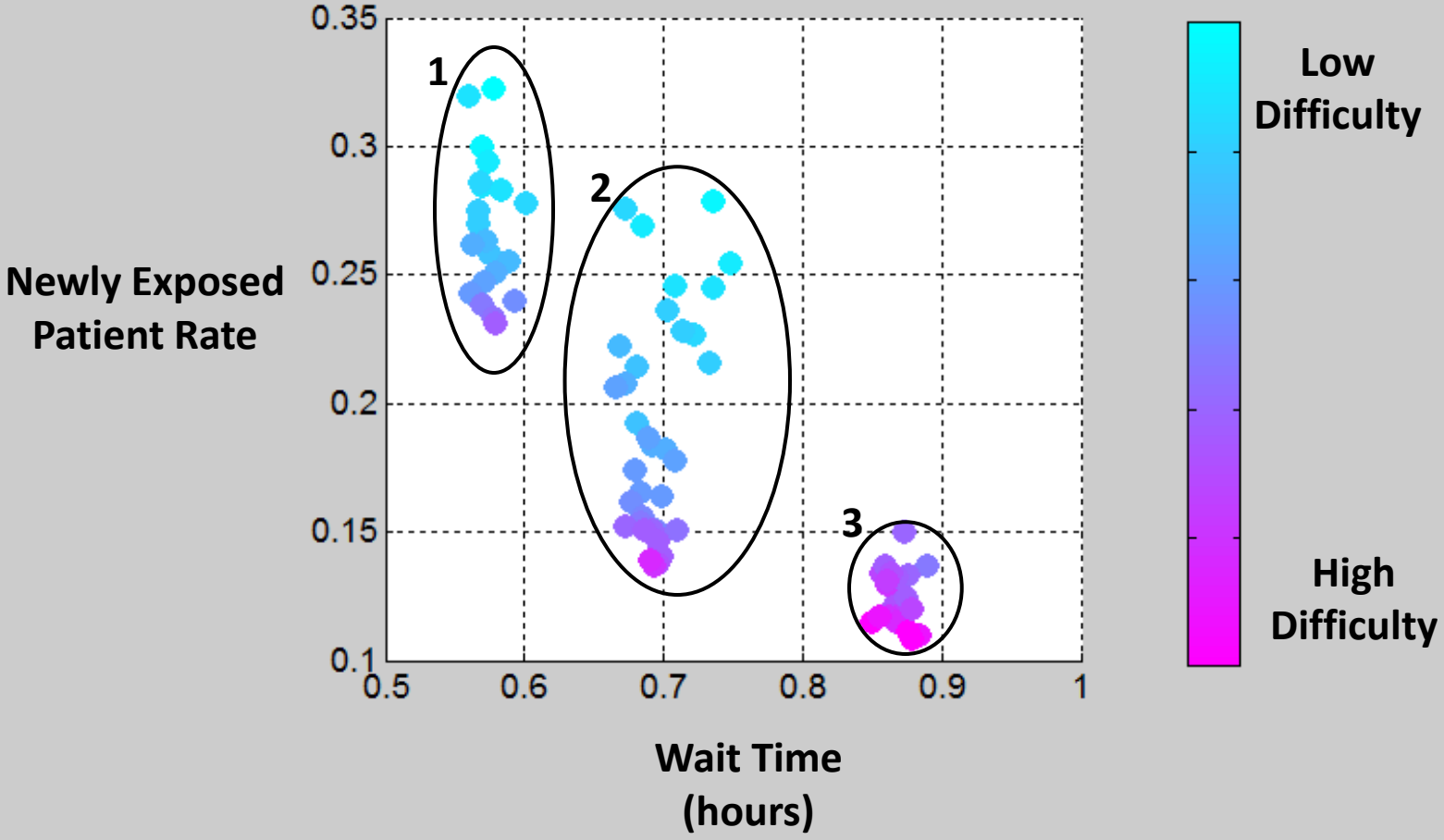
- Newly Exposed Patients
- Patient Wait Time
- Difficulty

Experimental Results



Experimental Results

Pareto Optimal Improvement Scenarios



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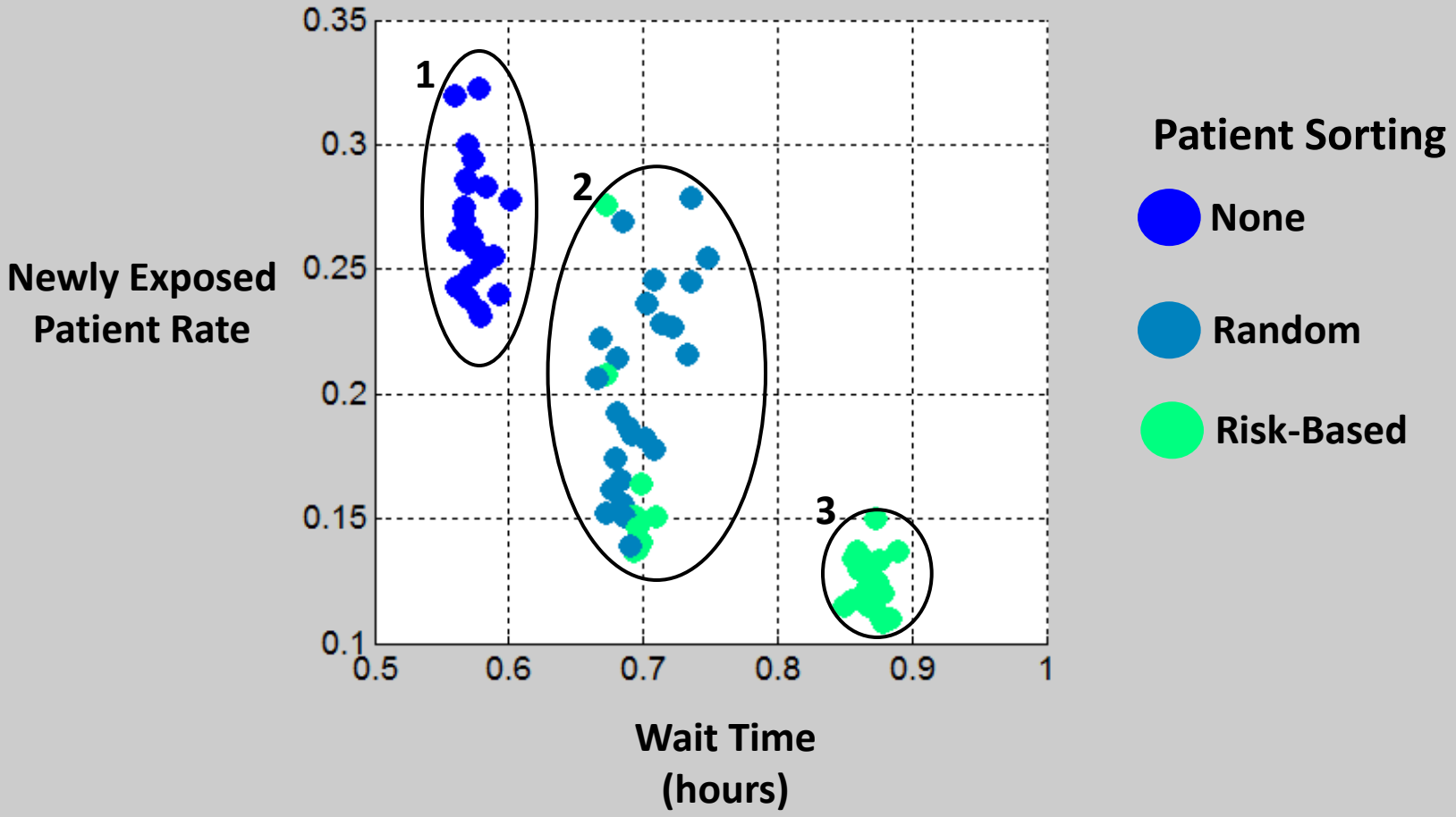
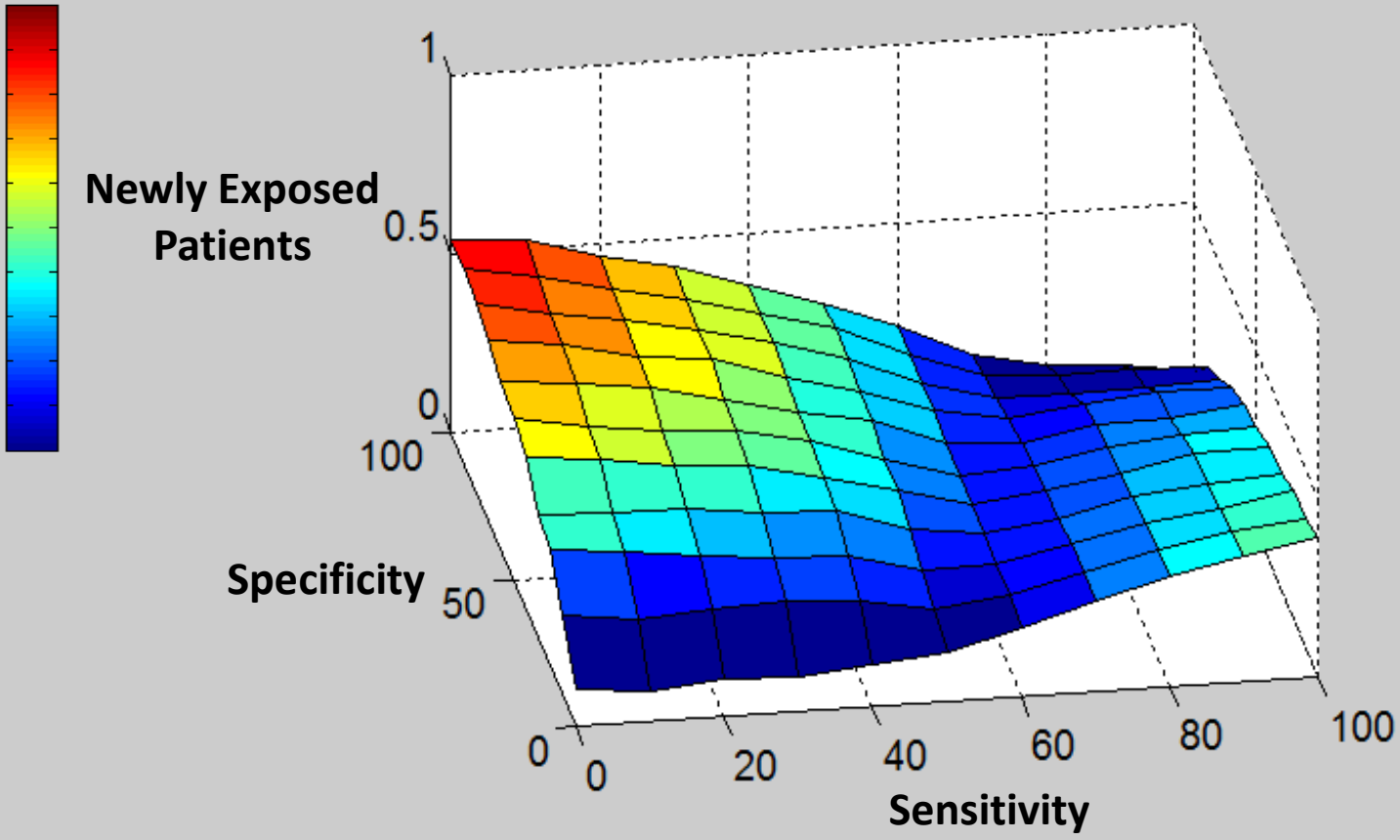


Experimental Results

Sorting Algorithm Parameterization



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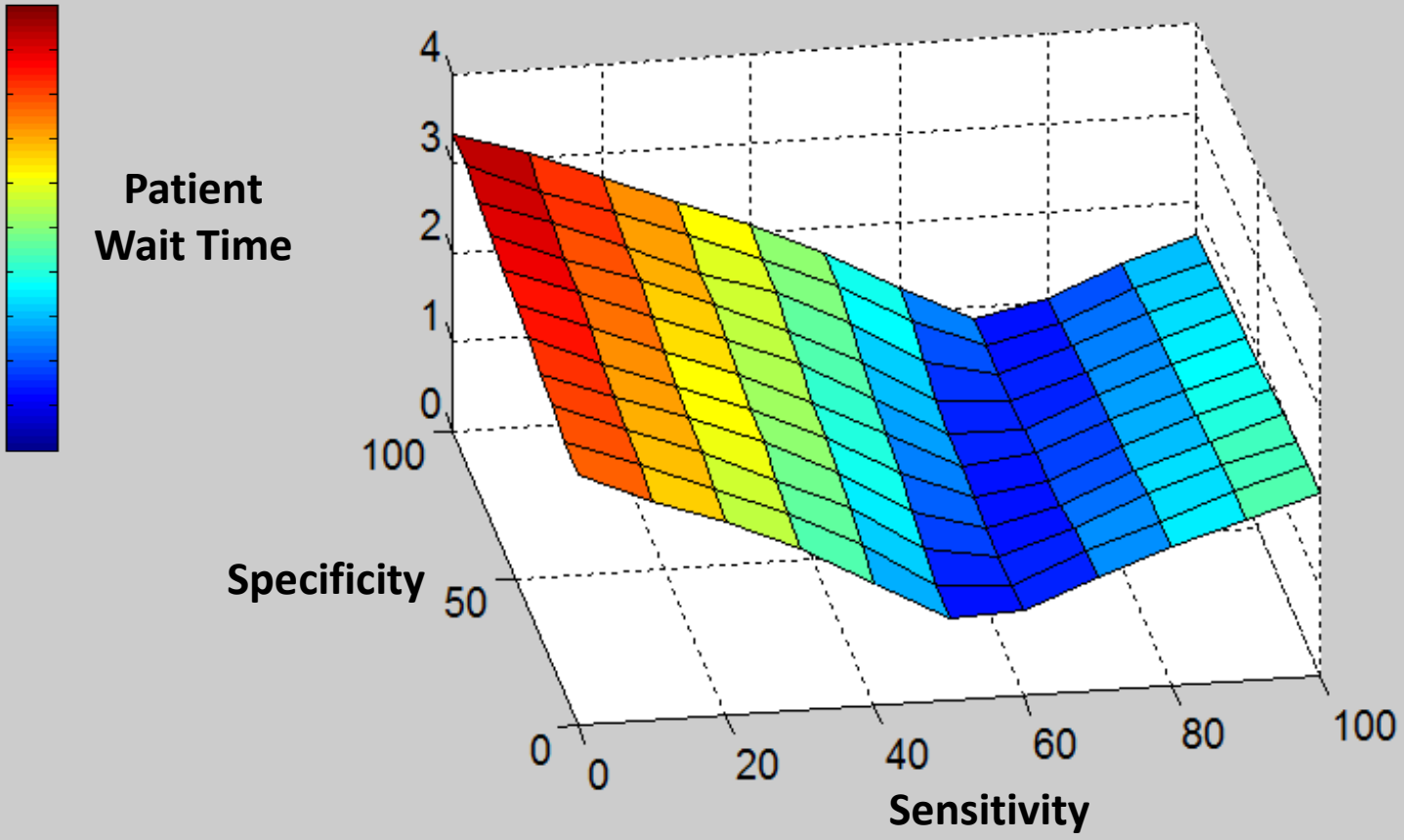
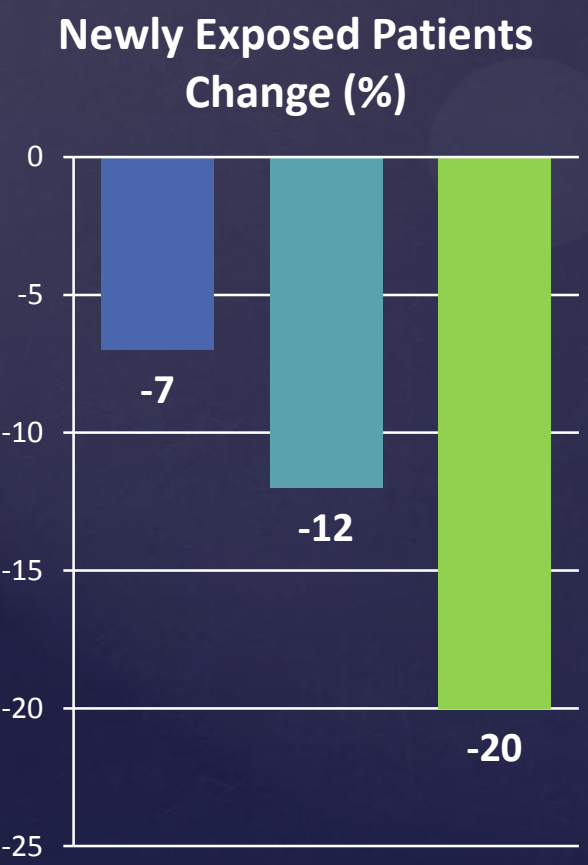
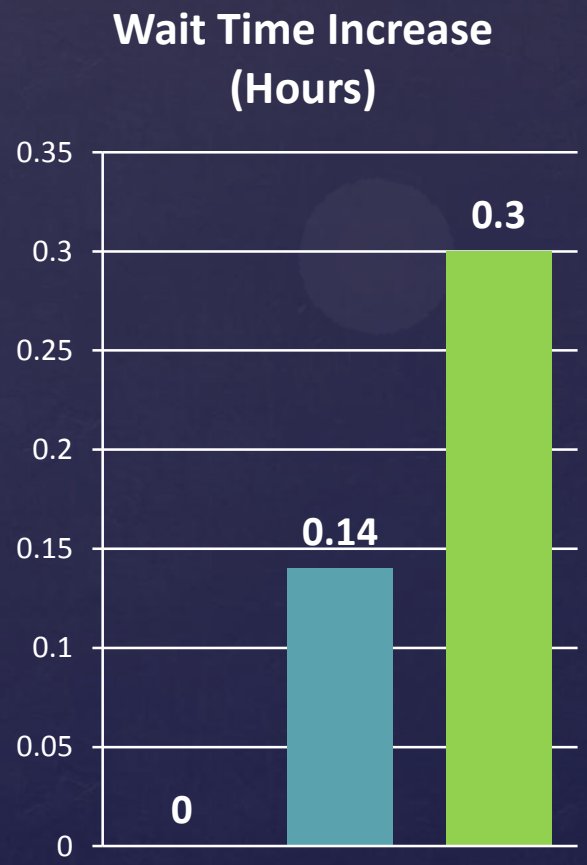
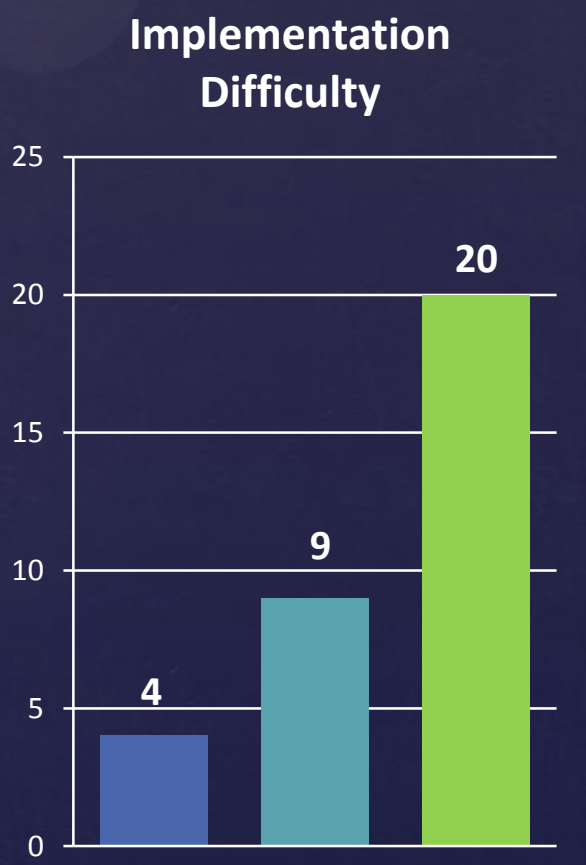


Recommended Policies

Patient Sorting Type	None	Random	Risk-Based
Compartmentalization Level	None	Early Medium	High
Hand Sanitization Improvement	Staff +5%, MD +10%	Staff +5%	Staff +10%, MD +10%, Nurse +8%







Triple Aim Impact

Patient Sorting Type	None	Random	Risk
Compartmentalization Level	None	Early Medium	High
Hand Sanitization Improvement	Staff +5%, MD +10%	Staff +5%	Staff +10%, MD +10%, Nurse +8%
Cost Savings	Additional Treatment Avoided ($56,300)	Additional Treatment Avoided ($96,400)	Additional Treatment Avoided ($160,700)
Quality	Increased Waiting Time (None)	Increased Waiting Time (5,100 Hours)	Increased Waiting Time (10,500 Hours)
Health	21% Reduction in Exposure	36% Reduction in Exposure	61% Reduction in Exposure

Conclusions and Extensions

Generalized Findings

- Proof of concept: queueing and agent-based infection spread model

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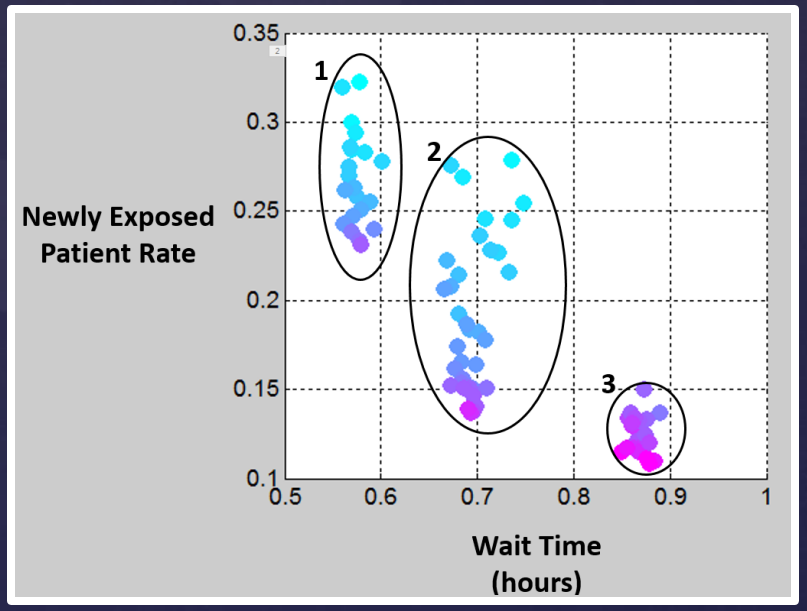

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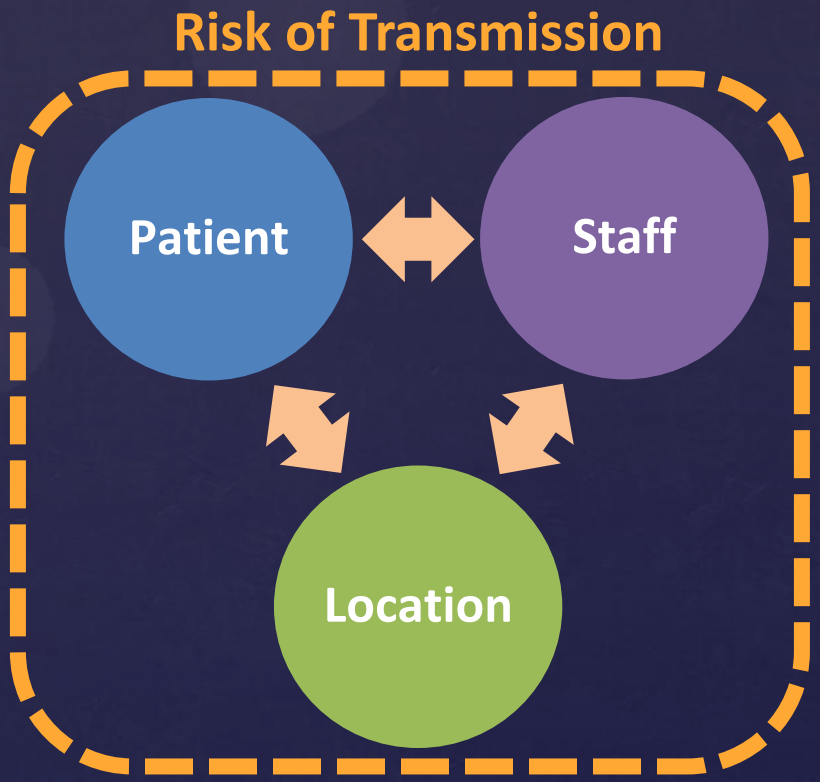

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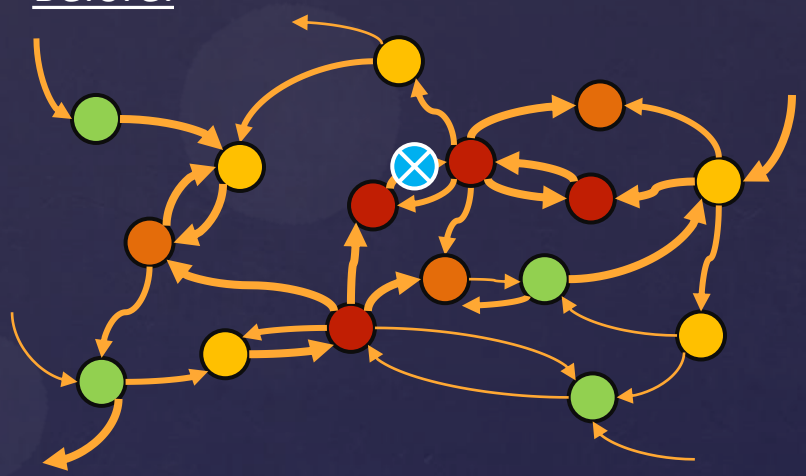

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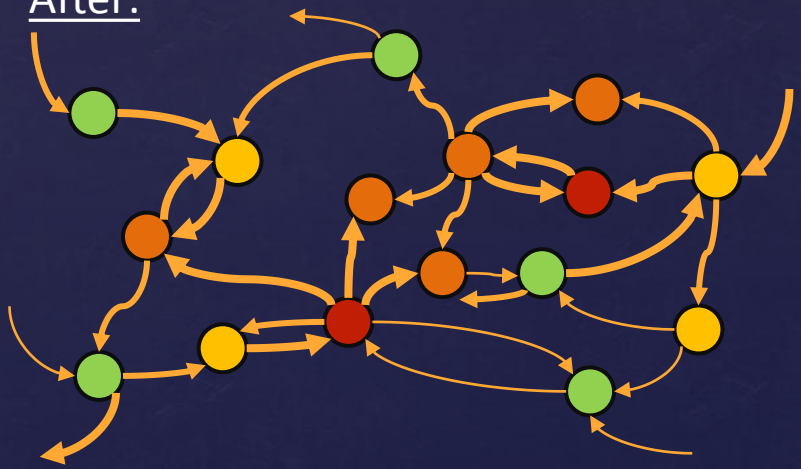

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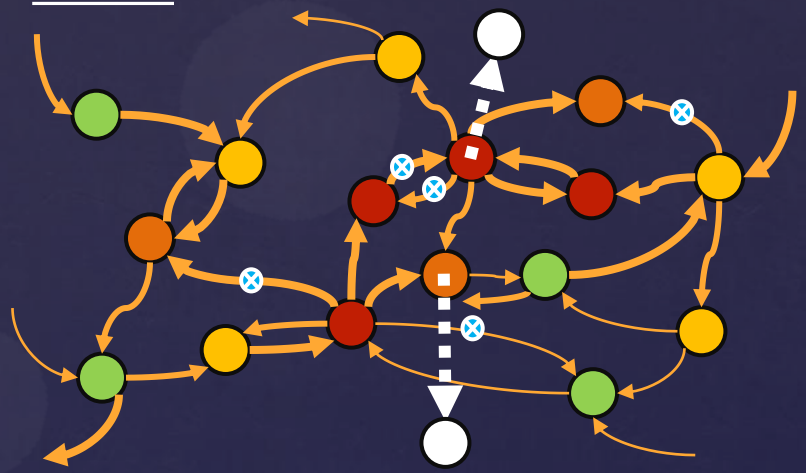

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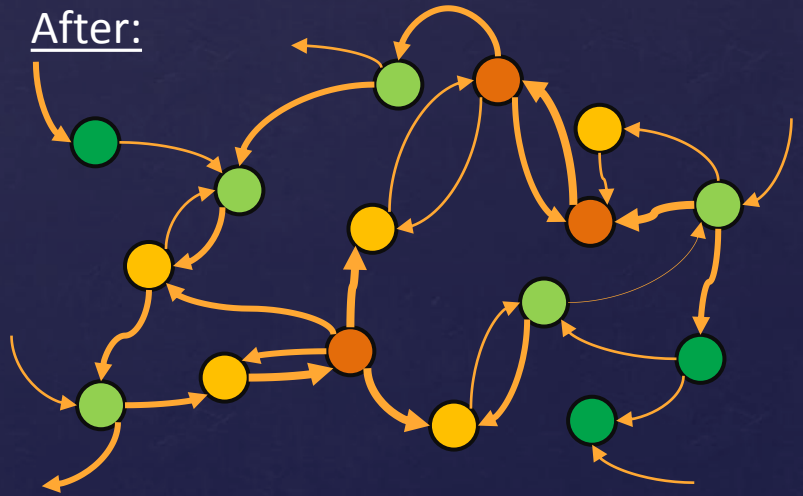

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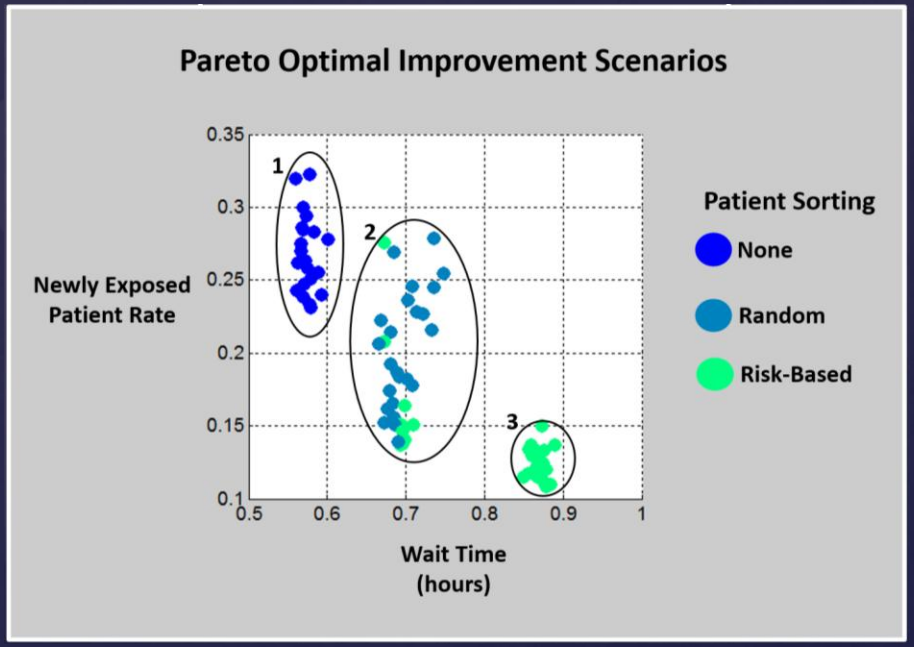

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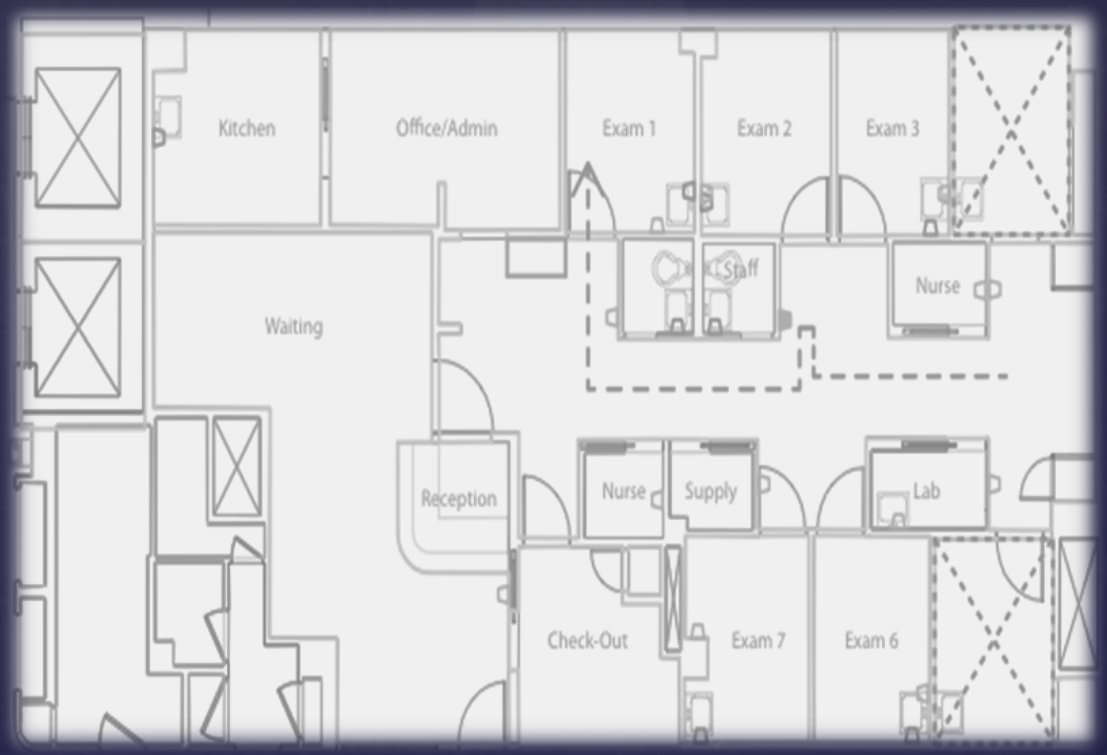
- Compartmentalize where resources are least constrained

Conclusions and Extensions

Further Questions

- What opportunities do clinics actually have for “compartmentalization”?



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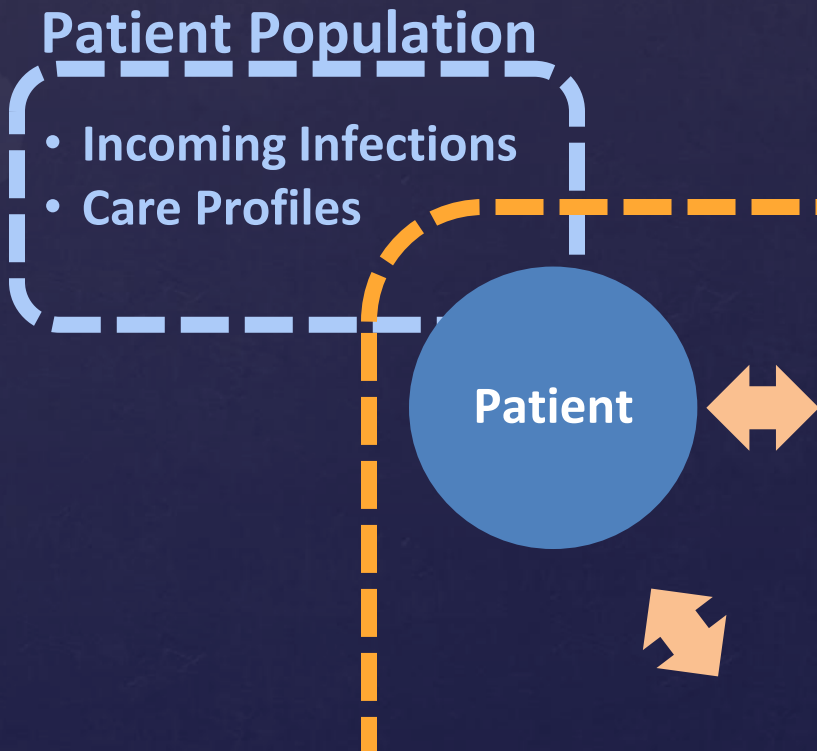

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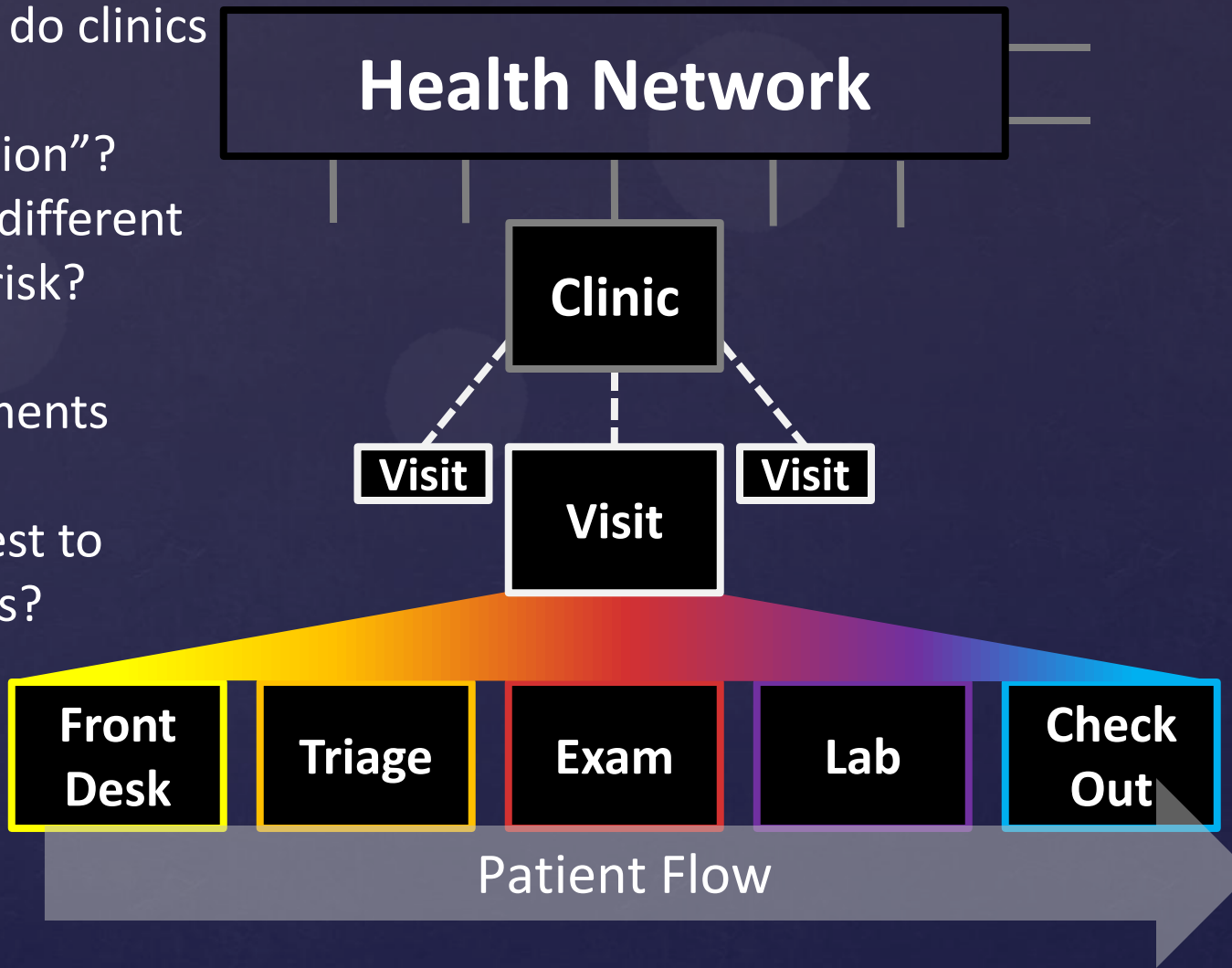


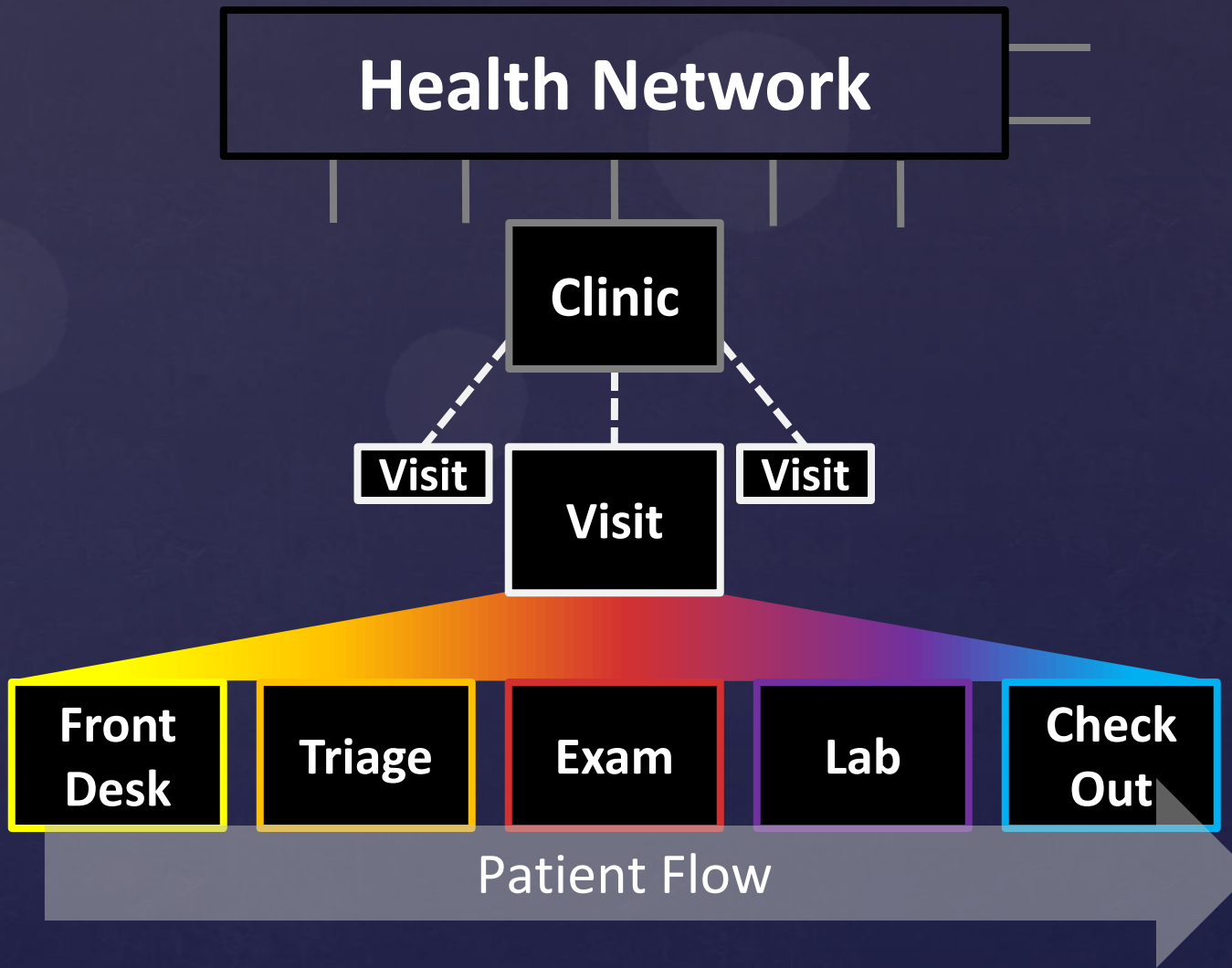
Conclusions and Extensions

Further Questions

System Dynamics

Agent-Based

Queueing



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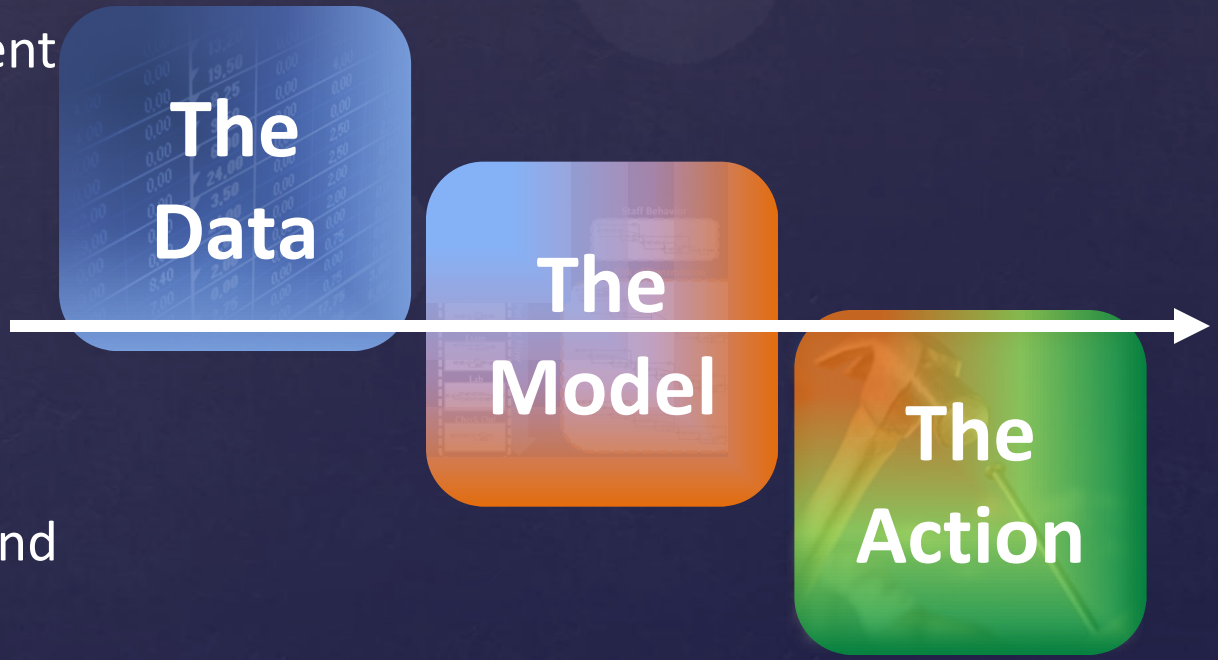
  - Where data, model, and action can align…



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Triple Aim Impact

	Compartmentalization Advantages	Compartmentalization Disadvantages
Cost	HAIs require additional treatment/admission Providers out sick reduce throughput, revenue	Dividing resources can limit throughput, revenue Compartments may require additional staff
Quality	Fewer exposures, fewer infections Compartments may improve care coordination	Compartments may increase waiting times
Health	Fewer infections introduced into the population	[No disadvantages identified]