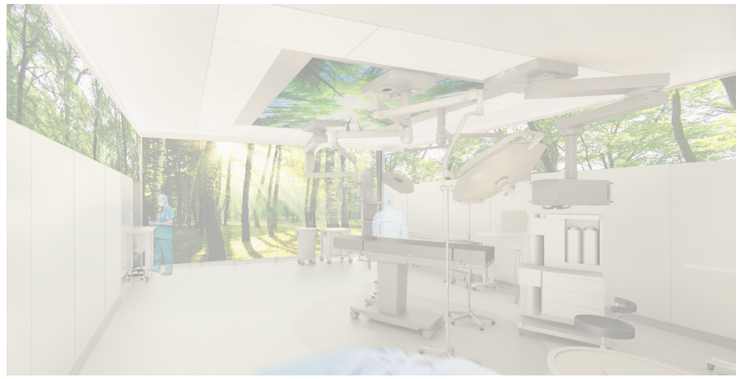

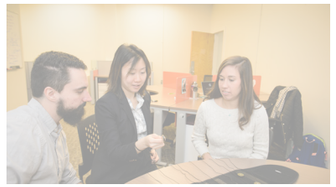

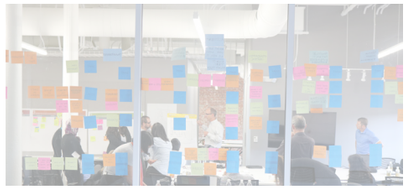

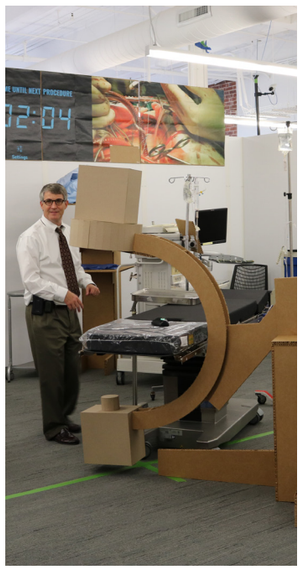

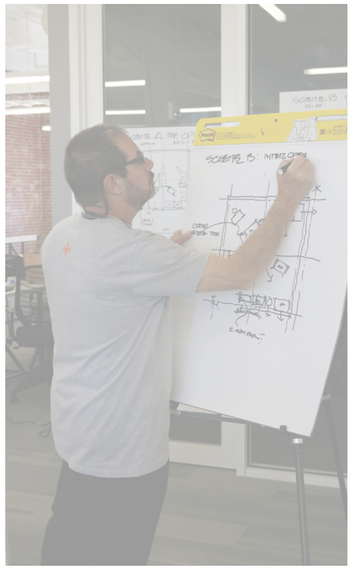

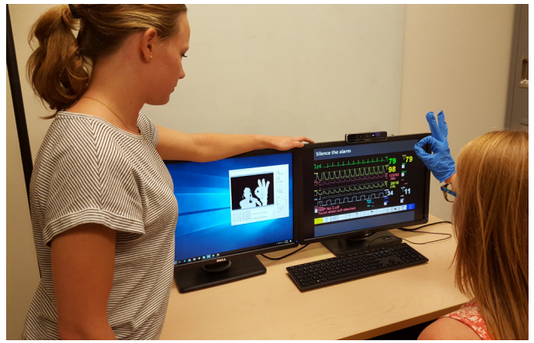

REALIZING IMPROVED PATIENT CARE THROUGH HUMAN-CENTERED DESIGN IN THE OPERATING ROOM

RIPCHD.OR

A+H CENTER FOR HEALTH FACILITIES DESIGN & TESTING

MUSC MEDICAL UNIVERSITY of SOUTH CAROLINA

CLEMSON UNIVERSITY

HOW LARGE SHOULD THE OR BE?

USING A MULTI-DISCIPLINARY SYSTEMS APPROACH TO DESIGNING SAFER OPERATING ROOMS

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AMIN KHOSKENAR | Doctoral Student, Clemson University

SARA BAYRAMZADEH | Research Assistant Professor, Clemson University

BRIDGING THE IDEAL WITH REALITY

WORK AS *IMAGINED*

BRIDGING THE IDEAL WITH REALITY

WORK AS DONE

INTRODUCTION

Crowding is a major problem in many contemporary ORs.

The solution has been to build larger ORs to accommodate more equipment and larger team

Schneider, 2012

Larger areas may reduce the number of disruptions, but can increase the travel distance

Neyens et al., 2018

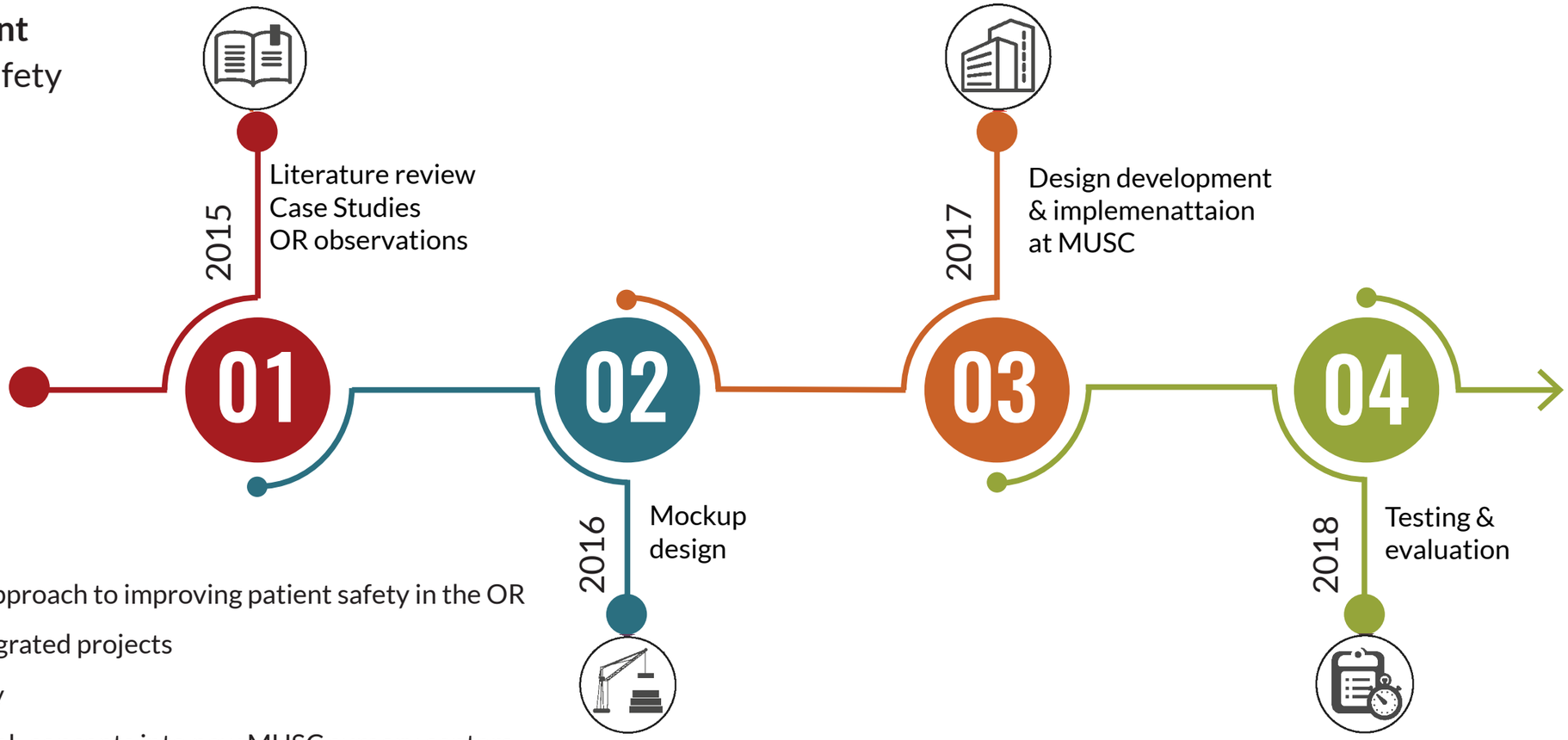
Lack of research on the potential impacts of OR layout and design characteristics of safety related performance characteristics.

IN A SNAPSHOT

Funded by Agency for Healthcare Research and Quality (AHRQ)

$4M over 4 years. $1M/year

A **P30 center core grant**
to develop a patient safety
learning lab



Multi-disciplinary systems approach to improving patient safety in the OR

Three individual though integrated projects

Focus on ambulatory surgery

Implementation of learning lab concepts into new MUSC surgery centers

Integration of research, teaching and practice

ITERATIVE DESIGN PROCESS

PHASE 1
Tape on the floor mock-up

PHASE 2
Initial cardboard mock-up

PHASE 3
Higher fidelity cardboard mock-up

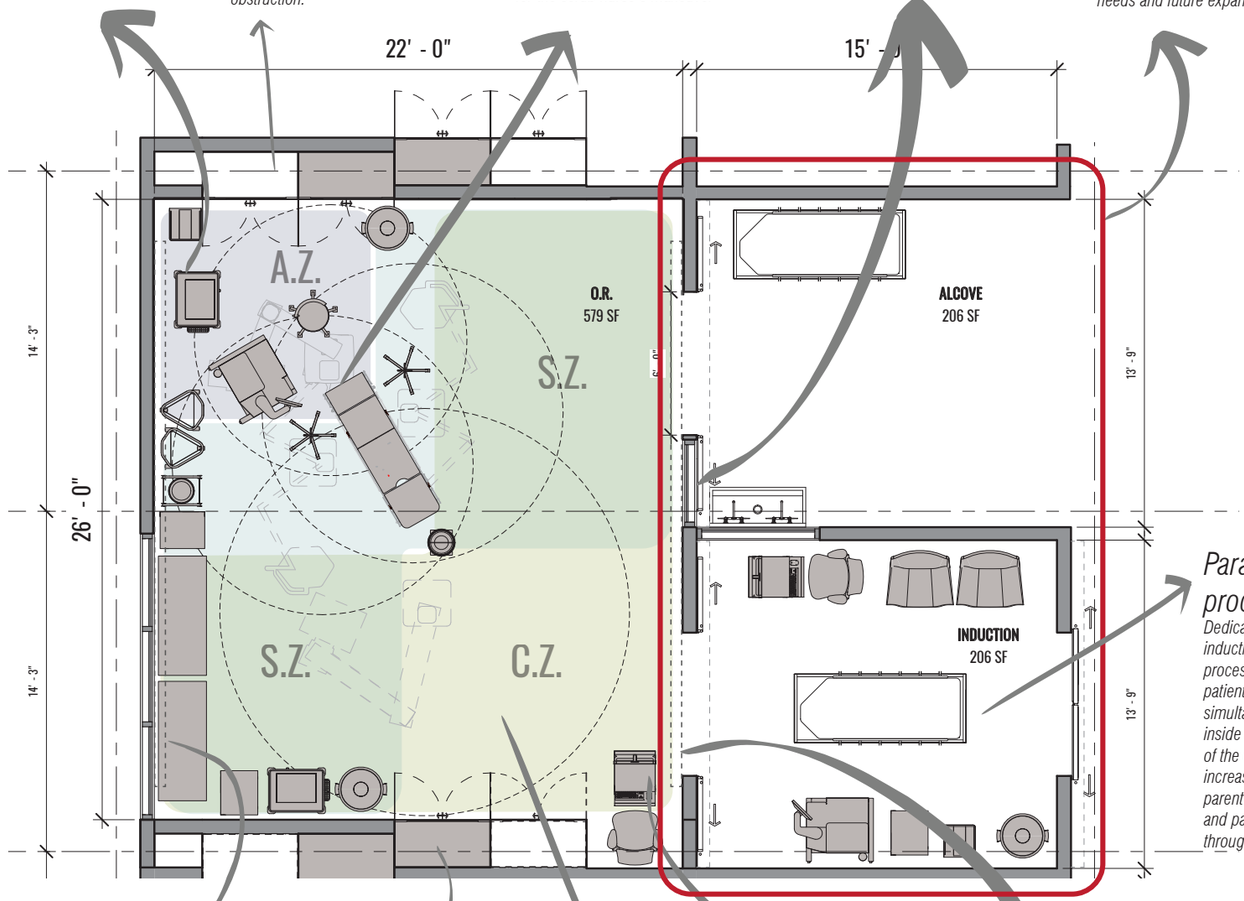
Anesthesia Workstation
Located in the corner away from the OR entry with ample space to minimize interruptions

Anesthesia Storage
Located within anesthesia work area and across the monitor to provide quick access for the anesthesia team with minimal obstruction.

Angled OR table position
OR table angled to accommodate sidedness of surgery and ample space for the scrub nurse's maneuver

Scrub Sink Window
Scrub sink strategically located and equipped with a window to provide view into the OR

Flexible room/suite chassis
Flexibility, adaptibility and expandibility to accomodate changing needs and future expansion



Parallel processing
Dedicating an induction room to process two patients simultaneously inside and outside of the OR can increase patient and parent satisfaction and patient throughput

Integrated Digital Information Displays
Wall mounted screens to maximize visual awareness

General Storage
Located near CN's workstation to accommodate quick access to supplies and material by the CN

Provision of sufficient circulation area
Optimize movement and flow in the operating room

Circulating Nurse Workstation
Mobile CN workstation provided flexibility with rotation and move of the workstation as needed.

Integrated Digital Information Displays
Conveniently provide information needed on vitals and patient information with minimal body movement and adjustment

ACCOMPLISHMENT

Project featured in

The Wall Street Journal

on *28th May 2018*!!

https://www.wsj.com/articles/the-operating-room-of-the-future-1527559862

JOURNAL REPORTS: HEALTH CARE

The Operating Room of the Future

A host of changes hold out the promise that surgery will be more efficient, more effective and less risky for patients

Dr. Scott Reeves and Dr. Anjali Joseph are leading a joint research team from Clemson University and the Medical University of South Carolina to design safer, more efficient operating rooms. PHOTO: MIC SMITH PHOTOGRAPHY LLC

By Laura Landro
May 28, 2018 10:11 p.m. ET

The operating room is getting smarter, more effective—and a lot less risky for patients.

Hospitals are investing in new devices, designs and digital technologies that promise a new era of innovation for surgery. The moves are part of a growing shift away from traditional open procedures that involve big incisions, lots of blood loss and long hospitalizations. They point toward a future where more patients can choose minimally invasive outpatient surgeries, with faster recoveries, fewer complications, and less pain and scarring.

JOURNAL REPORT

- Insights from The Experts
- Read more at WSJ.com/HealthReport

MORE IN HEALTH CARE

- Developing Opioid Alternatives
- Robots for the Elderly
- Debate on Defining Brain Death
- A Watchful Eye on Doctors

These new technologies cover a range of advances. With some, surgeons can control robot cameras with eye movements as they move into patients' bodies through tiny incisions. With others, doctors can create a GPS-like map projected onto a patient's body to virtually see inside the anatomy before an operation, track their surgical tools and help them operate more precisely.

Other advances aim to reshape the operating room itself, by adding more space for surgeons to work as well as imaging equipment that lets patients receive X-rays and other tests on the operating table instead of getting shuttled around the hospital. And machine learning and artificial-intelligence technology is being developed to let surgeons tap into big data before, during and after they work, to get guidance from computer systems that have analyzed the procedures and learned to make recommendations.

If successful, these changes could have a profound effect on patients. Despite years of progress, surgery remains a risky field. Infections are a frequent complication and can cause death.

https://www.wsj.com/articles/the-operating-room-of-the-future-1527559862

AIMS

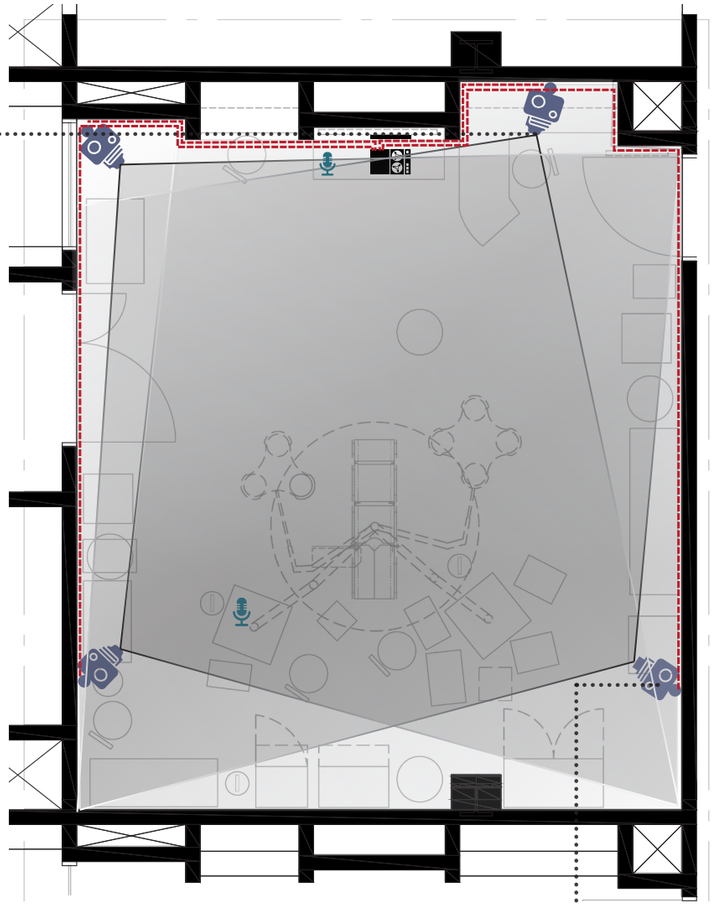
Using a simulation approach to analytically evaluate the design of an OR layout with regard to

1. Surgical table orientation
2. OR size
3. OR shape (square vs rectangular)

METHODOLOGY

METHODOLOGY

- Using observational method to collect data and playback of surgical team flows
- Develop and validate Markov chain simulation model
- Develop plan configuration to be tested
- Run simulations and analyses



35 Surgeries video recorded

04 Operating rooms

59 Hours of the video observations

78 Hours of the video lengths

CODES:
roles, location, PEMSI activities

NOLDUS
The observer XT12

4 video cameras

2 microphones

1 computer

cameras mounted on poles
microphones
base machine & computer screen
connections - camera to computer
field of view

OBSERVATIONS

SUBJECTS - 7 PRIMARY

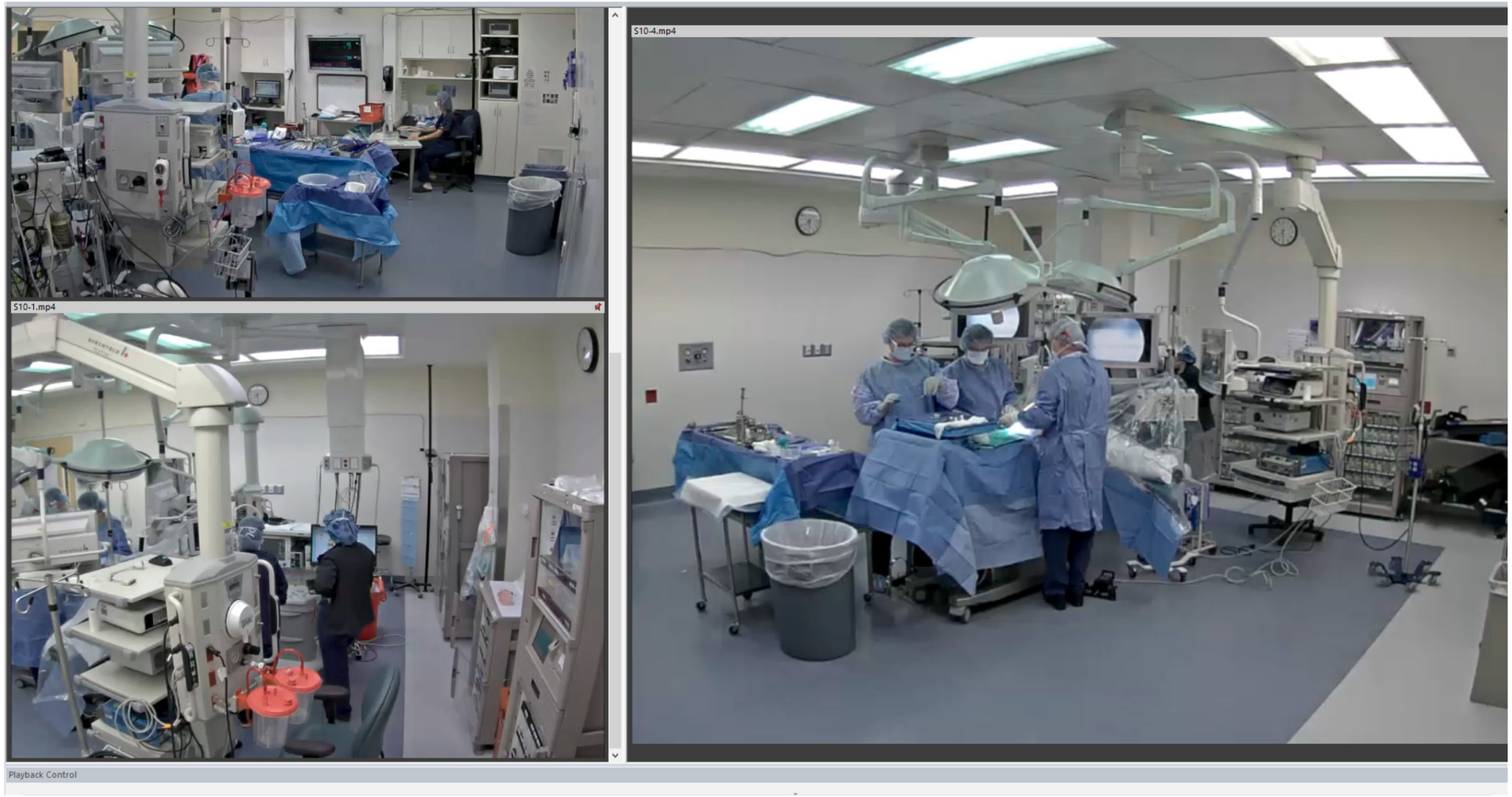
Clean-up tech
RN, circulating
Scrub nurse/surgical tech/student
Anesthesia personnel
MD, surgeon
Surgical assistant/MD, student/resident
Observer

OBJECTS - 8

Instrument tray
Instrument table
Main instrument table
Secondary instrument Table
Cart
Trash cans
Room

SURGERY PHASES

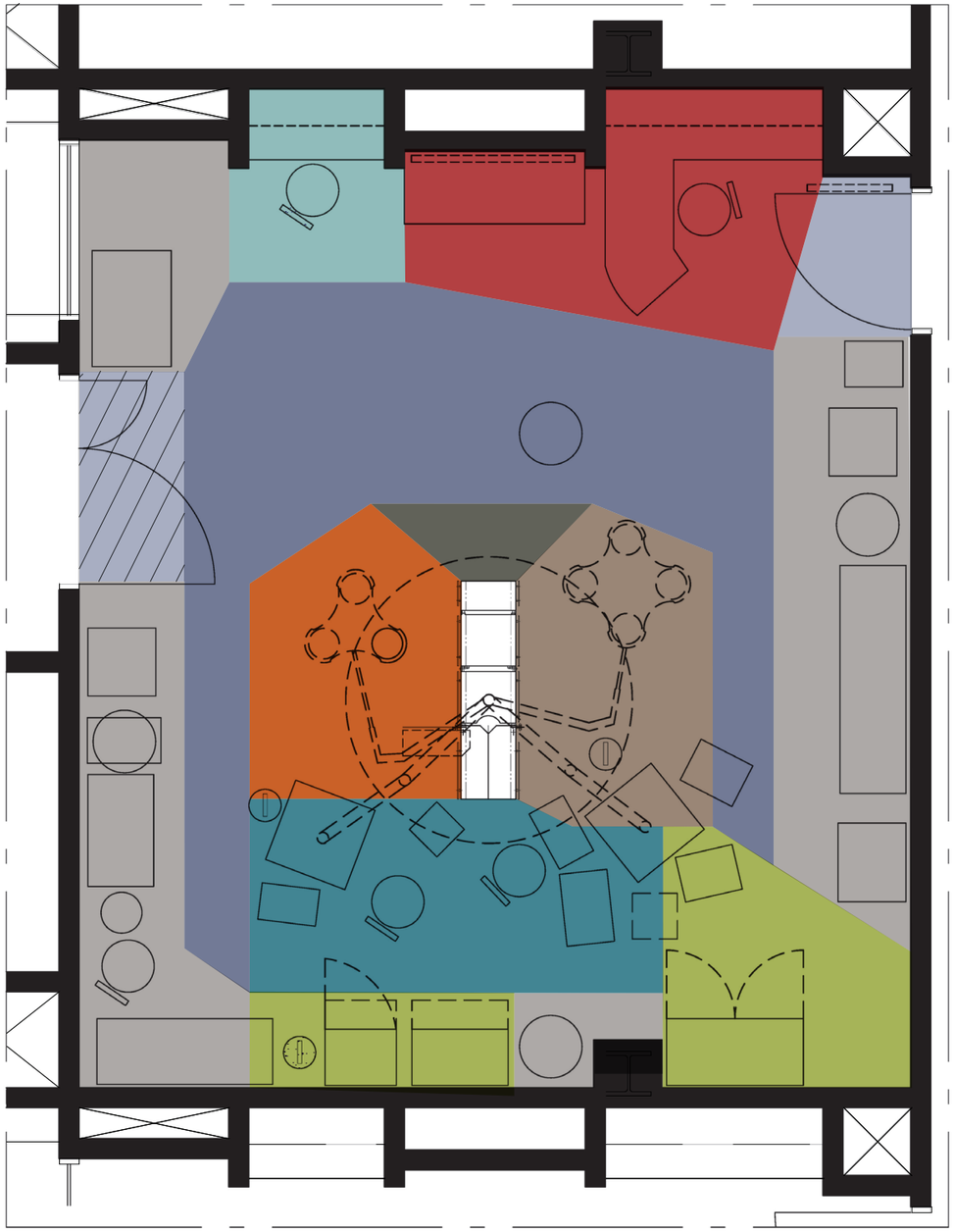
No Phase — Turnaround — Patient Preparation — Intra-operative — Post-operative



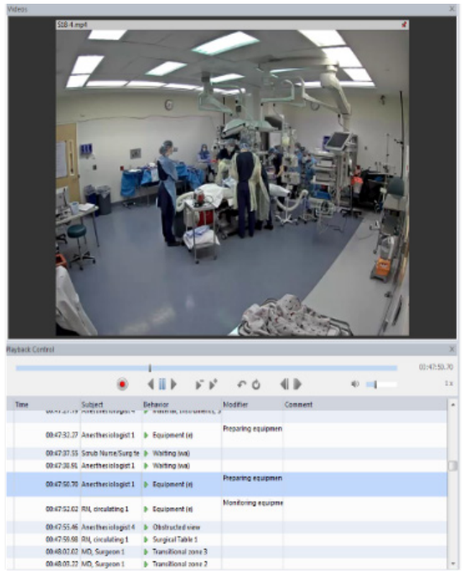
OBSERVATIONS

LOCATIONS

Circulating Nurse Workstation
Surgeon's work station
Foot of Surgery Table
Head of Bed
Surgical Table 1 - 2 (left/right side)
Door to Sterile Core
Door 1 to Corridor
Door 2 to Corridor
Transitional Zones 1 - 3
Anes Workstation
Supply Zones 1 - 2
Support Zones 1 - 6
Out of Room

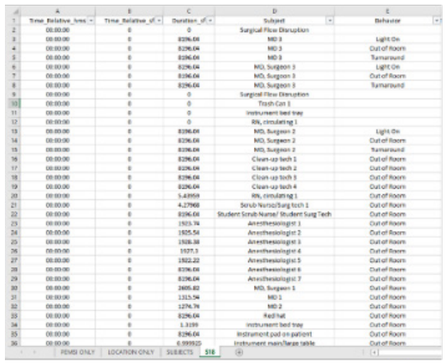


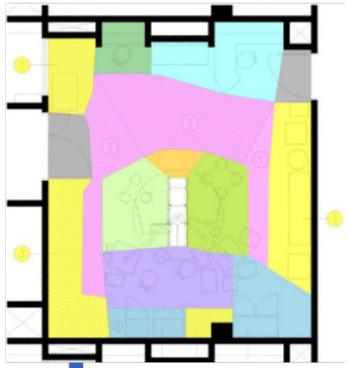
WHERE WE BEGAN



Exporting data into an Excel file (time, location, behavior, etc.)

Using the OR map to know where an agent is located at a given time.

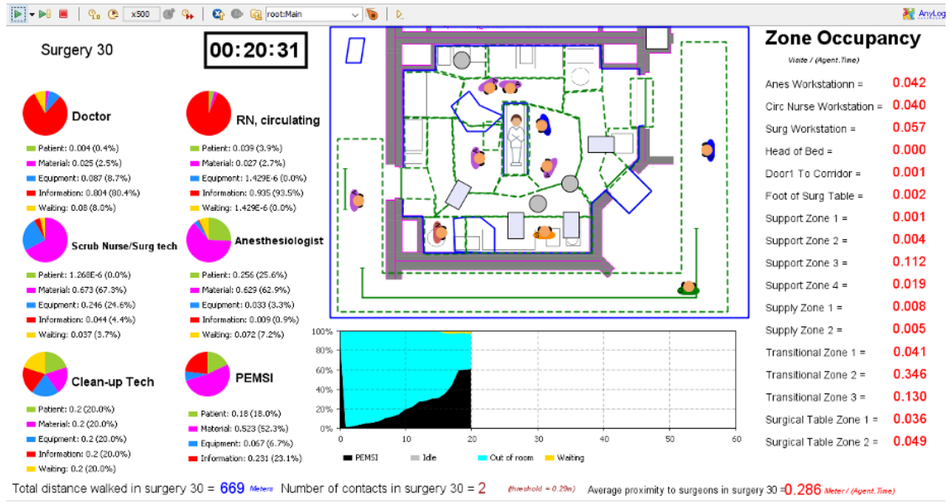




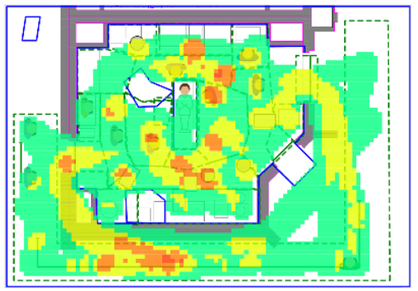
Simulation input

- AnyLogic software (pedestrian library)
- Building a **playback** simulation model

Simulation input



heatmap



Output

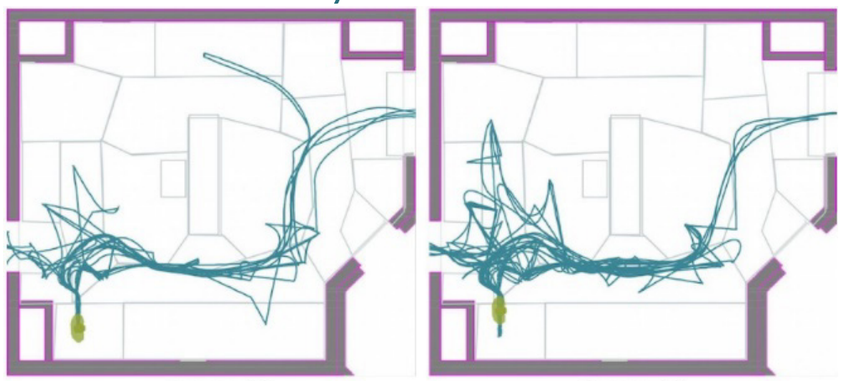
- Total distance walked
- Number of contacts

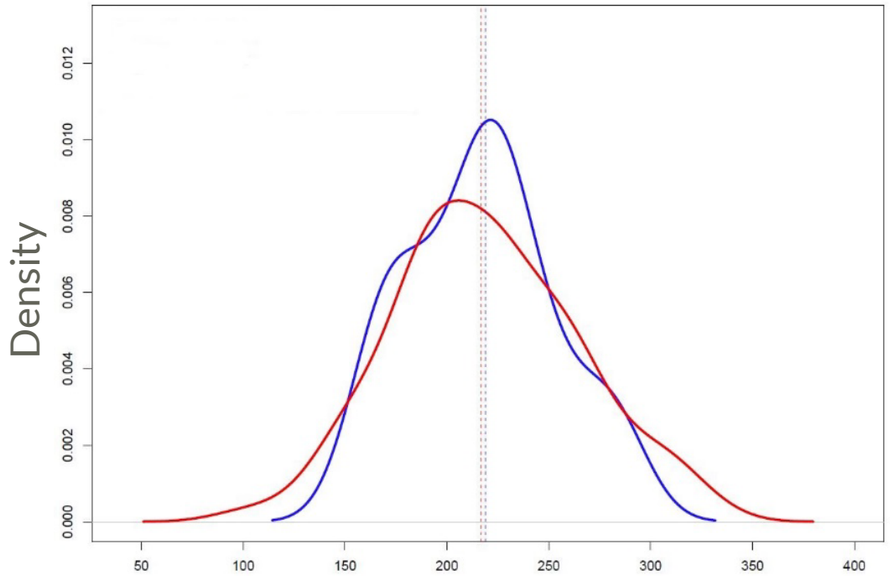
PDCTMC

PHASE-DEPENDENT CONTINUOUS-TIM MARKOV CHAIN SIMULATION MODEL (PDCTMC)

- In probability theory, a **Markov model** is a stochastic model used to model a system where the future state depends only on the current state.
- States are destination zones
- Probability transition matrices (phase dependent)

Playback model



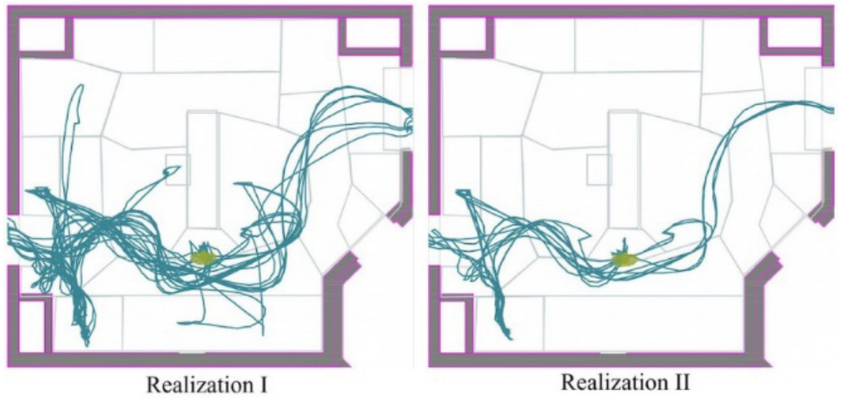


STATISTICAL VALIDATION

Playback Density

PD-CTMC Density

PDCTMC model



SAFETY AND EFFICIENCY METRICS

TOTAL DISTANCE WALKED (TDW)

$$total\ distance\ traveled = \sum_{i \in \{\text{moving agents}\}} \text{distance traveled by agent } i$$

TOTAL NUMBER OF CONTACTS (TNC)

$$total\ number\ of\ contacts = \frac{\sum_{i \in \{\text{moving agents}\}} \text{number of contacts experienced by agent } i}{2}$$

TOTAL NUMBER OF TRANSITIONS NEAR THE STERILE AREA (NTS)

It is counted as one if the initial zone (the zone where the subject starts traveling) and the destination zone is out of the sterile area.

The sterile area includes the following zones:
surgical table zone 1,
surgical table zone 2,
foot of surgery table zone,
and head of bed.

RESEARCH QUESTIONS

RQ Can a PDCTMC model be used to pro actively evaluate new designs to understand impacts on safety and performance ?

1. Does POSITION of the OR table affect safety and efficiency outcomes?
2. Does SIZE of the room affect safety and efficiency outcomes?
3. Does the SHAPE of the room affect safety and efficiency outcomes?

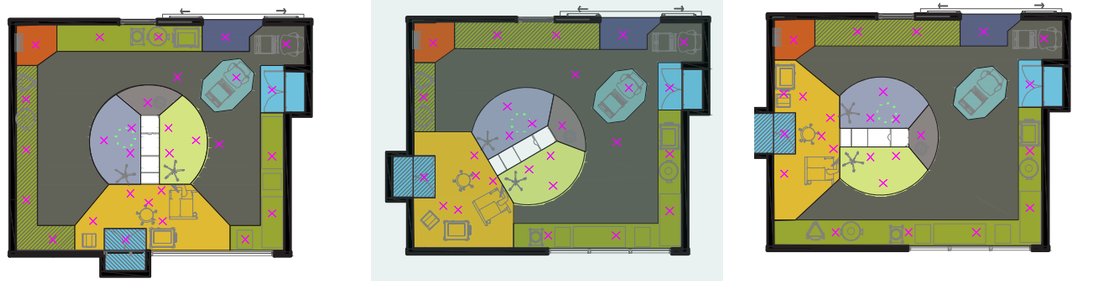
LAYOUT ANALYSIS

Each layout for each RQ was tested with

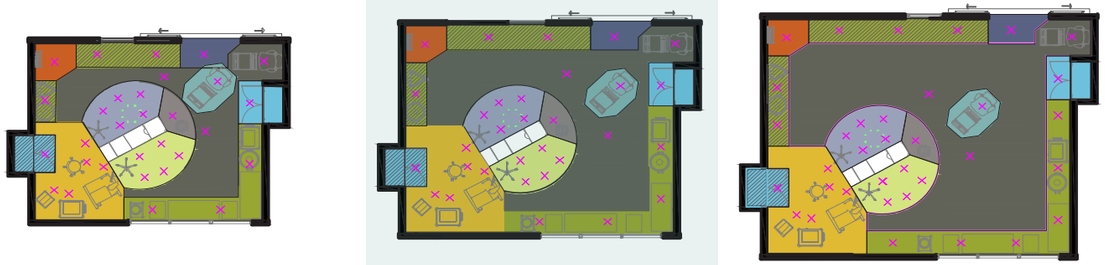
5 and **7 subjects**

2 different locations of mobile CN workstation
- Wall
- Foot of the table

POSITION of the OR table



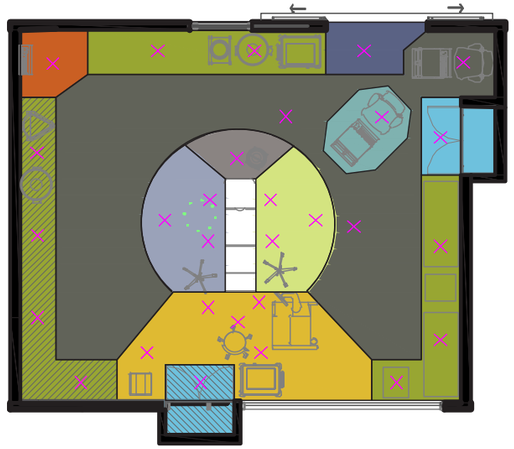
SIZE of the room



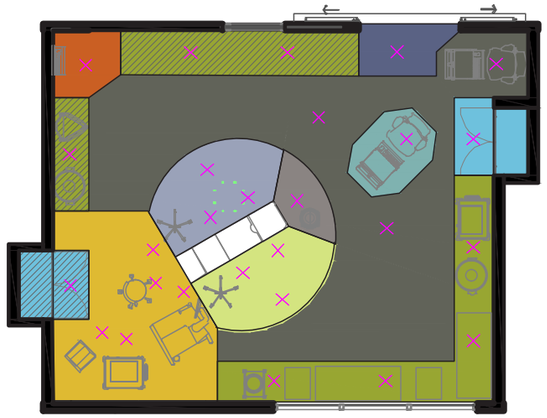
SHAPE of the room

Base prototype

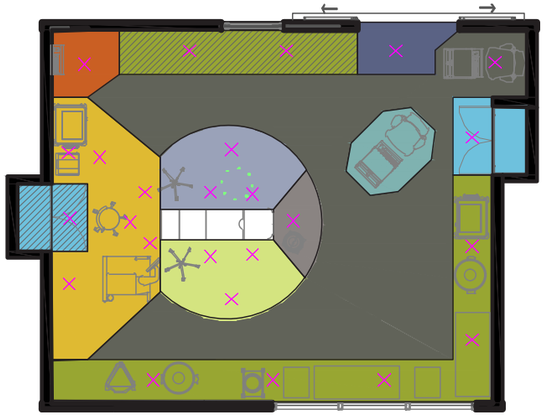
BED ORIENTATION



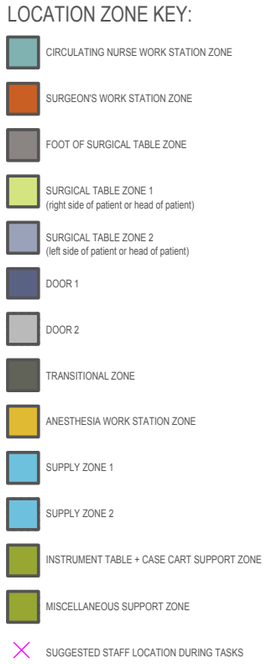
CASE 1
OR table perpendicular to the longer wall



CASE 2 (base case)
OR table angled



CASE 3
OR table perpendicular to the shorter wall



CNWS LOCATION- Wall

		CASE 1	CASE2	CASE3
n=5	TDT	864.3	817.8	862.3
	TNC	16.9	17.5	19.2
	NTS	3.5	1.9	1.9
n=7	TDT	1161.2	1125.7	1144.9
	TNC	32.7	33.6	40.2
	NTS	3.9	2.3	2.6

***shaded boxes are statistically significant

CNWS LOCATION- Foot of Table

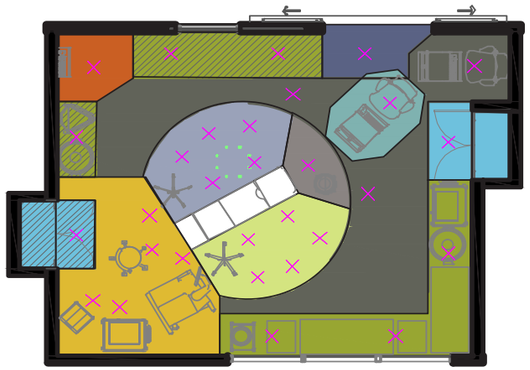
		CASE 1	CASE2	CASE3
n=5	TDT	820.9	808.8	805.9
	TNC	25.5	22.1	23.2
	NTS	9.1	8.4	7.4
n=7	TDT	820.9	1041.1	1086.1
	TNC	25.5	40.1	47.2
	NTS	9.1	9.8	10.4

CONCLUSION | BED ORIENTATION

ONE

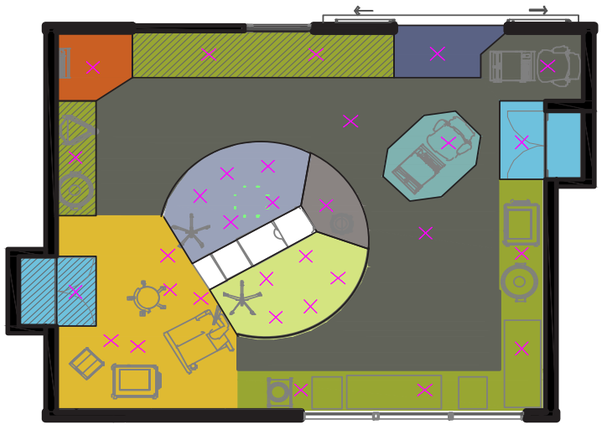
No clear patterns were observed in terms of performance metrics though the TNC appear to be fewest in the vertical bed configuration

ROOM SIZE



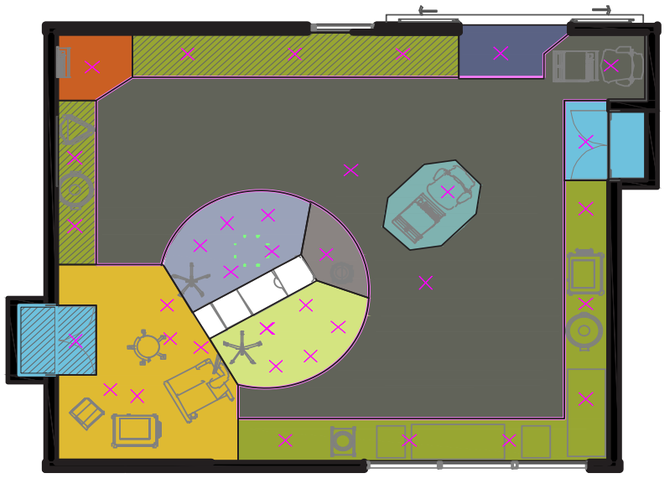
CASE 1 | 421.26 sq.ft.

Small- 72% from prototype OR size



CASE 2 (base case) | 579.98 sq.ft.

Medium OR prototype size



CASE 3 | 738.40 sq.ft.

Larger OR-27% more than prototype OR size

CNWS LOCATION- Wall

		CASE 1	CASE2	CASE3
n=5	TDT	731.5	817.8	925.5
	TNC	22.0	17.5	14.6
	NTS	2.8	1.9	1.2
n=7	TDT	973.9	1225.7	1264.2
	TNC	46.2	33.6	31.5
	NTS	5.0	2.3	1.4

***shaded boxes are statistically significant

CNWS LOCATION- Foot of Table

		CASE 1	CASE2	CASE3
n=5	TDT	679.3	808.8	860.6
	TNC	29.8	22.1	20.3
	NTS	13.2	8.4	4.4
n=7	TDT	885.3	1041.1	1144.0
	TNC	61.0	40.1	36.9
	NTS	17.2	9.8	6.3

CONCLUSION | ROOM SIZE

ONE

The smallest room resulted in the shortest distance walked for all CNWS positions and number of staff in room.

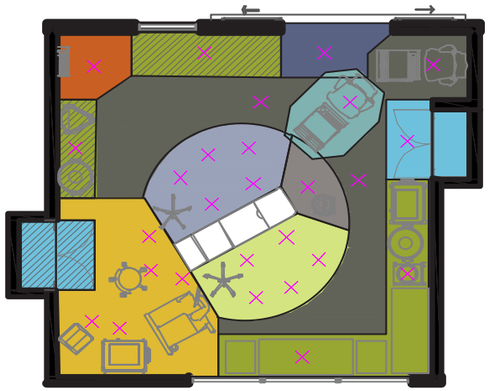
TWO

The largest room performed best in terms of TNC and NTS however we see diminishing returns with increasing size.

THREE

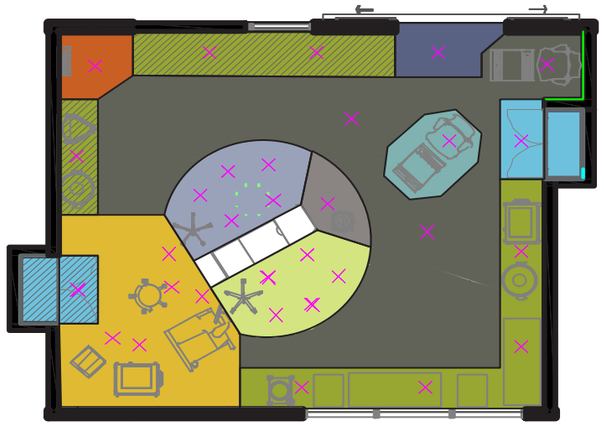
The prototype and the larger room both performed well in terms of number of contacts while the number of transitions to the sterile areas was lowest in the largest room.

ROOM SHAPE



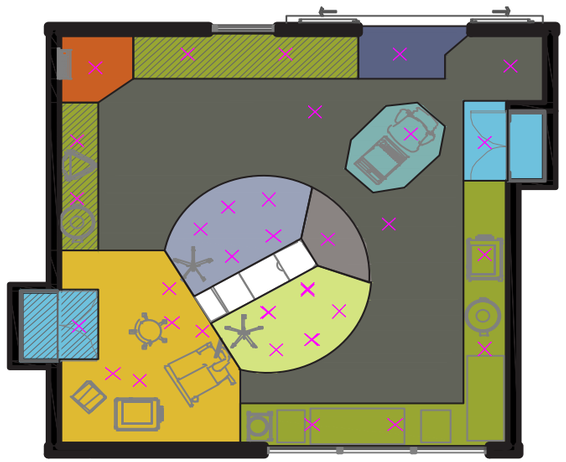
CASE 1 | 408 sq.ft.

Square and small OR-20’ x 20’



CASE 2 (base case) | 580 sq.ft.

Rectangular



CASE 3 | 584 sq.ft.

Square-24’ x 24’

CNWS LOCATION- Wall

		CASE 1	CASE2	CASE3
n=5	TDT	727.0	817.8	1024.1
	TNC	23.3	17.5	12.5
	NTS	16.3	1.9	4.6
n=7	TDT	965.0	1125.7	1337.8
	TNC	50.0	33.6	28.1
	NTS	19.8	2.3	5.6

***shaded boxes are statistically significant

CNWS LOCATION- Foot of Table

		CASE 1	CASE2	CASE3
n=5	TDT	666.9	808.8	977.7
	TNC	29.9	22.1	16.8
	NTS	16.3	8.4	9.4
n=7	TDT	874.0	1041.1	1256.9
	TNC	58.4	40.1	34.8
	NTS	20.1	9.8	12.8

CONCLUSION | ROOM SHAPE

ONE

The small square room performed well in terms of distance walked because it was smallest in area.

TWO

Case 2 and case 3 were similarly sized, but the rectangular prototype did better in terms of NTS, while the square room performed better in terms of TNC

CONCLUSION

CONCLUSIONS

1. We developed an algorithm which is able to differentiate destination zones from pass-through zones with a considerable accuracy.
2. We built and validated a unique simulation model that is capable of generating traffic scenarios and comparing design options based on flow-related performance outcomes in the OR.
3. We compared several layouts to the base layout in terms of three well-defined performance measures.
4. When CN workstation is closer to the surgical bed distance walked is less but NTS is higher
5. As number of people in the OR increases - all outcomes deteriorate
6. Distance walked was least in the small ORs though NTS and TNC were higher
7. NTS and TNC reduced with size though we observed diminishing returns of increasing area
8. Overall, the prototype appears to be effective for the measures tested

THANK YOU!

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