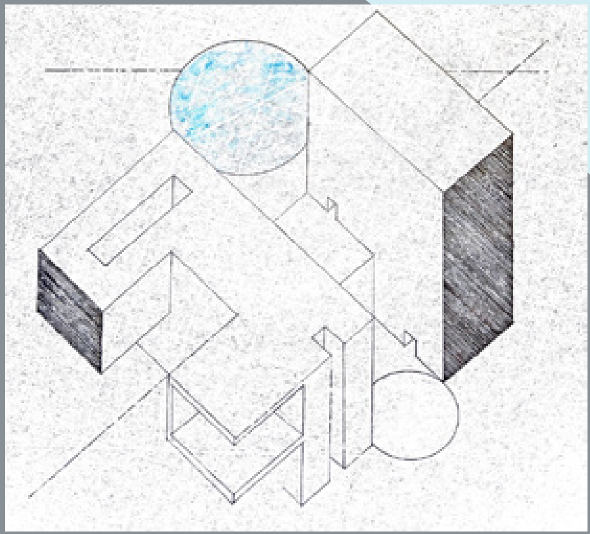
THE EFFICACY OF MODULAR DESIGN IN HEALTHCARE

THE EXPLORATION OF MODULAR DESIGN IN HEALTHCARE THROUGH THE COMPARATIVE ANALYSIS OF A TRADITIONALLY CONSTRUCTED HOSPITAL AND ITS MODULAR TWIN

INTRODUCTION

Modular design has become an industry leading philosophy for the future of community-based health services. Modular construction applied as a design principle subdivides a construction system into independently fabricated units, similar in size, shape, and functionality to formulate a structure. The benefits of this approach include time-to-build efficiency, cost-effectiveness, quality and precision, minimal impact, re-use, and modification. This process contradicts traditional construction, pre-fabricating spaces off site to be assembled later. Through correlational research and simulation software, products of modular and traditional construction methods can be compared using operational statistics. The purpose of this thesis is to study the efficacy of the current method of modularity among the industry with intention to refine the process for a safer, enjoyable, more efficient, and replicable solution.



RISE
MODULAR

OWATANNA, MINNESOTA

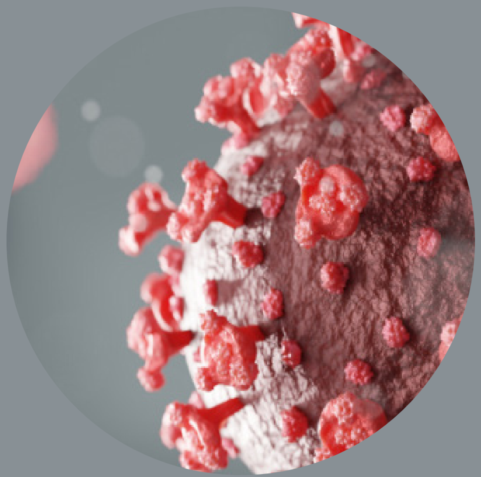
ALVERA APARTMENTS`- MODULAR MULTIFAMILY

DYNAMIC

ST. PAUL, MINNESOTA

BACKGROUND

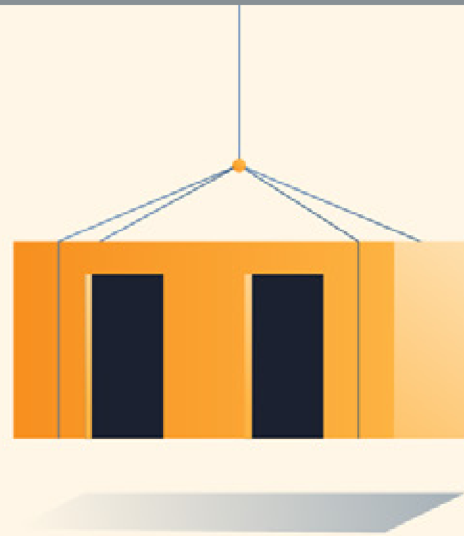
In practice, the study, and design of **Healthcare Architecture**; the application of medicine is steadily evolving to treat larger collectives of patients, demanding more ambulatory services and outmigration care. While not the first health crisis to spark this paradigm shift, **COVID-19** has proven that the field of medicine was ill-prepared for the pandemic; most notably in construction and design. The occupancy of hospitals are determined by the standard daily limit of a unit's typology. When a public health crisis occurs, this leaves hospitals without proper facilities for the influx of patient care. The first solution is expansion, often times in the form of permanent construction with the risk of vacancy when the crisis subsides. The sudden unbalance of supply and demand fuels the risk of **panic-architecture**. A fast paced solution to a problem with a high likelihood of error and often times patient discomfort results. The **Modular Twin** to the NGS Macmillan Unit proposes an idea that expansion is still achievable without the need for panic, discomfort, or waste. Modular architecture is not a new development in the field. Originally intended for residential design, It has expanded its purpose on a commercial scale.



Lowering the time of construction, design development and planning, efficient growth is achievable in emergencies like the pandemic. In the process, architects will be tasked with designing these mods, similar to a product patent that can be later repurposed to continue its line for expansion. The on-site construction is reduced to a short assembly with little noise and environmental pollution. Patients in attendance during these times will be subjected to less stressful situations and noise which will ultimately promote **recovery**.

PRELIMINARY RESEARCH

During **construction,** modular buildings **waste fewer materials** and **use less energy.**



On the **building site,** modular construction **eliminates hazards,** reducing the risk of injuries.

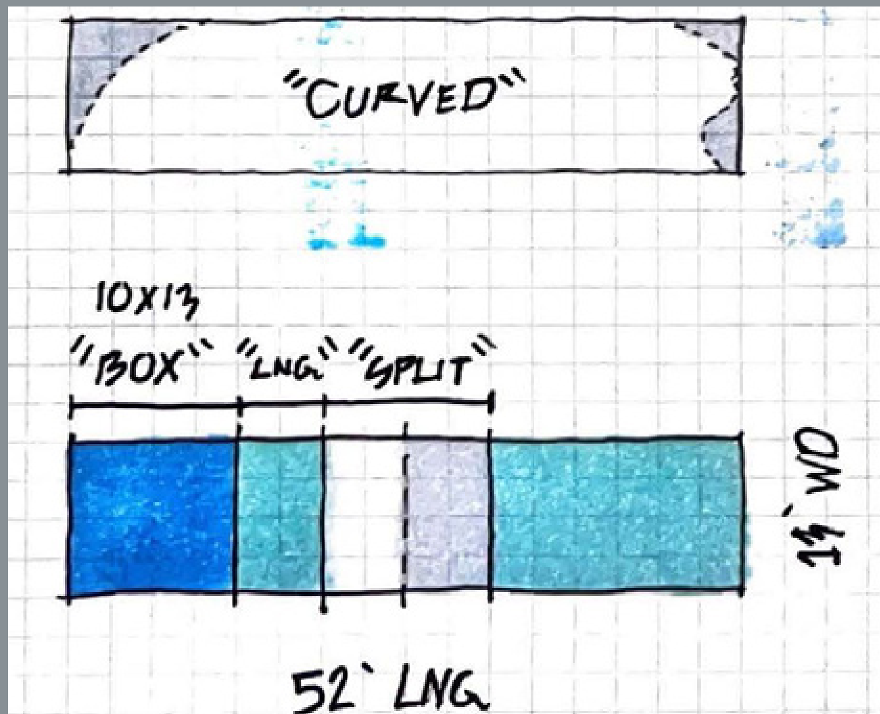
Modular buildings have a **long life span** and can be **reused or reconfigured** for new projects.

A MODULAR UNIT ITSELF IS A STRUCTURAL SYSTEM

WITH A CORNER POST SUPPORTED MODULAR UNIT ASSEMBLED WITH A BOLTED MARRIAGE JOINT, 6 TO 10 STOREYS CAN BE ACHIEVED

TRANSPORTATION DRIVES UNIT PARAMETERS

MODULAR ARCHITECTURE HAS THE POTENTIAL FOR A 50% REDUCTION IN MATERIAL WASTE AND TIME-TO-BUILD EFFICIENCY



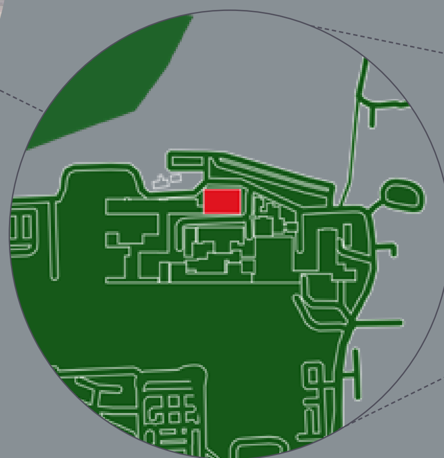
LOCATION

THE NGS MACMILLAN UNIT AT THE CHESTERFIELD ROYAL HOSPITAL

CALOW, ENGLAND - 53.2363° N, 1.3980° W

CURRENT UNIT

EXISTING SITE

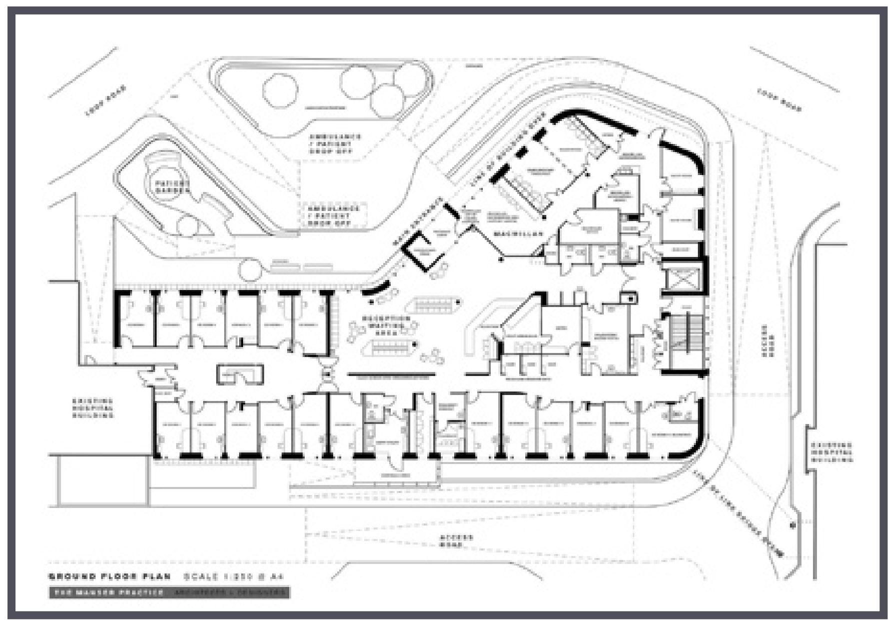


EXPANDED SITE

CORRELATIONAL STUDY:
NGS MACMILLAN UNIT | CHESTERFIELD, UK

PROJECT DESCRIPTION:

YEAR:	2017
ARCHITECT:	The Manser Practice
LOCATION:	Calow, UK
BUSINESS UNIT:	Healthcare
PHOTOGRAPHS:	Hufton + Crow
AWARDS:	RIBA East Midlands Building of the Year
CONSTRUCTION:	Traditional (£ 10m)
SIZE:	2,140 SQ. M. 23,034 SQFT.



PROJECT TYPOLOGY

The NGS Macmillan Unit is a standard ambulatory and cancer patient care facility constructed as an addition to the Chesterfield Royal Hospital. Its services, professionals, scale, and typology are a perfect example of a clinic that had the opportunity to use prefabricated construction methods. Its unique spatial organization and envelope are a great representation of the possibilities provided by traditional construction. Reaching the limits of an organic facade while maintaining high efficiency, it is the perfect sample to be tested.

Materiality

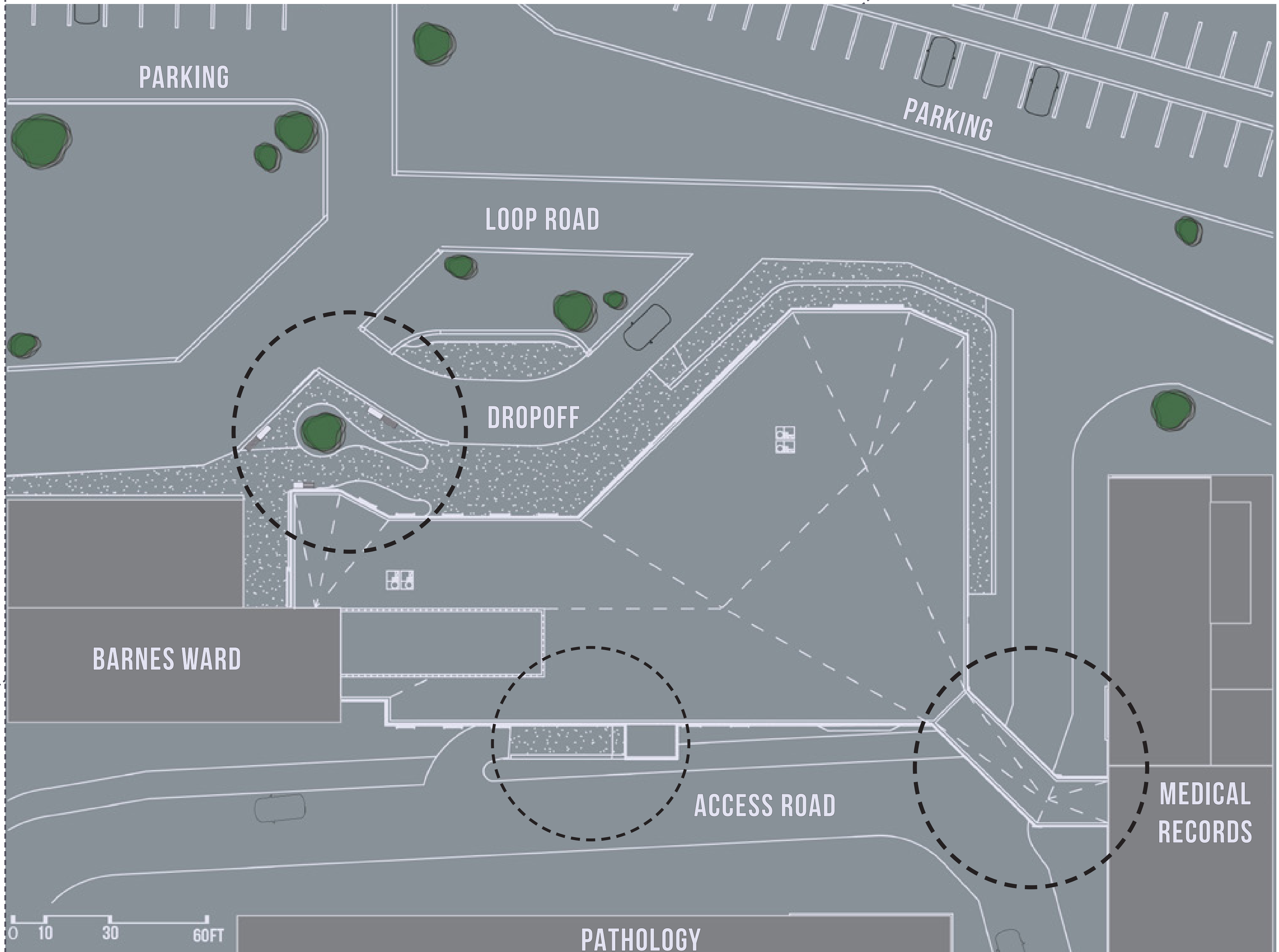
Healthcare facilities require an abundance of specific materials to maintain a sterile environment, provide safe passage and avoid contamination from units such as labs and X-rays. These are standardized and universal materials, however, the facade has more creative freedom. This would provide a challenge to create a design solution that not only functions internally but also captures the dynamic aesthetic of the NGS Macmillan's envelope. Utilizing the verticality of the seams between modular units, a similar effect can be drawn from the external fins on the existing facility. Window placement, white façade paneling and elbow shape all embody the characteristics of the form originally designed by The Manser Practice.

PROJECT GOALS

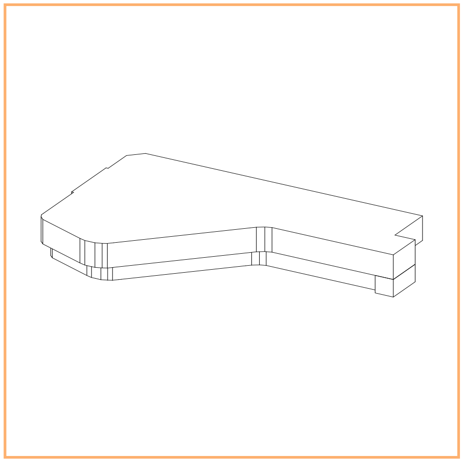
EF•FI•CA•CY | *noun*

the ability to produce a desired or intended result

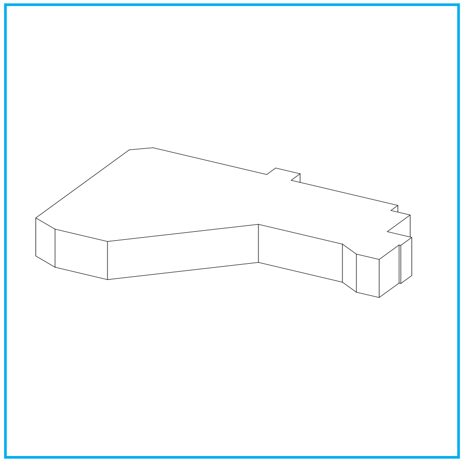
SITE PLAN


PARKING
PARKING
LOOP ROAD
DROPOFF
BARNES WARD
ACCESS ROAD
MEDICAL RECORDS
PATHOLOGY
0 10 30 60FT

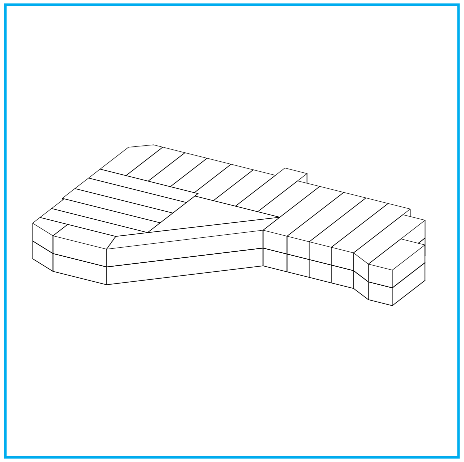
ORGANIZATIONAL MASSING



NGS MACMILLAN

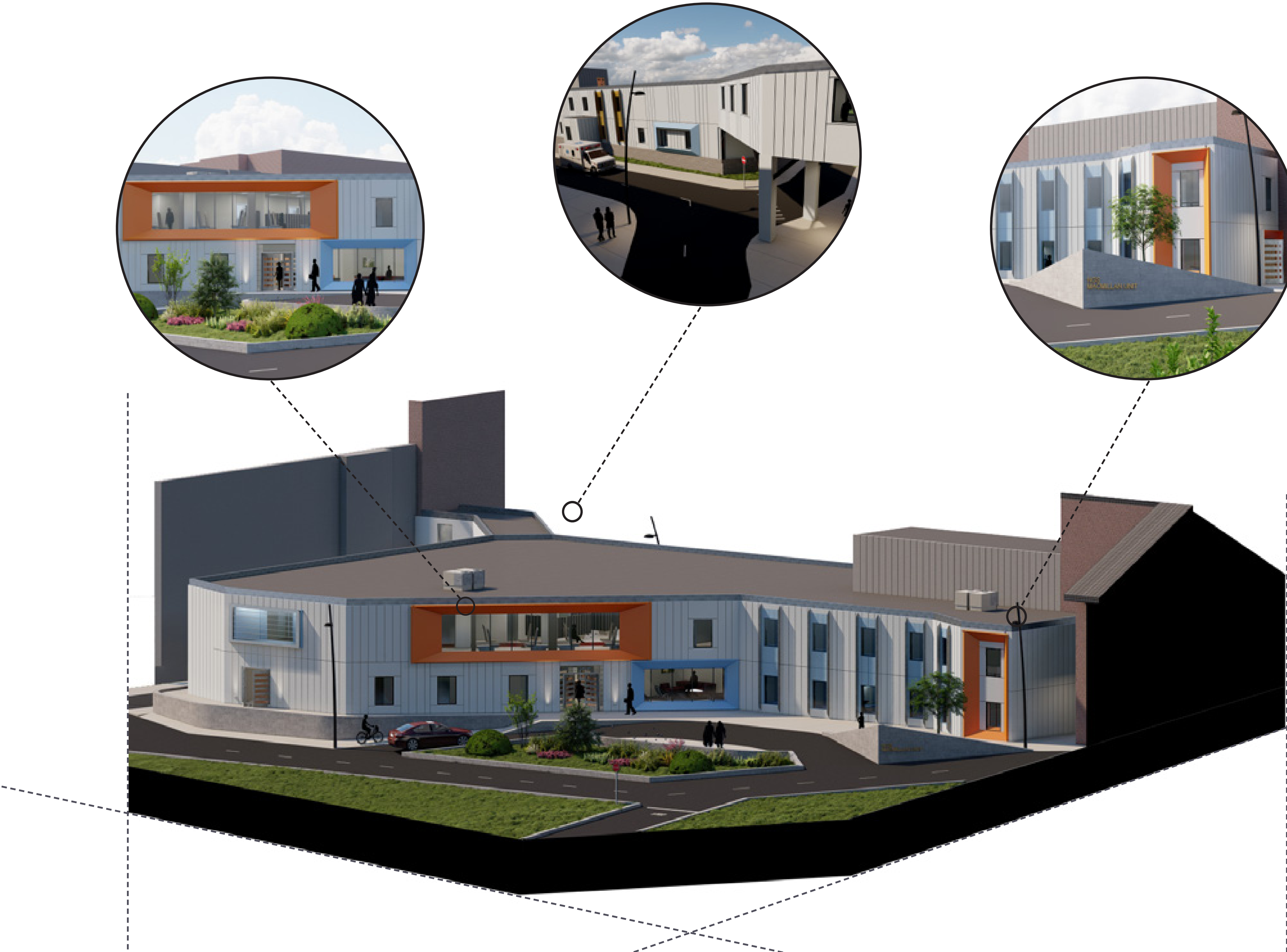


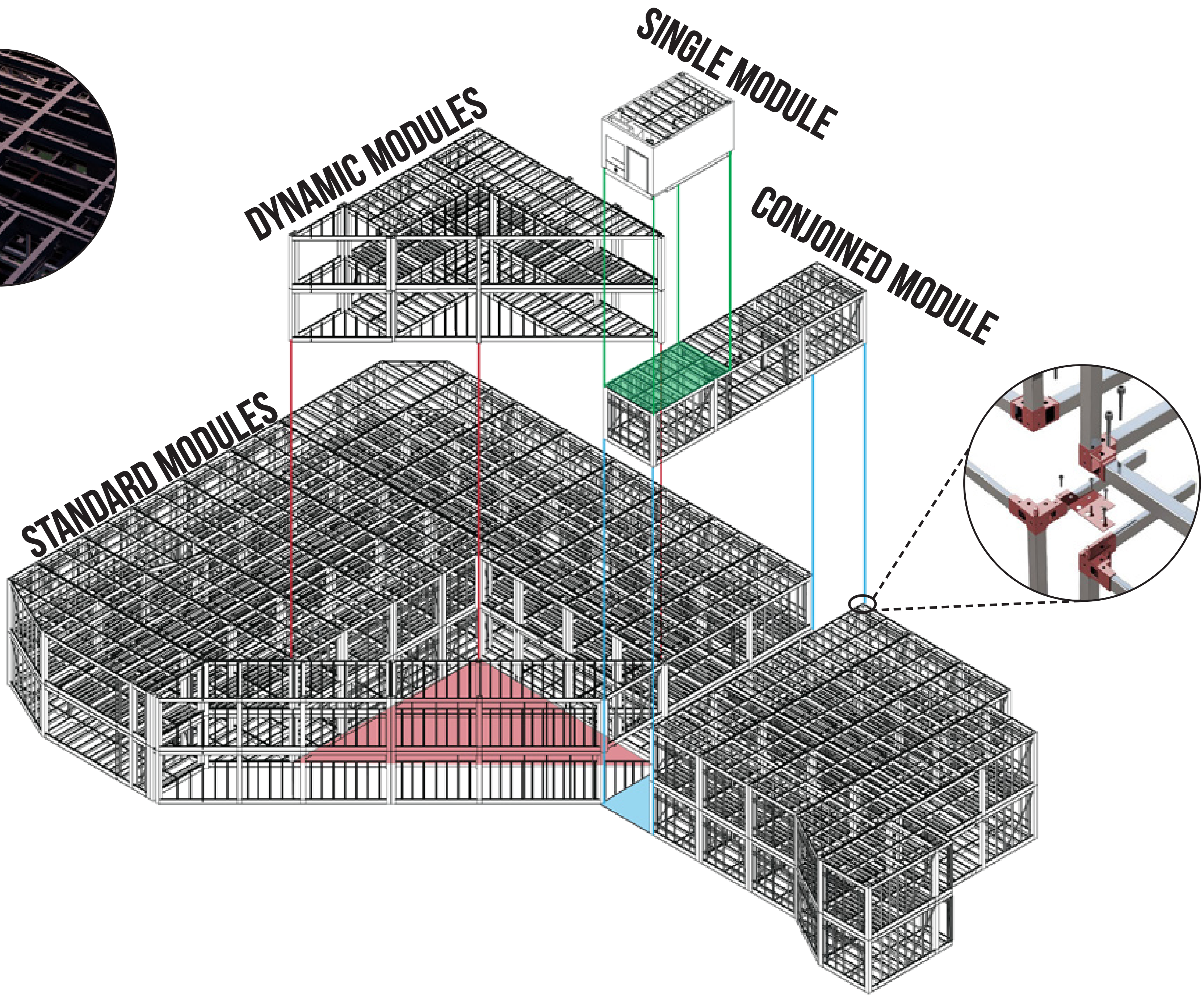
MODULAR TWIN



FULL UNIT ASSEMBLY

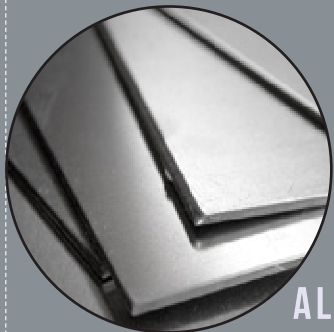
COMPLETED CONSTRUCTION



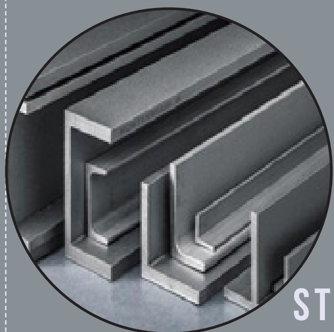


COMPLETE STRUCTURAL ASSEMBLY

INDIVIDUAL UNIT ASSEMBLY



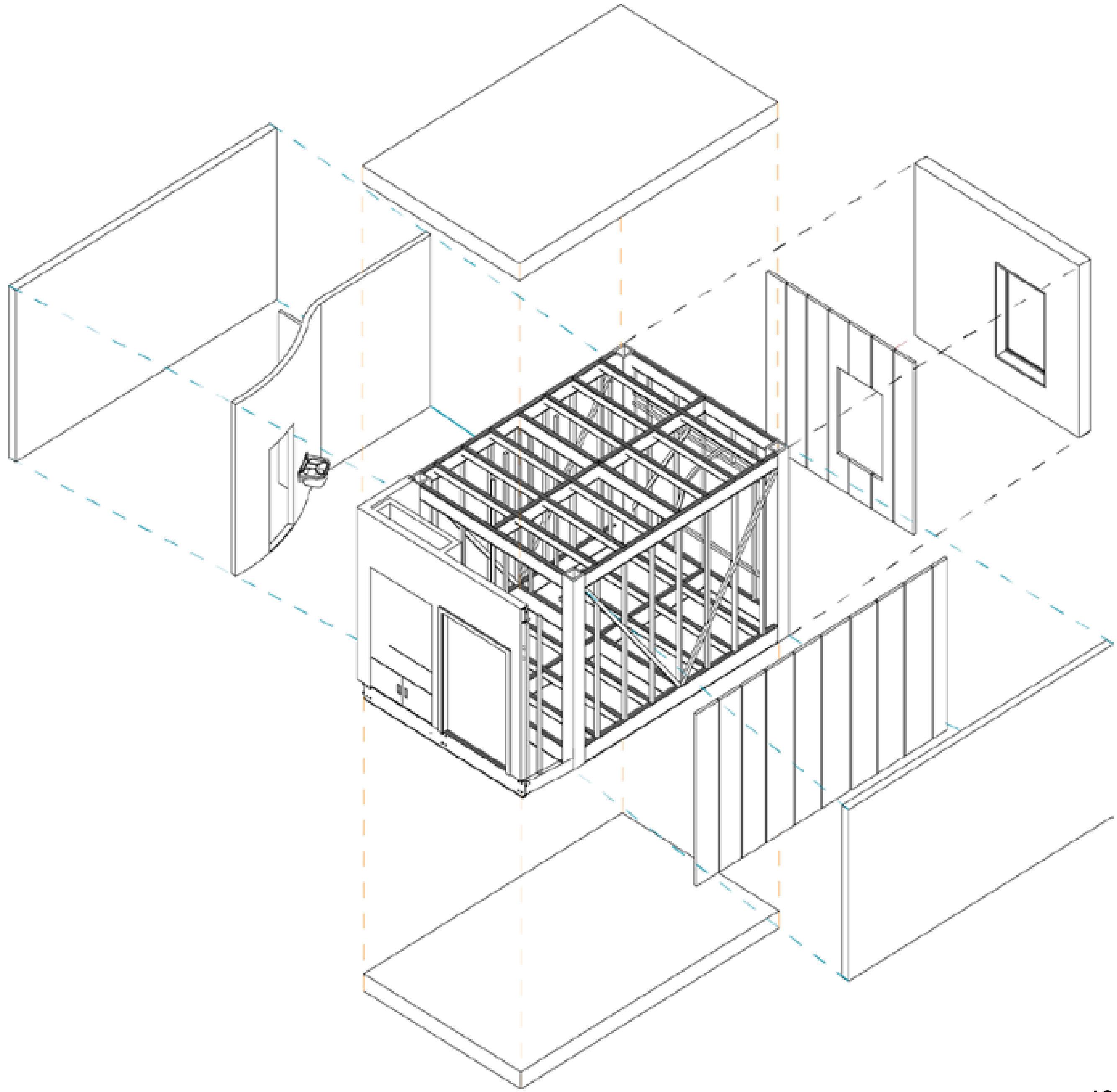
ALUMINUM



STEEL

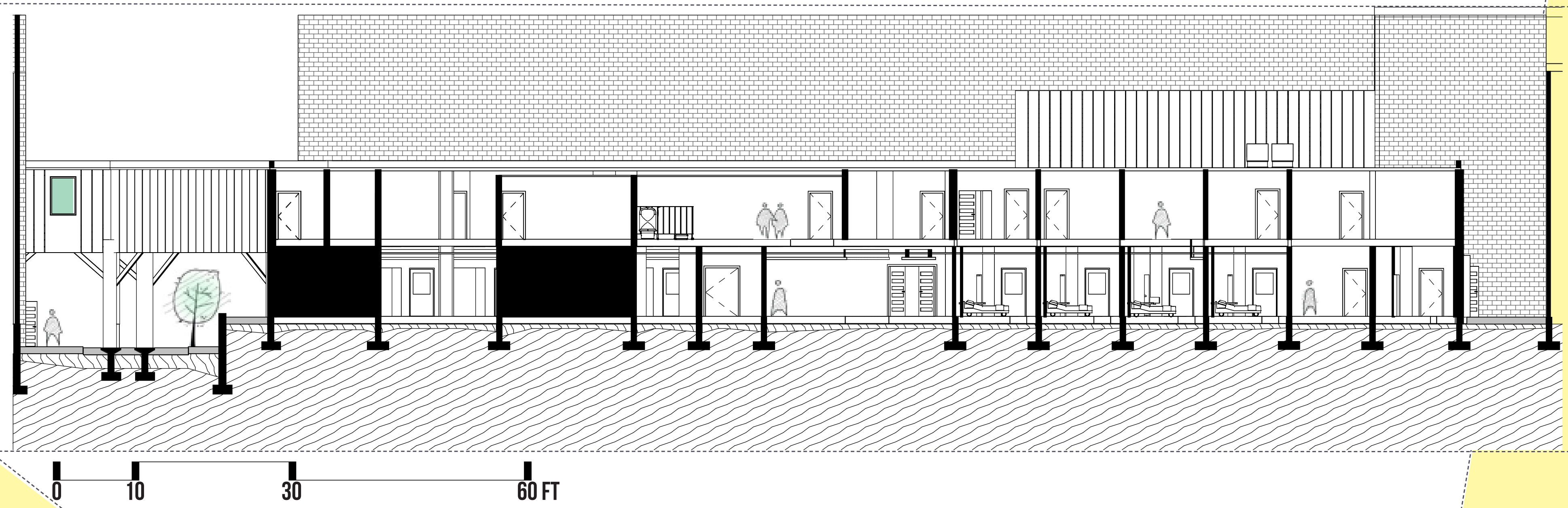
VINYL

PVC



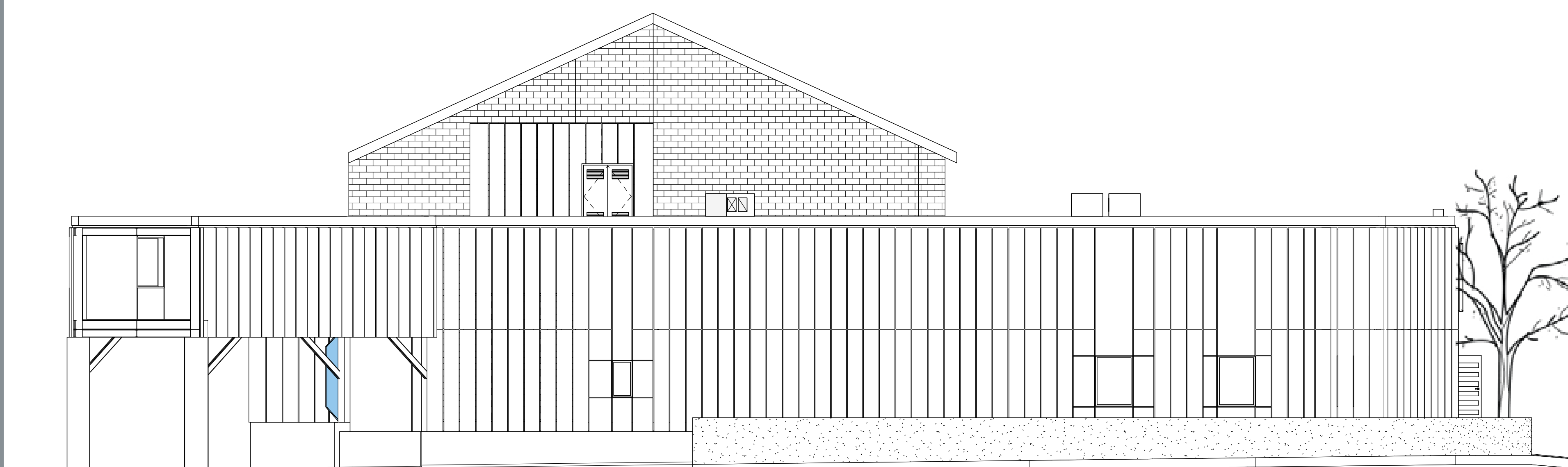

1:18 SCALE


SECTION CUT

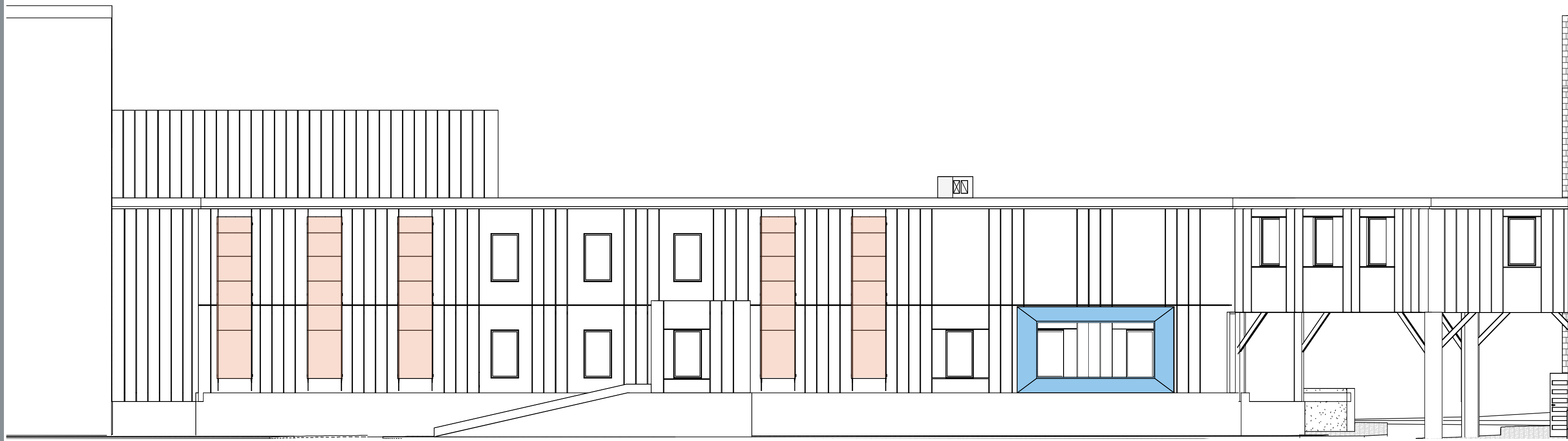


ELEVATIONS

NORTH



EAST



SOUTH

WEST

MODULAR TWIN

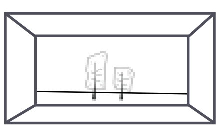
DESIGN ELEMENTS

NORTHWEST - MAIN ENTRANCE

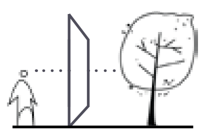
The Modular Twin's design philosophy takes subtle influence from its traditional counterpart, further solidifying the theoretical instance where it could be designed by The Manser Practice.

COLOR THEORY

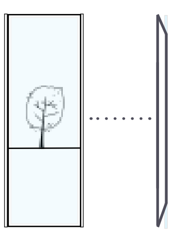
- Pureness, Cleanliness, Productivity, Trust
- Positivity, Creativity, Energy, Happiness
- Confidence, Passion, Warmth, Power

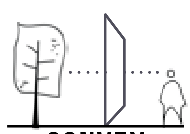


FRAMING

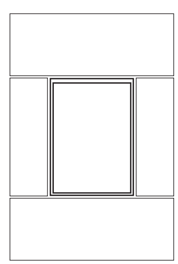


CONCAVE





CONVEX

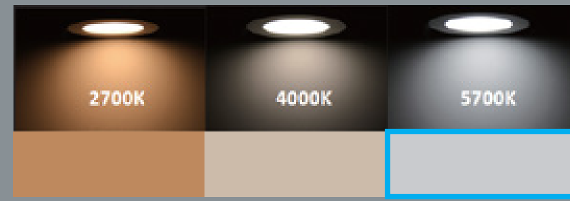


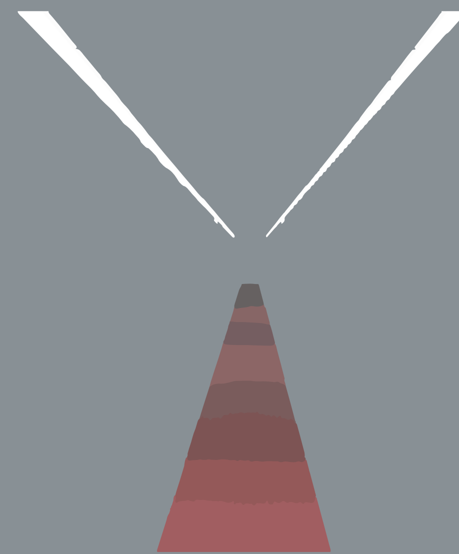
LAYOUT

NORTHWEST - MAIN ENTRANCE

INTERIOR - PRIMARY CORRIDOR

COLOR TEMPERATURE



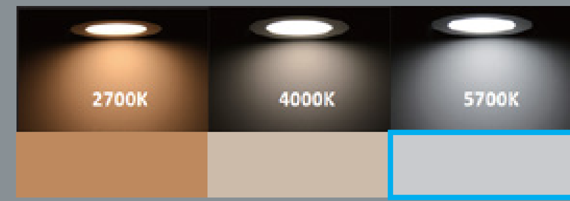


HIGHWAY

COLOR THEORY

INTERIOR - STANDARD EXAM ROOM

COLOR TEMPERATURE

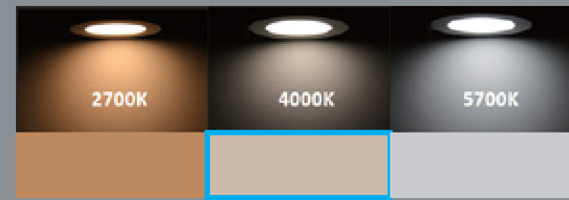


PAUSE...

COLOR THEORY

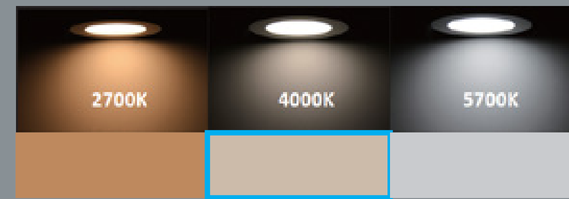
INTERIOR - MAIN LOBBY

COLOR TEMPERATURE

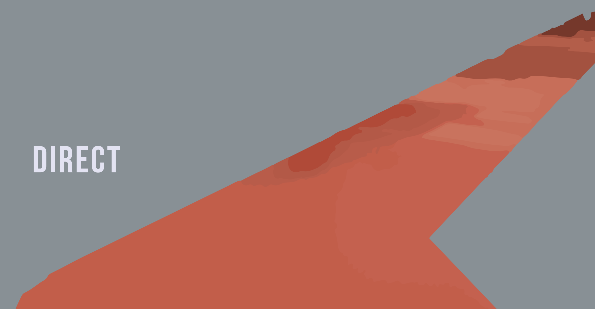


RELAX

COLOR TEMPERATURE



DIRECT



COLOR THEORY

ANYLOGIC

SIMULATION START

METHODOLOGY

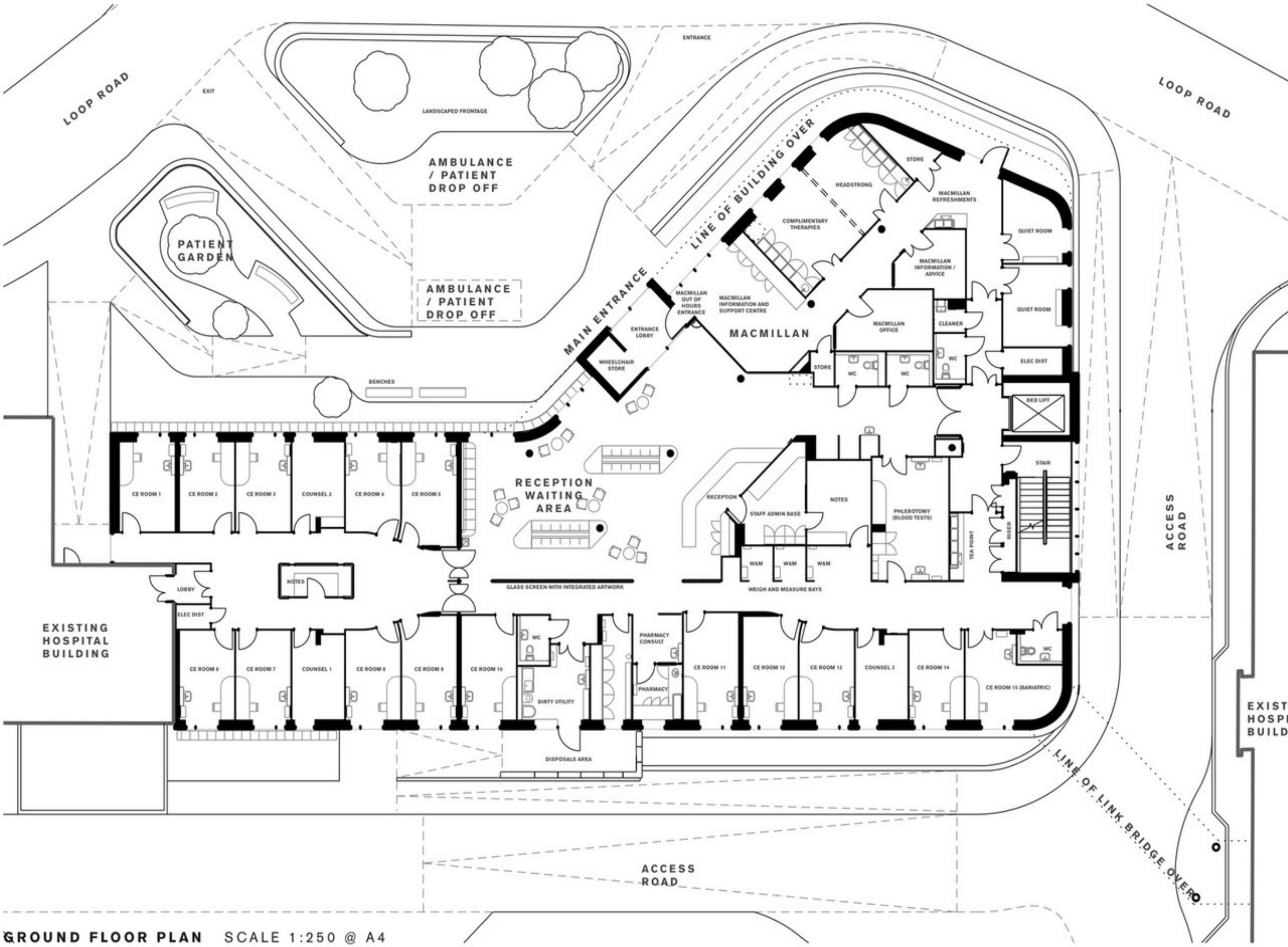
Creating a standardized/simplified simulation using a software called Anylogic to determine the efficiency of building circulation, time of arrival (TOA) and length of stay (LOS) statistics. Anylogic is a simulation modelling tool that supports agent-based and system dynamics simulation methods for business applications, planning and architecture. Using these tools, a comparison of the results can be conducted from the existing and theoretical designs, both traditional and modular. The completion of these simulations will address which design solution(s) creatively rectifies any design flaws that prohibit the most efficacious functionality.

OBJECTIVES IN ANYLOGIC

- Develope a model using a replicable process for an array of ambulatory clinics
- Measure Pedestrian Flow Statistics
- Measure TIme of Arrival Statistics
- Measure Length of Stay Statistics
- Use correlation tactics to compare clinics of different construction types

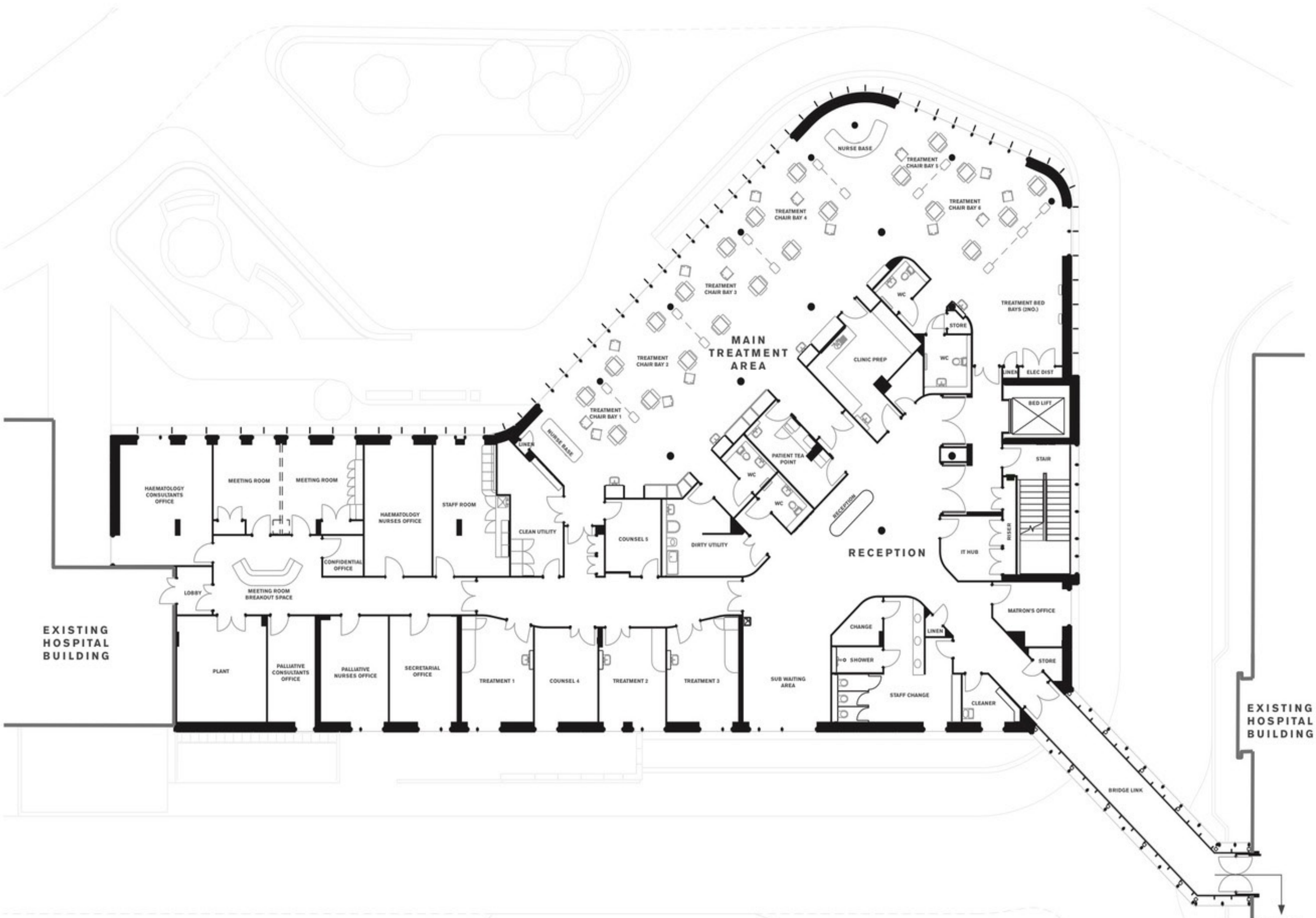
AnyLogic 8.8.1 Logo (https://www.anylogic.com/)

NGS MACMILLAN UNIT - FIRST FLOOR



GROUND FLOOR PLAN SCALE 1:250 @ A4

THE MANSER PRACTICE ARCHITECTS + DESIGNERS



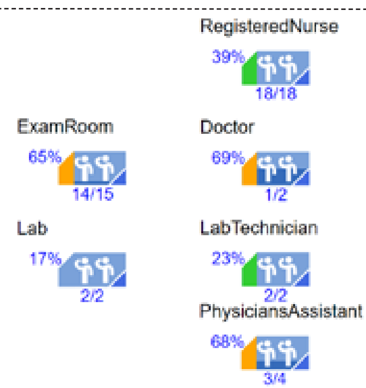
FIRST FLOOR PLAN SCALE 1:250 @ A4

THE MANSER PRACTICE ARCHITECTS + DESIGNERS

SPATIAL ORGANIZATION

- EXAM ROOM/IN USE
- NURSE (RESOURCE)
- DOCTOR (RESOURCE)
- PA (RESOURCE)
- LAB
- ENTRANCE
- EXIT
- EXISTING/UNACCESSABLE

CAPACITY

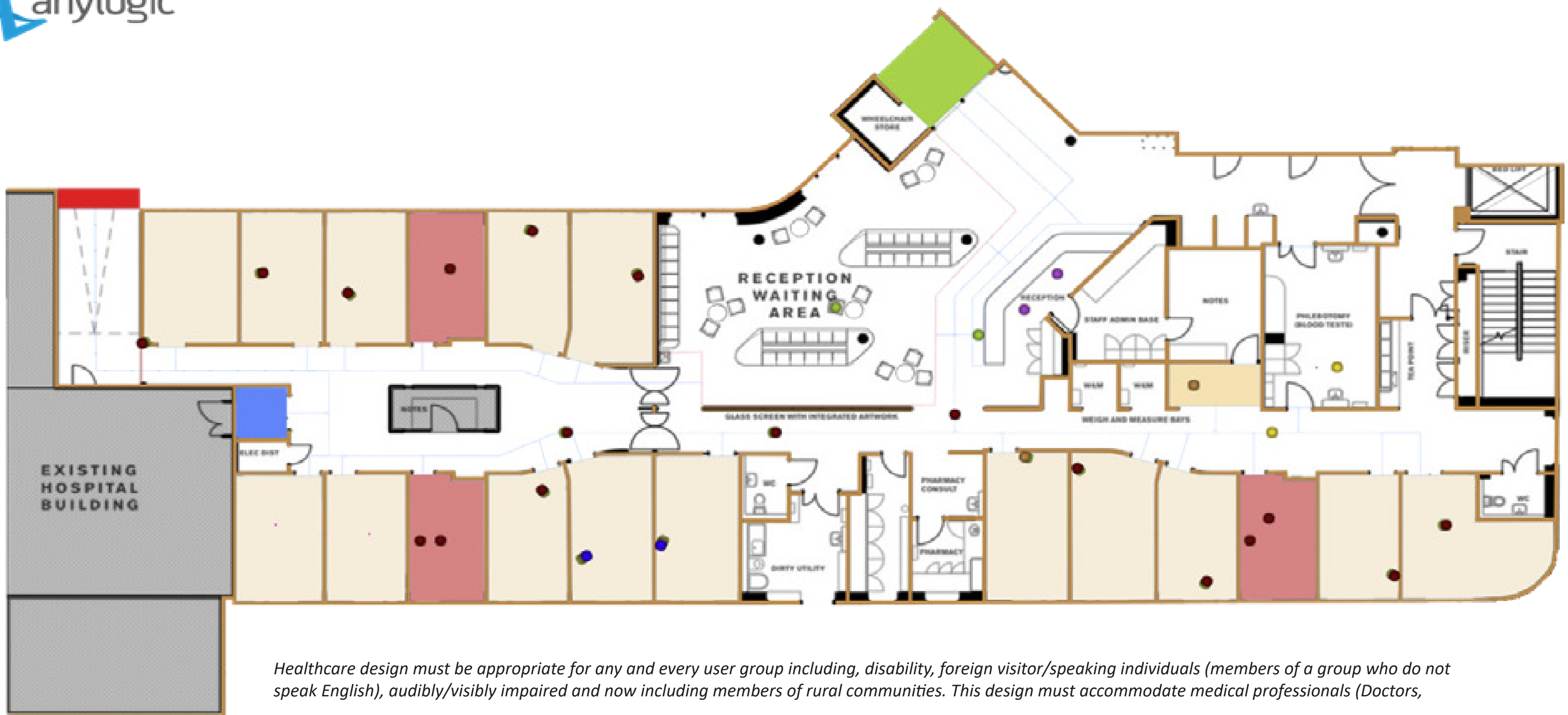


UNDERSTANDING THE "GUI"

Graphical User Interface (GUI) references the operating system used to manage the simulation's interactions. In this image, the entire layout of the model is presented in the running simulation. Here the user can see:

1. The constructed model (Room Boundaries)
2. Visualized - automatically updated statistics (Graphs)
3. Model manipulation tools (buttons and sliders)
4. The Process Model (Logic tree)
5. Agent interaction

anylogic



Healthcare design must be appropriate for any and every user group including, disability, foreign visitor/speaking individuals (members of a group who do not speak English), audibly/visibly impaired and now including members of rural communities. This design must accommodate medical professionals (Doctors, Surgeons, Radiologists, nurses, receptionist, janitorial staff, etc.) patients and victims of illness, mental and physical injury/disease.

RECEPTIONIST — PATIENT — NURSE (RN) — DOCTOR — PA — LAB TECHNICIAN

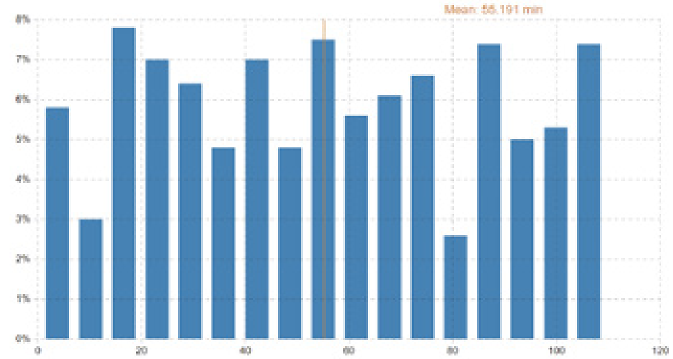
UNDERSTANDING AGENTS

Agents as represented above are the "living" entities within an AnyLogic model. Their appearance and actions can be defined individually or as a population - this is how they fulfill their roles. The listed agents in this model were specifically chosen as the core/control agents to be used in the replicable model.

PROFESSIONALS	
Physician (MD/DO)	*Doctors diagnose and treat illness and injury or provide referals for unique treatment.*
Physician Assistant (PA)	*Provides direct patient care diagnosing and treating minor illness and conduct minor procedures.*
Registered Nurse (RN)	*Provide and coordinate patient care and educate patients about health management.*
Lab Technician	*Prepare samples for analysis and conduct tests on biological samples.*
Receptionist	*Welcomes, directs and serves visitors upon arrival as well as over-the-phone directory.*

PROCESS LOGIC - MAIN

The logic or block code of the simulation is displayed below. Here is where the order of operations is defined. The goal of this logic network was to establish a core/generic tree that can be replicated to other models. The produced results will be the control variable for the proposed modular structure designed using similar spatial organization.



LENGTH OF STAY

Measures the patients Length of Stay at the clinic from the first data collection node at the start of the process to the second data collection node once the patient reaches the exit door.

Results:
Day - 51.088 min.
Week - 52.061 min.
Month - 55.191 min

Data collection node start {Length of Stay} (used for multiple tables)

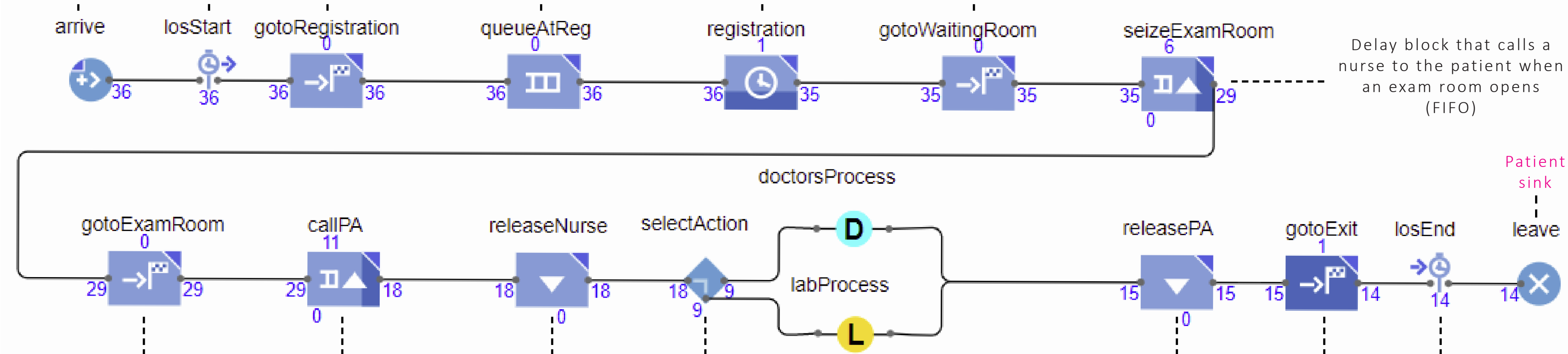
Source node for the # of patients that arrive

# of patients that arrive at the reception desk

Defined waiting line if the reception desk node is full

Delay period that represents the variable "avg. registration time"

on registration end # of patients waiting to be seen by a nurse



Delay block that calls a nurse to the patient when an exam room opens (FIFO)

Patient sink

Patient, nurse and exam room meet - # of patients

After specified exam time - nurse calls a PA from resource pool to patient in exam room

PA takes over remaining exam prompting release nurse

# of patients proceeding to the lab, doctor or new agent 0.5/0.5 probability

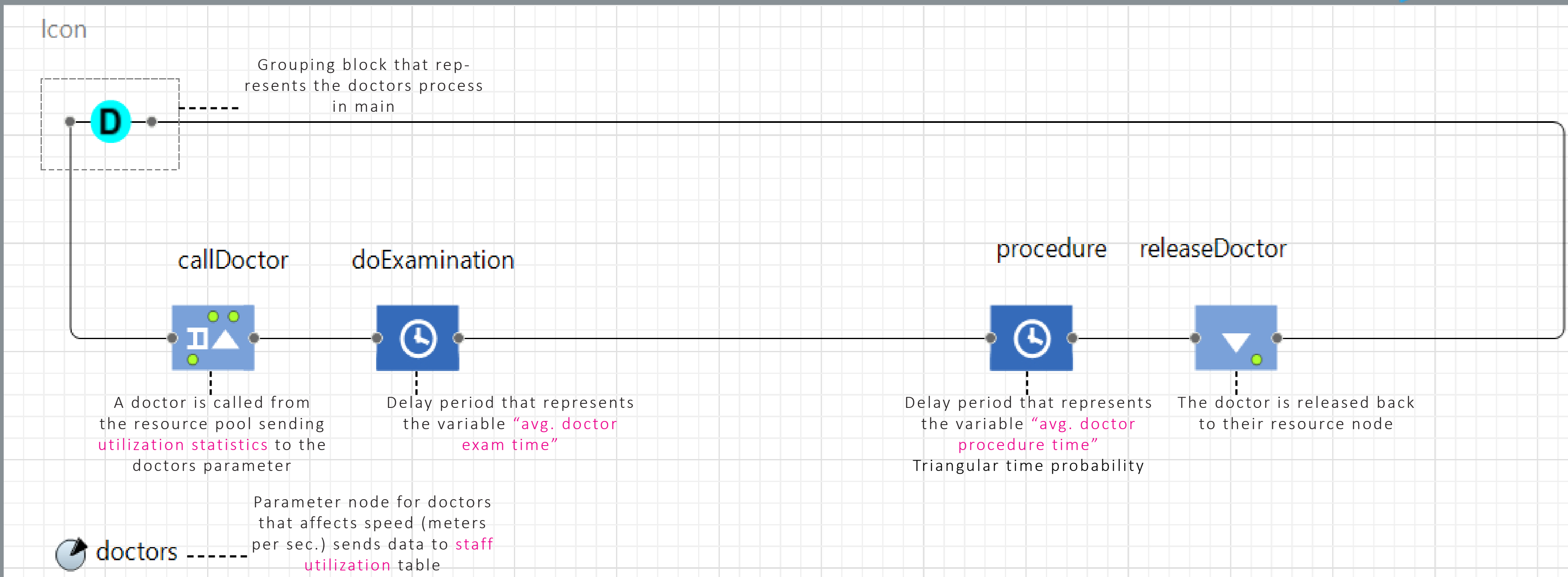
Process nodes are defined by a seperate hidden network

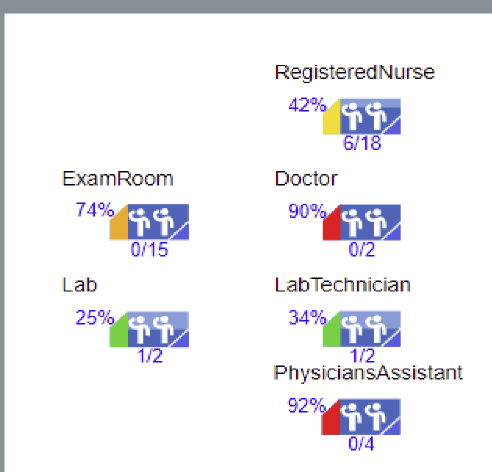
The PA is then released back to their resource pool

# of outpatients exiting the simulation

Data collection node end {Length of Stay} (used for multiple tables)

DOCTORS PROCESS



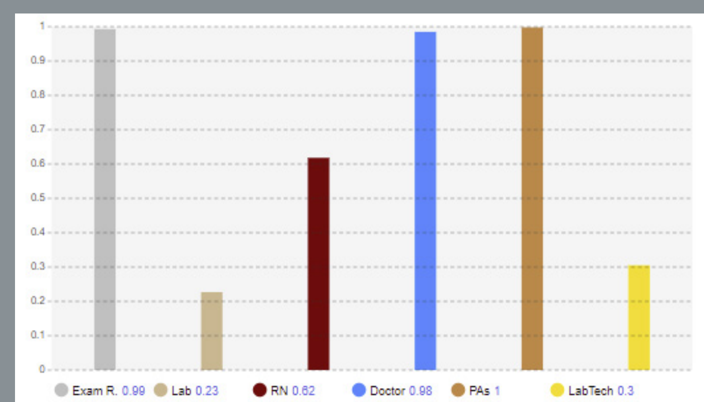


RESOURCE BLOCK

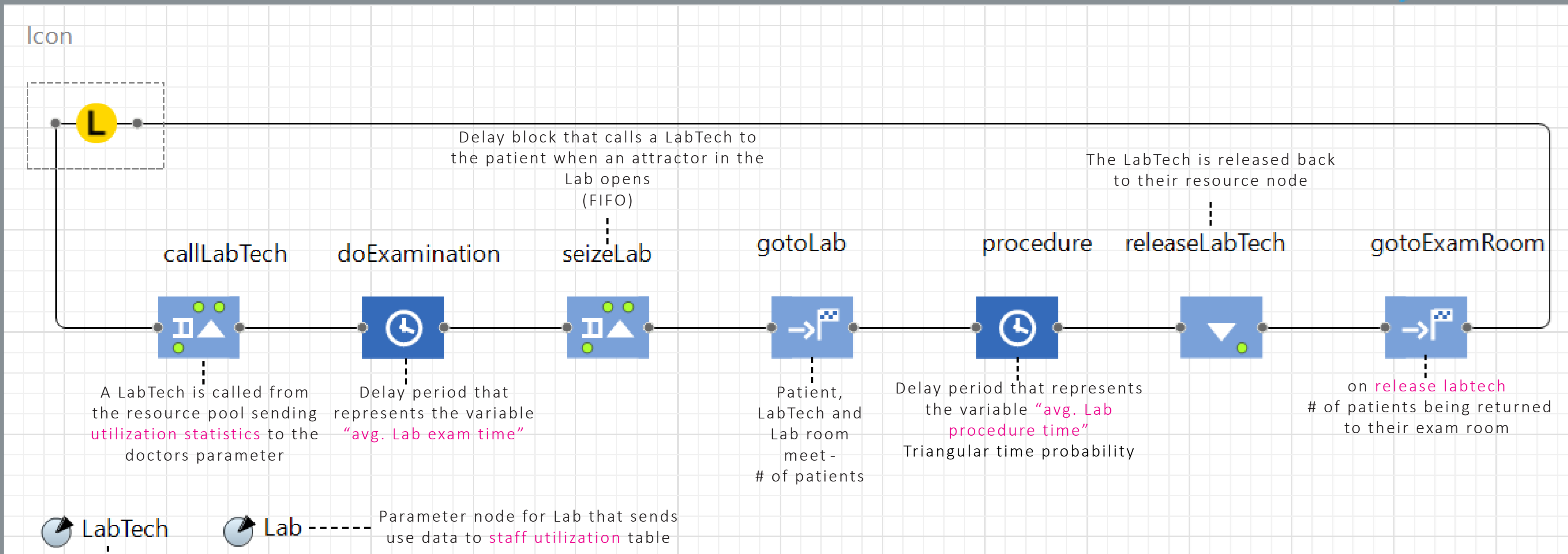
Resource blocks are grouping nodes that represent a resource pool of a particular agent. In this case the Doctor resource block is being utilized to seize an exam room, perform an exam, perform a procedure and then return to its resource node within the model. Resource blocks can work with data sets to visualize statistics. Their capacity and tasks can be altered using parameter nodes as well as interactive tools such as sliders or buttons.

STAFF UTILIZATION

The staff utilization table measures the percent usage of a particular agent. This variable is measured through agent parameters as seen above, sending the information to this table using the logic ExamRoom.utlization() for example. The importance of this data set is to ensure continuity among different simulations. The baseline mean should be replicated to test the logic network for errors.

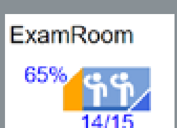


LAB PROCESS



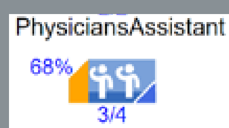
Parameter node for Lab Technicians that affects speed (meters per sec.) sends data to staff utilization table

RESOURCE BLOCKS



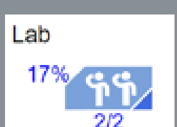
NODES:

callLabTech
gotoExamRoom



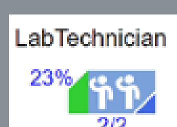
NODES:

doExamination
seizeLab
gotoExamRoom



NODES:

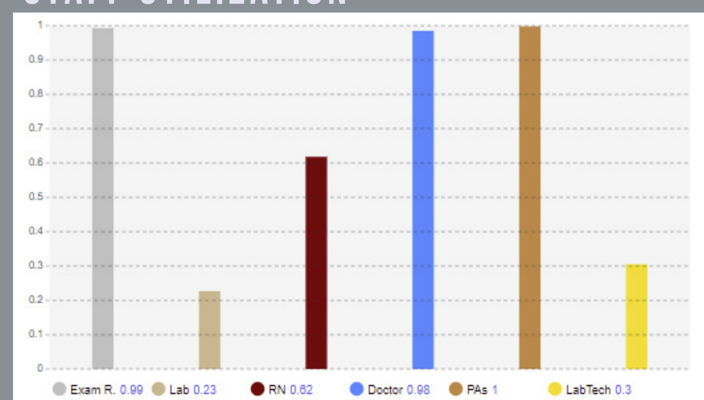
seizeLab
gotoLab
procedure



NODES:

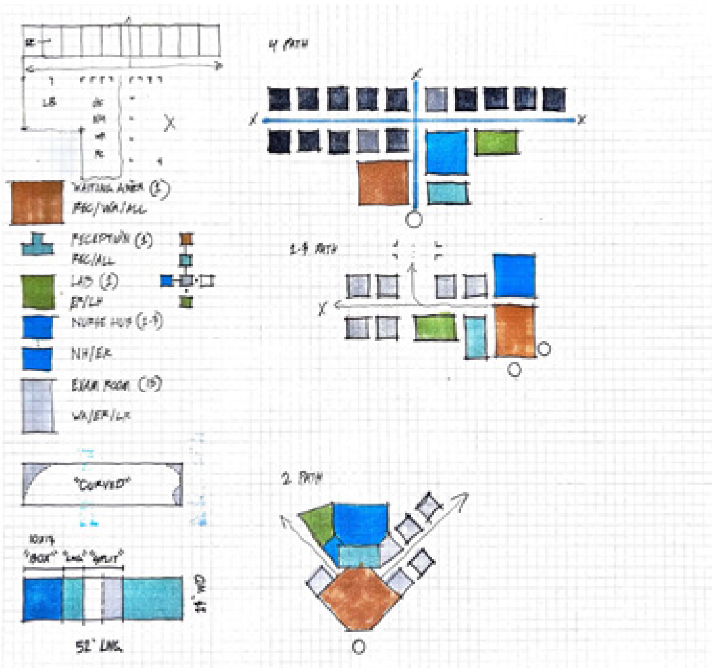
callLabTech
doExamination
seizeLab
gotoLab
procedure
releaseLabTech

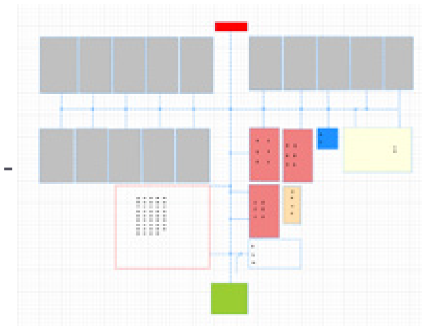
STAFF UTILIZATION

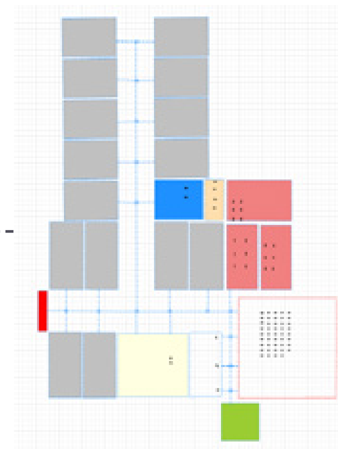


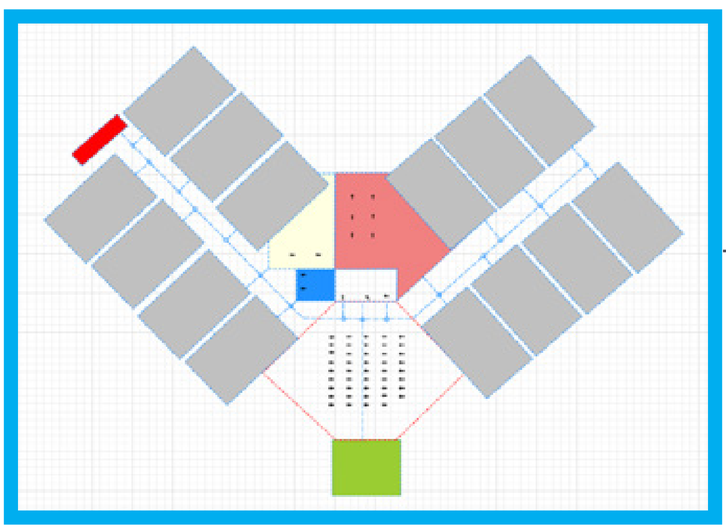
The staff utilization table measures the percent usage of a particular agent. These variables should remain relatively the same across every seperately run simulation. Variables change with arrival rate parameters.

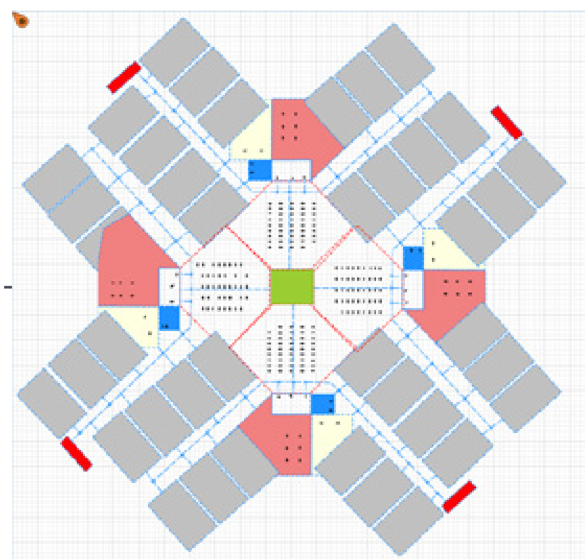
PROCESS OF ORGANIZATION



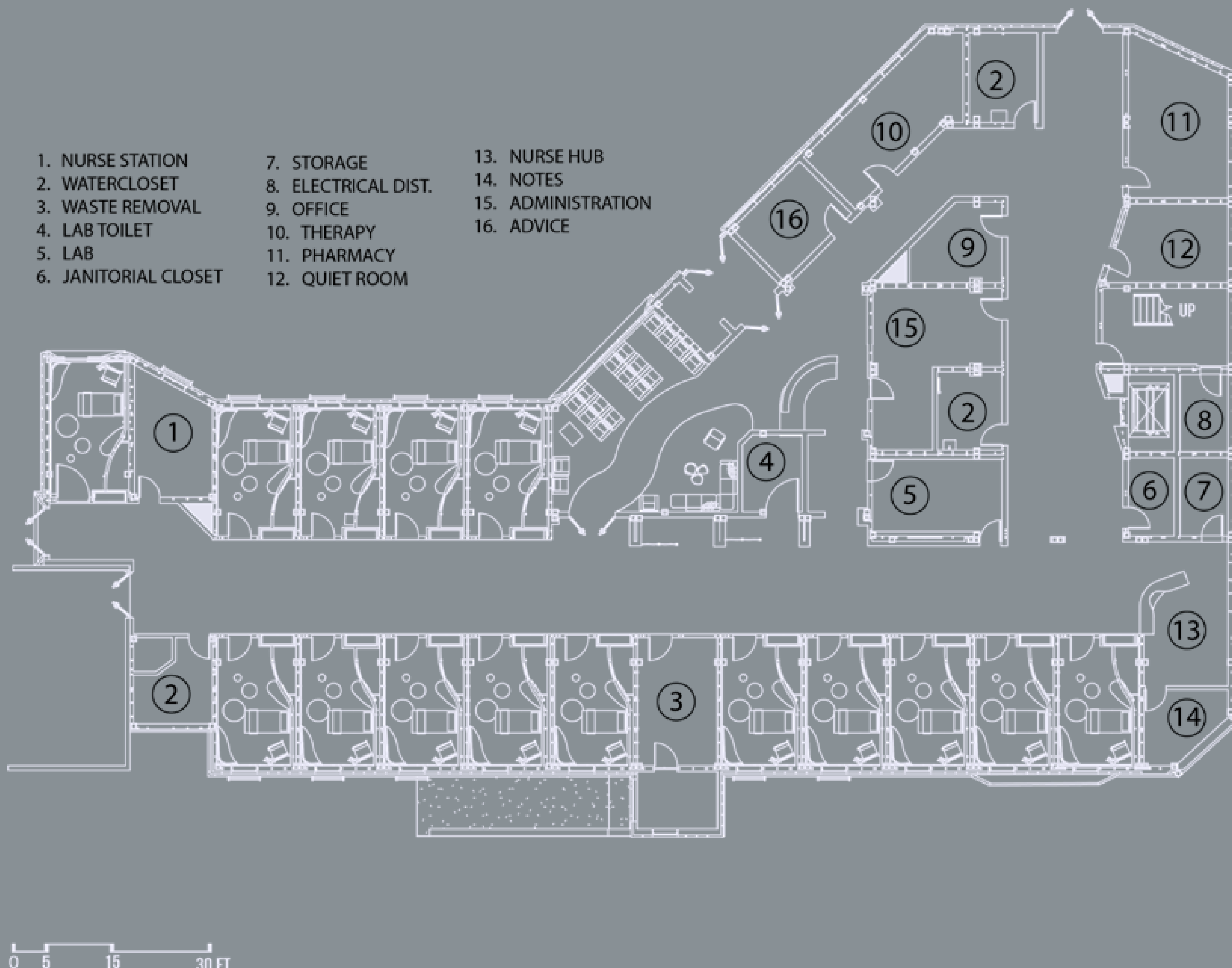




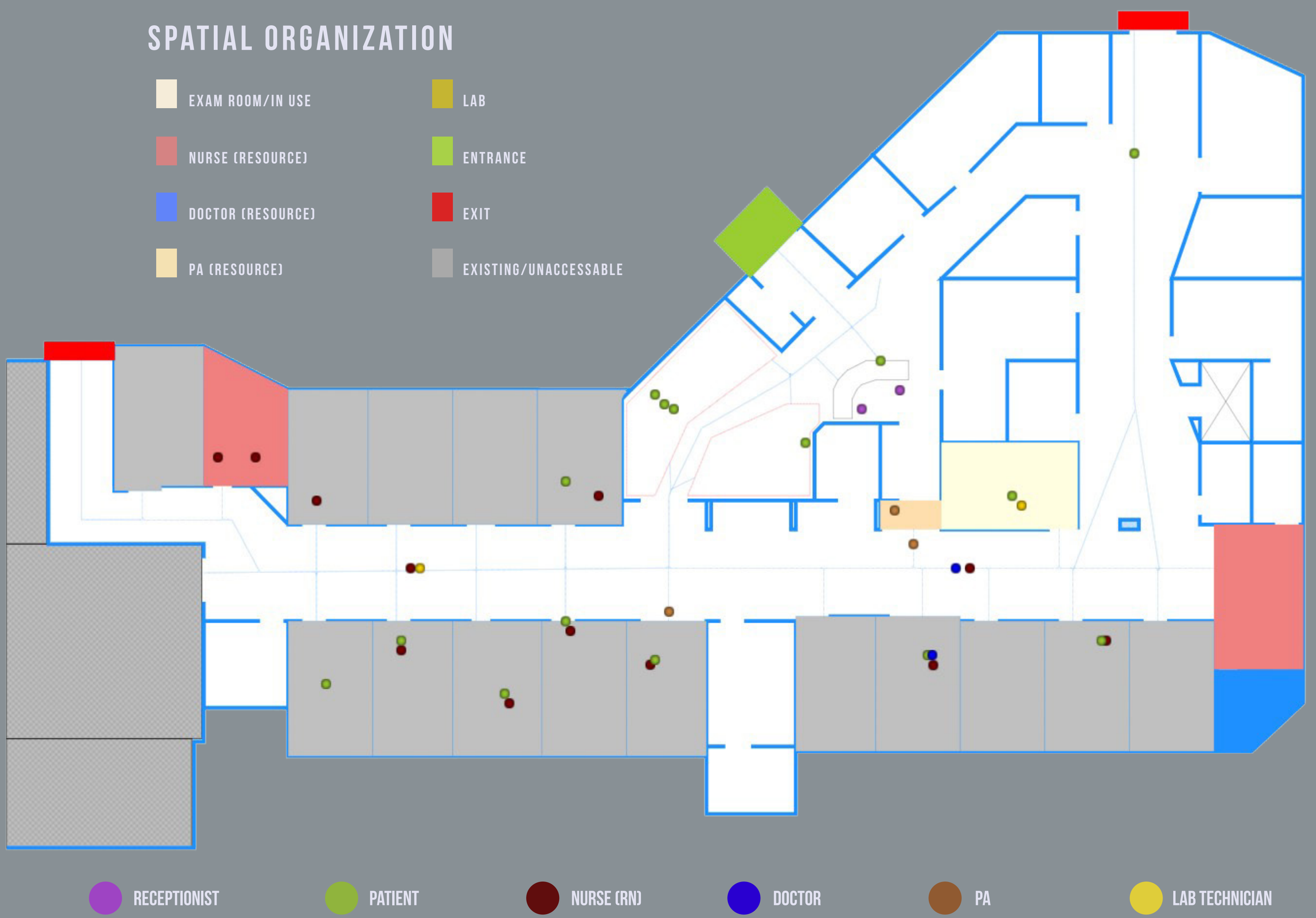




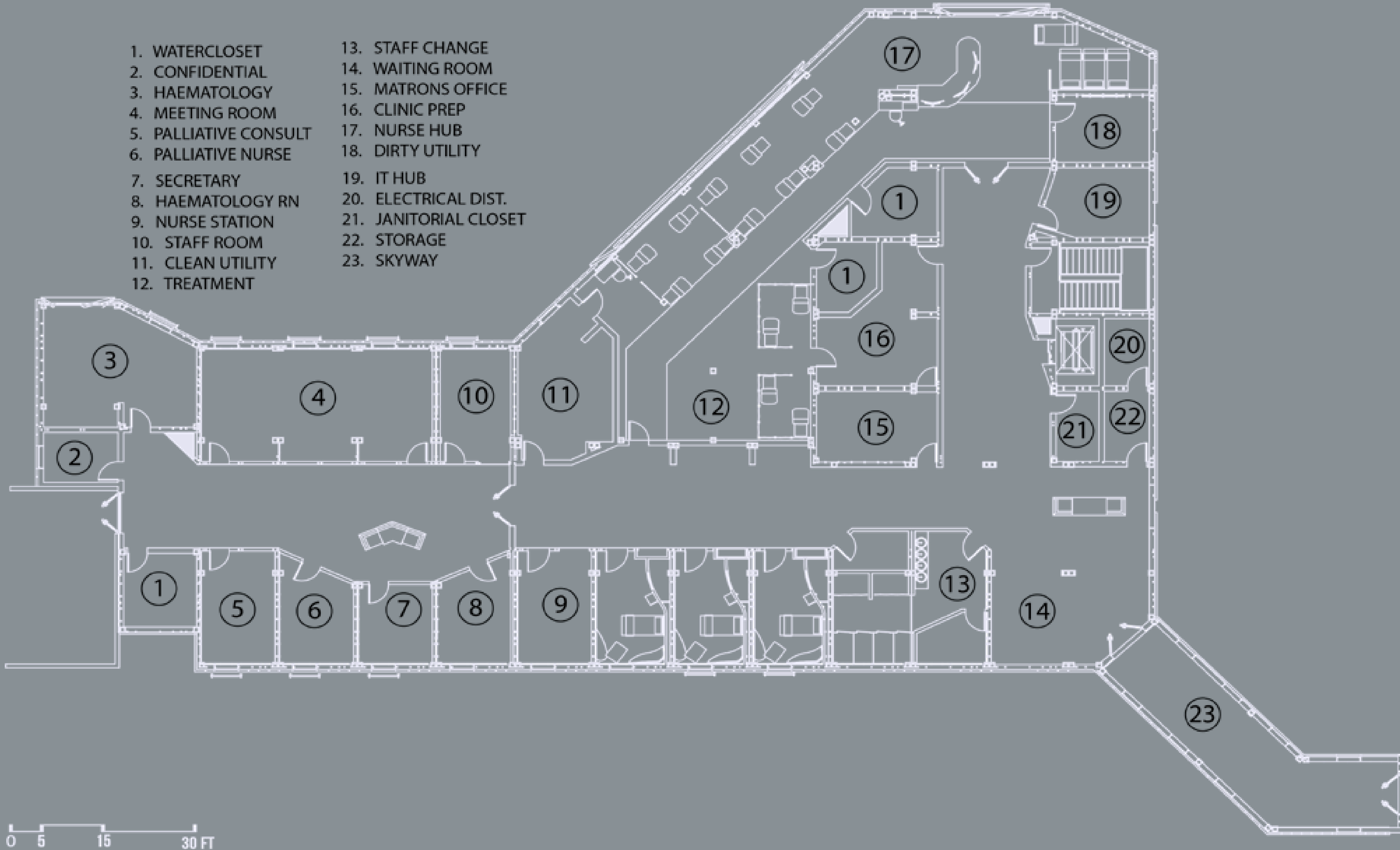
FIRST FLOOR PLAN



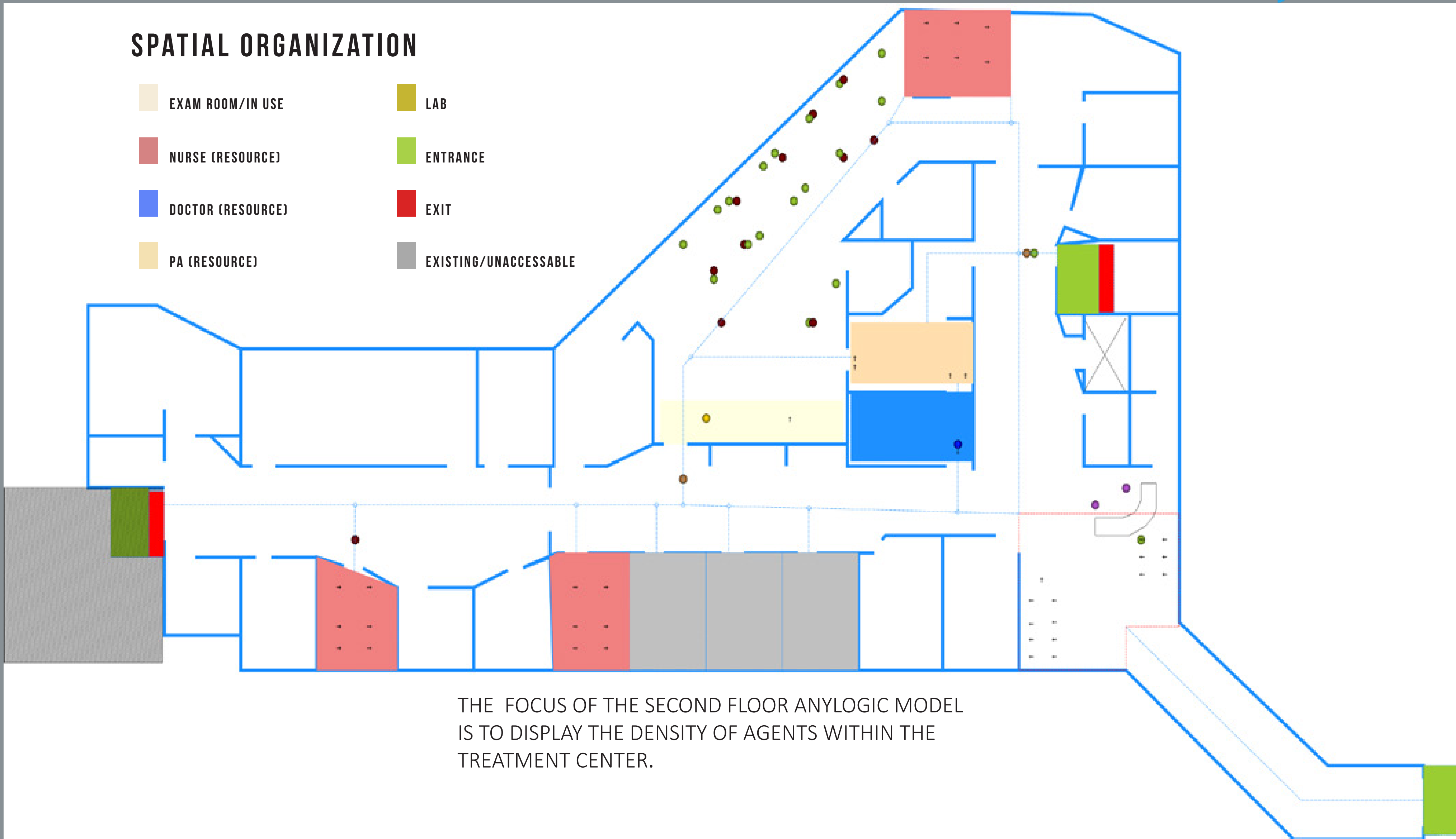
FIRST FLOOR PLAN



SECOND FLOOR PLAN



SECOND FLOOR PLAN



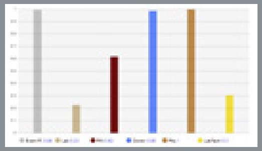
THE FOCUS OF THE SECOND FLOOR ANYLOGIC MODEL IS TO DISPLAY THE DENSITY OF AGENTS WITHIN THE TREATMENT CENTER.

RECEPTIONIST PATIENT NURSE (RN) DOCTOR PA LAB TECHNICIAN

RESULTS

The final results from the AnyLogic models are displayed below as an average or accompanied by a visual aid:

UTILIZATION RESULTS (6.2 AR):



NGS

LAB UTILIZATION (6.2 AR):
Day - 17 Units
Week - 120 Units
Month (30 Days) - 490

PA UTILIZATION (6.2 AR):
Patients per hour - 5.5

REGISTERED NURSE UTILIZATION (6.2 AR):
patients per hour - 2.24

LABTECH UTILIZATION (6.2 AR):
Patients per hour - 10.95

MT

LAB UTILIZATION (6.2 AR):
Day - 17 Units
Week - 119 Units
Month (30 Days) - 488 Units

PA UTILIZATION (6.2 AR):
Patients per hour - 6.5

REGISTERED NURSE UTILIZATION (6.2 AR):
Patients per hour - 2.24

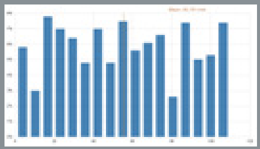
LABTECH UTILIZATION (6.2 AR):
Patients per hour - 10.95

NGS MACMILLAN UNIT

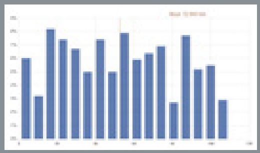
FULL LENGTH ETA (E/W) (6.2 AR):
Distance (m) - 51.52
ETA (sec.) - 78.128

FULL LENGTH ETA (N/S) (6.2 AR):
Distance (m) - 16
ETA (sec.) - 22.4

LENGTH OF STAY RESULTS (6.2 AR):
Day - 51.088 min.
Week - 52.061 min.
Month - 55.191 min



LENGTH OF STAY RESULTS (6.5):
Day - 52.646 min.
Week - 52.989 min.
Month - 57.300 min



EXAM ROOM UTILIZATION (6.2 AR):
Day - 73 Units
Week - 518 Units
Month (30 Days) - 2129 Units

DOCTOR UTILIZATION (6.2 AR):
Patients per hour - 5.55

MODULAR TWIN

FULL LENGTH ETA (E/W) (6.2
Distance (m) - 50.02
ETA (sec.) - 74.188

FULL LENGTH ETA (N/S) (6.2 AR):
Distance (m) - 16.1
ETA (sec.) - 21.05

LENGTH OF STAY RESULTS (6.2 AR):
Day - 50.91 min.
Week - 51.43 min.
Month - 53.65 min

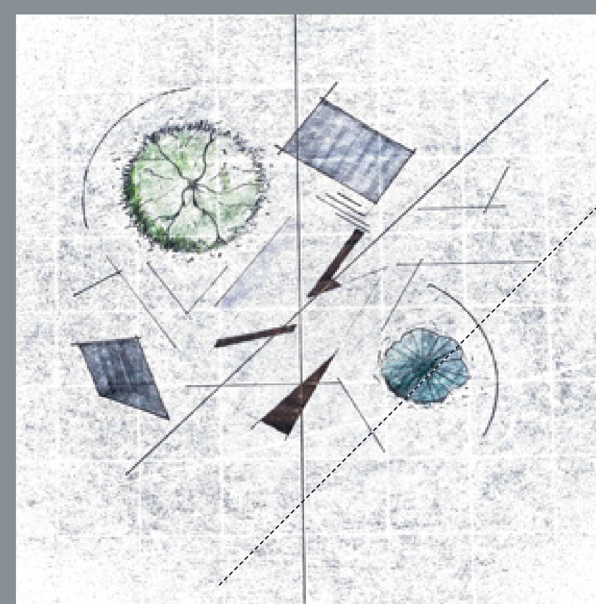
LENGTH OF STAY RESULTS (6.5):
Day - 52.486min.
Week - 53.111 min.
Month - 55.621 min

EXAM ROOM UTILIZATION (6.2 AR):
Day - 73 Units
Week - 519 Units
Month (30 Days) - 2144 Units

DOCTOR UTILIZATION (6.2 AR)
Patients per hour - 6.05

CONCLUSION

Having created a standardized Anylogic simulation to determine the efficiency of building circulation, the two structure's results indicate that modular construction was more efficient. The most recognizable attribution was the unavoidable close proximity of spaces in a modular layout. Having parameters set at 52' x 13' x 13', the distance between rooms was shortened. This limitation also caused the relocation of several room types. The angular walls of the **Modular Twin** in comparison to the **NGS Macmillan** remained relatively the same despite preconceived notions. In conclusion, through the process of replicating a building using strictly modular methods, the structure was successful in achieving aesthetic likeness, building program, creativity, and efficiency.



THANK YOU

Ganapathy Mahalingam
Cindy Urness
Laura C. Jones
My Peers
My Parents
My Friends