IAB330 – Applied IoT and Mobile Technologies

Assessment Cover Sheet

<table>
<tr><th>ITEM</th><th colspan="3">DETAILS</th></tr>
<tr><td rowspan="5">Team Details
(as per QUT records)

P – Primary member responsible for uploading assessment to Blackboard.

S – Secondary member responsible for uploading assessment to Blackboard.</td><td>Student #</td><td>Student Name</td><td>Individual Tasks Completed</td></tr>
<tr><td>N10219358</td><td>Declan Barrett</td><td rowspan="4">Group worked on the entire assignment</td></tr>
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<tr><td rowspan="2">Tutorial Details</td><td colspan="3">Tutor Name: Josh Aguiar Wallace</td></tr>
<tr><td colspan="2">Tutorial Day: Thursday</td><td>Tutorial Time: 6PM</td></tr>
<tr><td>Submission File/Name Format (PDF Document)</td><td colspan="3">IAB330 – 22 S2 Ax – TUTOR NAME – Team Name.pdf
Example: IAB330 – 22 S2 A1 – Sri – Awesome Team.pdf</td></tr>
<tr><td>Late Submissions</td><td colspan="3">Our team acknowledges that as per official QUT policy (stated under E/6.3 Student academic concessions, subsection 6.3.5 Late assessment and extensions), late submission without an approved extension in place, will be marked ZERO, without exceptions.</td></tr>
<tr><td>Submission Declaration</td><td colspan="3">Our team declares that:
1. We have understood the requirements of the assessment clearly, completing the group and assigned sections as required, which is reflected in this final submission.
2. Besides face-to-face meetings (where possible/applicable), we used MS Teams for online collaboration, as required in this unit.
We have reviewed this assessment cover sheet, completed the details required and included it in the final report.</td></tr>
<tr><td>Signature
(Member Initials ONLY)</td><td colspan="3">DB JD JK BB</td></tr>
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N

no-reply@qut.edu.au

To: Declan Barrett

Thu 08/09/2022 18:11

Hi Declan,

Thank you for your assignment extension request **(FORM-AEX-207381)**.

We have approved your request and the due date for your assignment **Assignment 1 Design of IoT Solution**, for unit IAB330 has been extended by 48 hours from the original due date. If your unit outline does not specify that your assignment is eligible for an extension, this confirmation email is not valid and unless you submit by the original due date, the late assessment policy will apply.

You are responsible for ensuring that this assignment is eligible for extension before submitting it after the original due date. Check your unit outline for eligibility.

As you indicated this is a group assignment, you are also responsible for informing other members of your group of this extension.

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Introduction

Project Space

Currently, hospitals and health-related services are having a difficult time identifying which rooms are occupied. A solution to this problem needs to account for both the security and privacy of key users' data since it is sensitive medical information. Our team is focusing on operating theatres where the main problems are that surgeries do not start on time; changeover takes too long, and session cancellations are not handled properly.

A major influence on these problems is the inefficient method of door checking by medical staff to find spare rooms. This violates the privacy of those inside the room, often disrupting medical procedures that occur within. This inefficient system leads to a lower throughput of patients due to the slowdown of medical procedures to deal with distractions, which can be potentially life-threatening. Only 74% of available theatre time is used, thus enabling the utilization of the other 26% is paramount (Queensland Audit Office, 2016). Doctors and nurses unable to find a spare room have their patients at risk as many injuries are time-sensitive and the time taken to find a room could be spent on treating patients.

An additional problem is determining whether the operating theatres are being used correctly. Improper usage of operating theatres can lead to personal and patient injury due to inexperience with medical equipment. All improper room usage ends up removing critical facilities from those who need them. Having the wrong room type used or the correct room type used for incorrect procedures can also impact the throughput of patients. Operating theatres need to be thoroughly cleaned thus having the room be used incorrectly results in further cleaning needed and the room being unavailable.

Operating theatres are unique in the problem space since they are usually placed on a schedule that states the operation, operating surgeon, and anaesthesiologist. However, displaying this information, detecting whether the operating theatre is still being used from outside the room and whether it is being used correctly, still needs addressing. There are many items in operating theatres that need to be present like large electronic equipment such as the anaesthesia machine, surgical headlight and vital signs monitor as well as small utensils such as scalpels, scissors, and saws, to name a few. The requirements for which items are present are dependent on the surgery that is being performed in the room, with teardown and setup focusing on the provision and cleaning of these items (Avanteh, 2022).

Stakeholders

Nurses

Nurses cover a large range of duties in hospitals and are the largest group of stakeholders employed by hospitals. Their duties include caring for and assessing patients, recording medical information, providing interventions, treatments, therapies and administering medicine. A subset of nurses are midwives who provide health support during pregnancy, labour, birth, and the postnatal period. Nurses work together with doctors to provide healthcare to patients. Nurses in an operating theatre will often stay the duration of the surgery to help the Doctors perform their specialities (Department of Health and Aged Care, 2022).

Considerations

Psychological:

- May not be willing to adopt new technologies due to different computational skill levels among nurses
- Frequently over-worked with long shift hours and underpaid
- Dealing with life and death situations daily

Social:

- Different hospitals have different internal cultures
- May have a strong attachment to the hospital
- Has strong work relationships with doctors and other nurses

Physical:

- Have endurance from working all-day
- Often have hands full dealing with patients

Nurse Persona

Name: Fiona Grievous

Job: Registered Nurse at Hospital

Age: 26

Lifestyle: Single, Renting a single-bedroom apartment

Personality: Extroverted, Thinking, Intuitive, Perceiving

Goals:

- Save enough for a house deposit
- Be promoted to senior nurse (My Skills Future, 2022)
- Help as many people as possible during the shift
- Not experience avoidable loss of life due to incorrect action

Frustrations:

- Patients not following given instructions
- Being unable to find a nurse-ready patient room (Herriot, 2022)
    - Unclean rooms
    - Missing equipment and supplies
    - Inadequate space
- Doctors ignoring recommendations
- Unnecessary injury and death
- Paperwork

Background:

- Bachelor of Nursing at UQ for 3 years including a year of student nursing experience (UQ, 2022)
- Born and raised in Brisbane by 1st generation English immigrants and is of Anglo-western culture
- Working at the hospital for the past 3 years

Motivation:

- The loss of both sets of grandparents to treatable illnesses gives the motivation to help those who can be treated
- Lack of stability due to the rental market means continuing to perform acceptably at work to continue to save money for a house
- Wants her image and legacy to be that she was a person that always helped people

Doctor

There is a range of different doctors that are present in hospitals. Some of the Doctors that often use Operating Theatres include ER Doctors that are trained to quickly prevent obvious life-threatening complications; surgeons, who often specialise in heart, brain, and more, who perform surgeries; anaesthetists who specialise in using drugs to put people to sleep; and a range of other specialised medical Doctors depending on the operation. Doctors will usually perform their speciality and then leave the operating theatre to allow others to do their work.

Considerations

Psychological:

- May not be willing to adopt new technological systems that are implemented due to rigidly following a status quo
- Different computational skill levels amongst doctors
- Responsible for life and death situations that directly impact their career
- Often work at multiple hospitals so do not want to learn multiple different systems

Social:

- Specialists can be elitist due to a decade spent in higher education
- Multicultural groups due to immigration incentives
- Has strong work relationships with nurses, hospital managers and other Doctors

Physical:

- Usually have a steady hand as needed for performing surgery
- Hygienic

Doctor Persona

Name: Samantha Raiyat

Job: Heart Surgeon

Age: 47

Lifestyle: Married, 1 Kid, Owns 5 investment properties

Personality: Extroverted, Vain, Smart, Intuitive, Perceiving

Goals:

- Make the largest donation to a cancer charity out of her acquaintances
- Renew vows at 20th anniversary with medical staff invited
- Maintain a clean record of no preventable deaths during surgery
- Not cut any vital, veins, arteries, or organs during surgery

Frustrations:

- Nurses not following given instructions
- Operating theatre not being ready upon arrival
- Nurses and medical students not providing instruments during surgery
- Patients ignoring recommendations
- Interruptions during surgery
- Unintuitive hospital layouts

Background:

- Bachelor of Biomedical Science for 3 years at QUT
- Doctor of Medicine and resident Doctor for 5 years at UQ and Royal Brisbane
- Heart Surgeon Fellowship for 4 years
- Born and raised in Brisbane by 1st generation Indian immigrants and is of Indian culture
- Works at 4 different hospitals – 2 public, 2 private

Motivation:

- Must maintain a high social status due to the cultural pressure latent from the Indian caste system
- Underlying want of helping people in need
- Wants her image and legacy to be that of an affluent and impressive individual

Administration Staff

Administrative and clerical staff coordinate and facilitate patient care by scheduling appointments, answering phones, greeting patients, keeping medical records, handling medical billing and insurance forms, arranging for laboratory or other diagnostic services, and handling financial records. They allow Doctors and nurses to perform their duties without worrying about the majority of paperwork and bills (Denver Health, 2022).

Considerations

Psychological:

- Interact with existing booking system on daily basis and thus may be attached to existing system processes
- Different computational skills depending on the existing system
- May fear losing their job to automation and thus be uncooperative in handover

Social:

- Different hospitals have different internal cultures
- Most likely has a strong relationship with the nurses they interact with
- Customer-facing role requires being pleasant

Physical:

- May be disabled and unable to walk

Administrator Persona

Name: Fred Kaczynski

Job: Front-Desk Administrator at Hospital

Age: 54

Lifestyle: Divorced, Owns 2 Bedroom House

Personality: Introverted, Thinking, Intuitive, Perceiving

Goals:

- Save enough for retirement
- Improve the lives of those around him

Frustrations:

- Patients complaining about waiting times
- Patients attempting to access off-limit areas
- Keeping track of the bookings via a paper-based system
- Not being able to see what rooms are available at what times without physical checking

Background:

- Graduated Highschool and landed a desk job
- Worked at the hospital for the past 12 years

Motivation:

- Maintain the status-quo of life as time goes on
- Doesn’t care about a legacy, just that he makes himself and the people around him happier than they otherwise would have been
- Manager praise

Cleaning Staff

Cleaning staff at hospitals are responsible for the cleaning and organising of rooms and hallways. Operating theatre clean-ups require specialised equipment and PPE due to the presence of bodily fluids and biomaterial. Vacuuming, scrubbing, mopping, disinfecting, and disposing of waste are all part of the job. Cleaning staff work on operating theatres before the first patient, between patients and after the last patient (Mathenge & Prasad, 2022)

Psychological:

- May lack computational skills
- May have a routine that they desire to follow that if disturbed could impact IoT adoption

Social:

- Often isolated from other staff due to biohazardous nature of job thus often do not form relationships with those outside of cleaning staff
- Work done before and after hours adds to the isolation
- Multicultural group

Physical:

- Endurance from the physical demands of cleaning
- Exposure to harsh chemicals may impact health

Nurse Cleaner Persona

Name: Penny Smith

Job: Dedicated Nurse Cleaner

Age: 32

Lifestyle: Single Parent, 2 Children, Frugal

Personality: Introverted, Sensing, Feeling, Judging

Goals:

- Save enough for retirement
- Not experience avoidable loss of life due to incorrect action

Frustrations:

- Extremely dirty rooms
- Not knowing what has been soiled
- Not being able to see what rooms need cleaning without a physical check

Background:

- Worked at the hospital for the past 2 years
- Bachelor of Nursing for 5 years at QUT

Motivation:

- Maintain the status-quo of life as time goes on
- Nurse praise

Patients

Patients in hospitals are those in need of care. They may be suffering either long- or short-term injuries, diseases, or mental health problems. Patients have surgeries and operations performed on them in operating theatres. They are usually led from a waiting room to the theatre, anaesthetised, operated on, and then returned to the waiting room.

Psychological:

- May have mental health problems
- May have intellectual disabilities
- May be going through life and death surgery that could be emotionally distressing

Social:

- A varying range of social skills
- Usually have family or friends present for emotional support
- From all demographics

Physical:

- Often sick or injured and in need of medical intervention
- Going through a physically traumatic experience in the operating theatre

Hospital Managers

Hospital managers work with everyone at the hospital and oversee the general administration. Their central goals are to prioritize patient safety, as well as to ensure the financial and operational sustainability of the sites they manage. Hospital managers oversee the implementation of relevant medical and IT infrastructure and thus are the business sponsor in the scenario (George Washington University, 2022).

Psychological:

- IoT implementation results reflect on them so will be pressuring for an on-time and complete solution

Social:

- Interacts with most staff daily

Visitors

Hospital visitors are there to accompany patients. This may be because a patient is staying long-term at the hospital, needs help in everyday life, and needs transport or emotional support. Depending on the surgery and on the room, visitors may be able to enter the operating theatre for a small period before an operation or view the operation from a viewing area.

Psychological:

- Usually unfamiliar with hospital layout
- Disturbed while viewing surgery

Social:

- Will most likely be worried about the patient's health they are visiting

Physical:

- May be physically disabled

Worst Possible Ideas Brainstorming

CCTV & LiDAR

CCTV & LiDAR in every room and every hallway that is watched by a combination of security personnel and AI with all videos permanently stored in an external cloud for future learning without anyone's permission. This system can then identify individuals using facial recognition software by training on top of a purchased pre-trained model with biased data that exclude racial minorities and females. All video transmissions from cameras would also be streamed all the time, constantly, in 4K and unencrypted, with the hospital's Wi-Fi infrastructure being un-upgraded. The app connected to this solution would show all of the streams simultaneously. This would solve the problem space by allowing patients and staff to see whether a surgery room is occupied and for security to immediately know how each operating theatre is being used incorrectly.

Terrible because:

- Violates privacy and law by exposing critical health information, nude video, and body scans of patients without consent
- Lacks security by:
    - Transfers the data unsecured allowing MITM attacks and exposes the patient to blackmail and identity theft
    - Stores the information in a third-party server that isn't deleted meaning if that cloud provider were to have a data breach it would be exposed and is also costly
- Ethically unsound as it discriminates against women and minorities
- Will suffer from:
    - Poor performance due to the bad training set of the facial recognition
    - Using all the bandwidth of the hospital's existing Wi-Fi infrastructure from streaming the video constantly from all over the hospital makes the feeds unviewable
    - Is expensive due to CCTV cameras and cloud

Internal and External Health Monitors

Upon entrance to the hospital patients, visitors and staff are injected with a tracking capsule as well as multiple sensors all over the body that track vital signs such as heart rate, blood pressure, body temperature, oxygen, and CO_2, so that anytime during the hospital stay if the vital signs drop slightly, they can have immediate medical attention. As the location of all individuals is tracked, a cloud-based map can be used to monitor the health of all the people in each room, which will also be able to determine whether a room is being used, as well as whether it is being used properly. The application will display this map to everyone and include every other person's location, full name, and vital signs. Those who are about to die, as determined by cloud-based machine learning, and have functioning organs that could be donors will be able to be immediately identified.

Terrible because:

- Violates privacy and endangers patients by tracking all individuals and their personal health information and exposes it to those who do not have the consent of the individual
- Requires an invasive medical procedure to be performed
- Stores all information in a third-party server which is costly and requires strong network infrastructure
- Violates ethics by allowing organ harvesting to be prioritized over patient health

Occupant Observation Drones

Video capable drones would be used to track employees and quests of the hospital as they conducted business within the hospital. Collected video footage would be stored and processed in the cloud and mined for data to improve service delivery and effective space utilisation. Drones can be used to hospital announcements, updated appointment information, and deliver targeted advertising.

Terrible because:

- Small-scale drone technology has an insufficient energy efficiency
- Footage stored means the cloud is expensive
- Gross invasion of privacy for guests and employees
- Undermines trust in the health care system.

Auto-Clean

Install an 'auto clean' functionality into surgeries and theatre rooms for faster room turn around. When the room has been used and once no occupant has been detected after a certain period the room can trigger a self-cleaning cycle and can be cleaned with superheated steam, or UV light depending on the surfaces being cleaned.

Terrible because:

It's dangerous to automatically trigger a cleaning cycle as several issues could occur such as:

- Not all areas / surfaces being cleaned thourgly
- Presence detection could fail and could be triggerd whilst the room is in use which would be detrimental for any occupents inside

Remote Surgeries

Use Meta VR and robots to perform surgeries remotely from home freeing up space and making surgeries and theatres potentially smaller. Large robots instead of nurses and cleaning crew would perform the setup, teardown and cleaning, as well as interact with patients. Surgeons could also perform and monitor multiple surgeries at once to enable those with similar injuries to be addressed quicker.

Terrible because:

- It makes sensitive medical information available outside of the hospital, making the security of the solution dependent on each surgeon's setup as well as possibly exposing the medical information to others who are in the house.
- The current meta-VR does not have the fine motor skills capability to perform surgeries without injuring patients, making the solution dangerous
- Current large robots do not have sufficient cleaning nor service capabilities for those about to go into surgery
- Allows the surgeon to become distracted via in-house as well as dual surgery distractions.

Attributes of Good Solutions

- Allows anonymity of patients
- Safe
- Low bandwidth
- Low power-usage
- Cost Effective
- Non-invasive
- Quick to Implement
- Highly focused
- Doesn’t discriminate
- Secure
    - Doesn’t transfer sensitive data over unencrypted network streams
    - Doesn’t unnecessarily store patient information
    - Reduces usage of third parties

Final IoT Solution

Solution Explanation and Value to Stakeholders

The hospital will need to implement a tag system using RFIDs. RFID tags will be given to all doctors, nurses, cleaning staff and on patient beds which will grant room access specific to their role. All but the patient beds will have unique identifiers for security. Each operating theatre will have two accompanying RFID readers, one on the outside unit and one inside with the doors opening and closing based on the access level of the tag as well as whether the specific Doctor or nurse is meant to be attending. This, with the combination of smart locks, will decrease cleaning time for cleaning staff by reducing the misuse of the operating theatres after hours.

As the range of the RFID sensor can be 1m these can be used as “vicinity” tags with automatic door openers able to open to maintain the hygiene of all personnel and decrease the cleaning time of staff (RFID4u, 2022). Multiple radar sensors on the ceiling of the room will be able to track the location of those who are in the room, but not who they are. The combination of radar, RFID and a screen outside the room will be able to display whether the room is occupied from the outside, reducing unnecessary interruptions to surgery.

Operating theatres go through multiple stages: in use, needs cleaning, being cleaned and cleaned. This status and the next booking’s information will be displayed on a screen outside so that staff can make sure they are entering the correct operating theatre and signify to interlopers the theatre is off-limits. This will reduce cleaning and setup by allowing nurses and cleaners to identify which rooms need to be processed, as well as allowing those needing to find a spare room to find one quicker. Bookings will be made by administration staff who have a screen that shows the current bookings, as well as all current and future, estimated ‘cleaned room’ slots.

The millimetre wave radar, smart plugs and tool camera will be used to track room utilization. The large electronic items in operating rooms such as anaesthesia machines, surgical headlines and vital signs machines that are plugged in will use smart plugs to monitor the current wattage to determine whether the instruments are in use, as well as turn-off applicable devices to prevent any misuse outside of surgeries. This will be integrated with the door system to only allow the use of electrical equipment when the correct tag is used at the door.

A camera facing the utensil tray will be added to use image recognition to determine which small utensils are being used that cannot have an electronic usage sensor. This means that these items can be confirmed before surgery to make sure that the correct utensils are being used for the surgery that has been booked. The provides value by decreasing the setup time required by nurses as well as increase safety for patients, since if the wrong utensils are used it could severely injure the patient. After surgery has concluded the same utensil tray will need to be returned underneath the camera to track the presence of each utensil. This decreases the teardown for nurses as they only need to look for missing utensils and have administrators source replacement utensils quicker. It also improves safety for patients as nurses being able to immediately discover that a utensil has gone missing means that if it has been left inside a patient in can immediately be removed.

The millimetre radar data will be collated into heatmaps from which the locations of humans in the room can be derived by AI. This information will then be collated into an average overall heatmap for each surgery and each cleaning session. The surgery session heatmap will be made available to the cleaning staff to help them gauge how and where a room has been most used. This should improve cleaning quality and reduce cleaning time as cleaners will be able to focus on areas with heavy usage. The cleaning staff heatmap will be provided to hospital managers to evaluate the extent of the cleaner’s sanitation of each room. This improves safety as bacteria and viruses from previous surgeries could infect current patients, causing death. An average of the average heatmaps across surgeries can be provided to hospital managers to improve the ergonomics of rooms via identifying common room usage patterns for procedures and changing the room layout as needed.

Overall, the solution provides improved cleaning, improved room ergonomics, reduced interruptions, increased safety and decreased setup and teardown time.

Devices & Data

Devices	Characteristics	Components	Input	Output
Texas Instruments IWR6843AOP mmWave Radar (IWR6843AOP)	- Object detection up to 130m - Multiple radar sensors required for an accurate trajectory for 2D density/heatmap plot - Mounted on the ceiling - Needs to be soldered into the device hub (Texas Instruments, 2022)	- FMCW Transceiver - Arm microcontroller -SPI, UART, CAN-FD	-64Ghz mmWaves	-Stream of 10bit raw ADC signal -625 Kilo-samples per second
ARDUCAM IMX135 MIPI 13MP COLOR CAMERA (B0163)	-Small Camera -13 MP -FOV 60 Degrees with motorized focus lens -Needs mounting on lamp style arm over tray (IOT Store, 2022)	-Sony Exmor-R sensor -FPC Cable	-Standard image wavelength	-1080p RGB RAW10 Output -1 image before, 1 after surgery
Medium Range RFID Scanner (DOR9282)	-Reads RFID cards up to 1-5 metres customizable -High sensitivity -PoE interface -Relatively low powered -200 tags simultaneously (D.O RFID Group, 2022)	-RFID Reader -RFID Cards	-865-868/902-928 MHz Frequencies	-Time series stream of RFID Card IDs within range
Jetson Nano	-Small Powerful Computer for AI -Capable of processing and decoding images and signal data -Includes JetPack SDK with libraries for deep learning and computer vision (NVIDIA, 2022)	- NVIDIA GPU - ARM CPU - 4GB Memory - 16GB Storage - ports include HDMI, Ethernet, MIPI, USB, GPIO, SPI UART	-Image & Sensor Data -Pre-set ML algorithm	-Utensils detected list -2D Heatmap of room usage -Converts ADC to 256x256 RGB via ML Algorithms -1 frame per second
Delta-Advanced-HMI DOP-110WS	-Small colour screen with computer -Can be loaded with software -Water resistant (IP-65) -Needs power cable (TroPacific, 2022)	-Cortex-A8 CPU -10.1 Inch Screen -256MB ROM -USB, Ethernet & Com Port	-All high level information -Updates when update provided by server	-Displayed App
The Invisible Smart Lock	-Bluetooth connectivity -Can use Bluetooth module with the network hub to connect to network -Able to lock and unlock over network (Amazon, 2022a)	-Smart Deadbolt Lock	-Unlock and Lock Requests over network	-Unlocks and Locks Door
STANLEY M-Force™ Automatic Swing Door Opener	-Automatic swing door opener -Can integrate with electric locks and RFID -Able to be opened manually or automatically (Stanley Access, 2022)	-3/16HP DC Motor -Microprocessor controller - 315 MHz Wireless communication	-Open requests over network	-Opens door

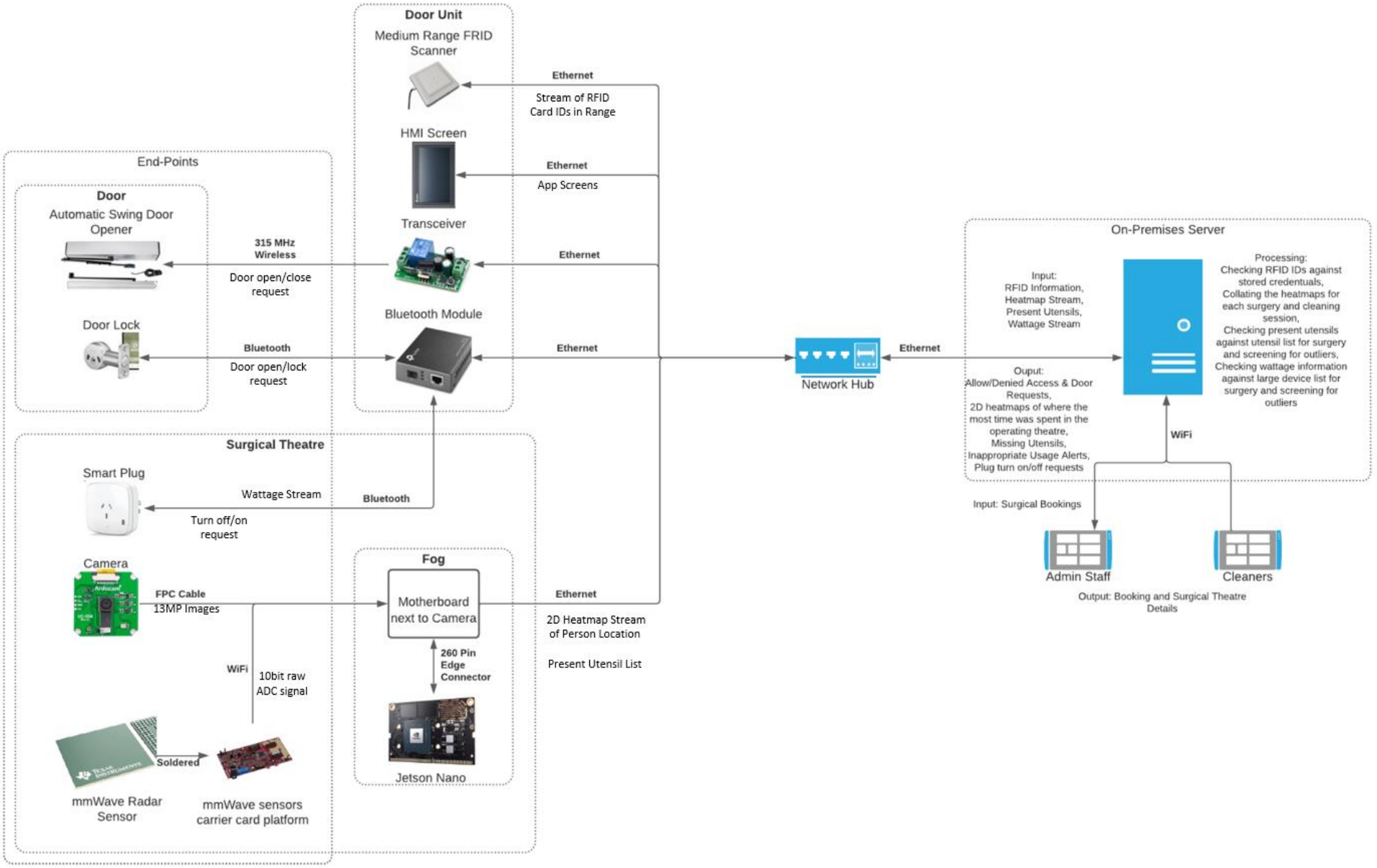
Eve Energy Smart Plug	-Smart plug that outputs energy usage in wattage -Can turn power off/on -Bluetooth connectivity (Amazon, 2022b)	-Smart plug	-Electricity	-Turns off and on -Stream of wattage information -Updates every second

Data Storage Considerations

- A relational database such as MySQL will be used for storing the accounts of the staff that the RFID cards will check against. A list of expected and missing items will be stored for each theatre, with it being updated when items are missing or there are additional needs. The booking system will also use the relational database.
- A timeseries database such as InfluxDB will be used to store the timeseries of heatmaps for each surgery and cleaning session. Once the session has been concluded, this data will be collated into a single image and stored, with the stream images (possibly 100mbs) deleted to save space.
- Wattage information will not be stored but analysed for outliers immediately with infractions stored in the timeseries database

Infrastructure Diagram

Ethernet has been chosen for the primary connection as it is a more reliable connection when compared to wireless counterparts. Ethernet also offers Power over Ethernet (PoE) which is capable of powering devices with up to 100 watts of power. Having separate networks for content delivery and the IoT system increase security.



Privacy & Security

Patient health information is the main concern as it is extremely sensitive information and protected by both ISO standards and law (ISO, 2022). Nurses and Doctors in the surgery and the administration staff who booked the operation are allowed to know both the patient and the operation they are undergoing. All other individuals must not be able to derive this information.

To protect this information access control measures will only allow those with the correct username and password, or RFID tag, to be shown the screen designated to them. However, if an RFID tag is stolen or the information on the screen shoulder surfed, the individual's privacy would be breached, as it would be if a surgery paper form was stolen, or shoulder surfed.

Patients have their location tracked by the radar in the room, but this does not violate their privacy as there is no identifiable information able to be directly derived nor what surgery is being conducted. The tracking of individuals within the hospital with tags could infringe on the privacy of those tracked but only staff are tracked with unique IDs, which isn't a breach of privacy as they are on the job and patients are given generic patient tags (Empeek, 2022).

The utensils and devices used data could allude to which medical procedure was being conducted. However, this information is not shown to other patients. With only missing utensils being displayed on the screen outside the room to nurses and inappropriate large device usage is reported to hospital admins (Chacko & Hayajneh, 2018).

The availability and integrity of the system are of paramount importance. A successful MITM attack, through the attack vector of manual ethernet intercept, could send requests to the smart plugs to turn off midway through surgery causing a denial of service of the electronic machines, most likely killing the patient. Standard Bluetooth key-based encryption, WPA2, 802.1X authentication for ethernet devices and SSL encryption will be used for all data, especially to and from the database, and when serving information to the app. There will also be a firewall on the network hubs and routers. This will also protect the location and tool utilization data as it is transported across the network. The system will not be using the cloud and is designed so that no patient data leaves the hospital premises, reducing the risk that 3rd parties accidentally leak the data, or it being intercepted over the internet. Having it be a mostly closed system only available over Wi-Fi means that the attack surface is small (Mehrtak et al., 2021).

A MITM attack, stolen administrator credentials through phishing emails, or malware could also display the incorrect information on a screen meaning a surgeon performs the incorrect surgery on a patient, again most likely killing the patient. To protect against phishing, anti-phishing add-ons to staff email portals on the administrator computers as well as router and device firewalls will be used. Malware can also be reduced by having all ports on the door screen and jetson nano disabled after installation and setup, and virus protection such as Malwarebytes installed on each staff device (Rapid7, 2022).

A denial-of-service attack could be launched against any networking device causing it to be unavailable, with a lack of information given to doctors and nurses interfering with operating theatre proceedings and making it unclear what the state of the room is. A malicious visitor who gains access to the theatre could unplug the smart plugs (availability) or point the utensil camera at the surgery (confidentiality) but both of these would immediately cause outlier data and would easily be detectable (Cassetto, 2022).

RFID tags are the largest security risk for this system as they transmit data unencrypted. A malicious actor with an RFID reader could gather the transmitted unique IDs and spoof the RFID to gain access to rooms or sign out doctors and nurses without them knowing (IoT Agenda, 2022). This would cause some disruption but would not be life-threatening as the radar would still pick up that there are people in the room and thus would not shut off electronic medical devices immediately. The door system will also communicate with the server preventing local overrides. If the server for bookings and access control was breached then Doctors could be removed from bookings and would be denied access, causing fatal injury to those in life-threatening situations (Fernández-Caramés et al., 2017). Power outages could also disrupt the system.

Cost Breakdown

Cost Per Operating Theatre:

Area	Item	Specific	Price
Surgical Theatre	Radar	Texas Instruments IWR6843AOP mmWave Radar x 4	$30 * 4
		MMWAVEICBOOST mmWave sensors carrier card platform x 4 (Texas Instruments, 2022)	$200 * 4
	Camera	ARDUCAM IMX135 MIPI 13MP COLOR CAMERA (B0163)	$109
	Fog	Jetson Nano	$99
		Motherboard (Spark Fun, 2022) (Only Price Reference)	$110
	Smart Plug	Eve Energy Smart Plug	$55
Door	Door Lock	Level Bolt, The Invisible Smart Lock	$270
	Automatic Swing Door Opener	STANLEY M-Force™ Automatic Swing Door Opener	$500
Door Unit	RFID Scanner	Medium Range RFID Scanner (DOR9282)	$1500
	HMI Screen	Delta-Advanced-HMI DOP-110WS	$1,341
	Transceiver	315MHZ Channel Wireless RF Transmitter Receiver Relay (Aliexpress, 2022)	$3
	Bluetooth Module	Anybus Wireless Bridge - Ethernet - Bluetooth (Anybus, 2022)	$50
Total:			$4,957.00

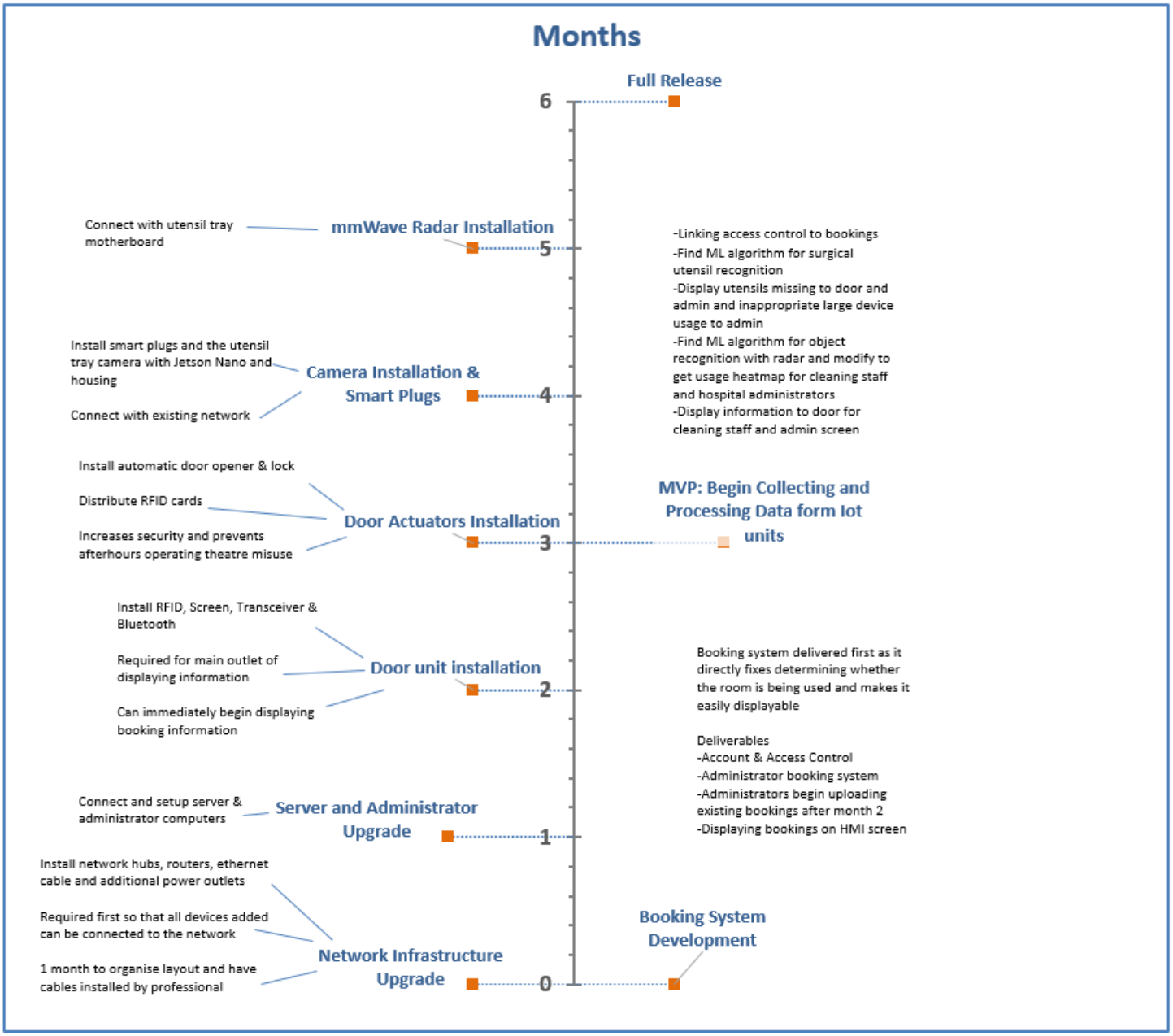
Entire Solution Costs

Connections	Cables	Ethernet Cable Category 6 U-UTP Blue 305M (MSS Data, 2022)	$77
	Network Hubs	S5860-24XB-U, 24-Port Ethernet L3 PoE++ Switch (FS, 2022)	$6,077
	Routers	(Umart, 2022)	$179 * 10
Delivery	Server	ThinkSystem SR530 (Lenovo, 2022)	$6,718
	Computers	ASUS M3400 23.8" Ryzen 5 8GB 512GB Win10 Pro All-in-One PC * 10 (Scorptec, 2022)	$1299 * 10
	Staff RFID Cards	(Advanced Group, 2022)	$200
Wages	Installation	1 Casual Network Technician for 6 months (SEEK, 2022)	85000 * (0.5)
	Developers	4 Developers for 6 Months (indeed, 2022)	$78,000 * 4 * (0.5)
Total:			$226,352

Existing administrators will manage the system. Ongoing costs only include extra electricity usage and device repairs. Assuming there are five operating theatres the solution will cost $246,180.

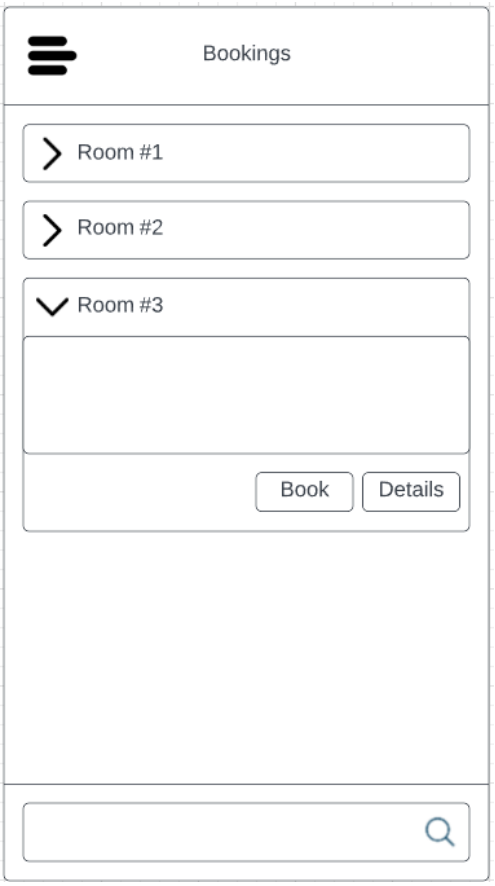
Pilot Timeline

This timeline assumes that the hospital has no network infrastructure and that their previous booking methods are paper-based. It also assumes that operating theatres need to continue to stay in use and thus only small periods would be available for hardware installation, extending the period over which it is installed.



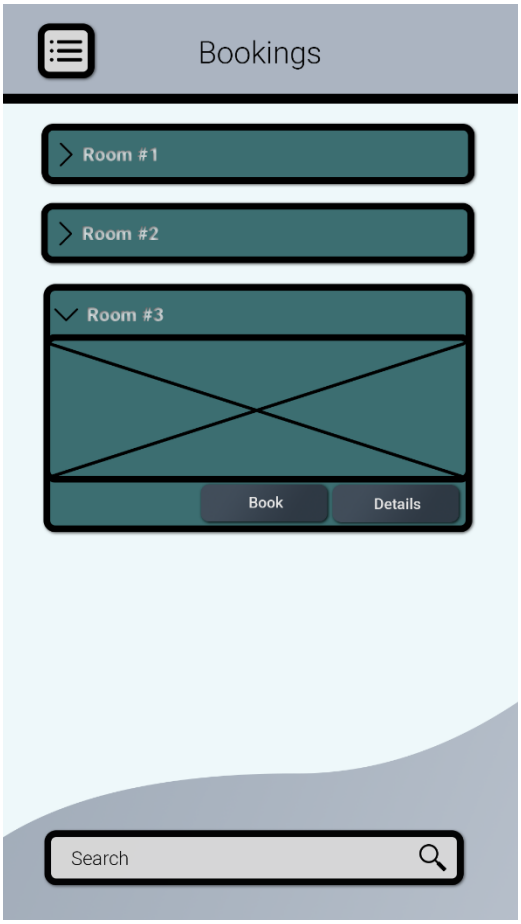
Screens

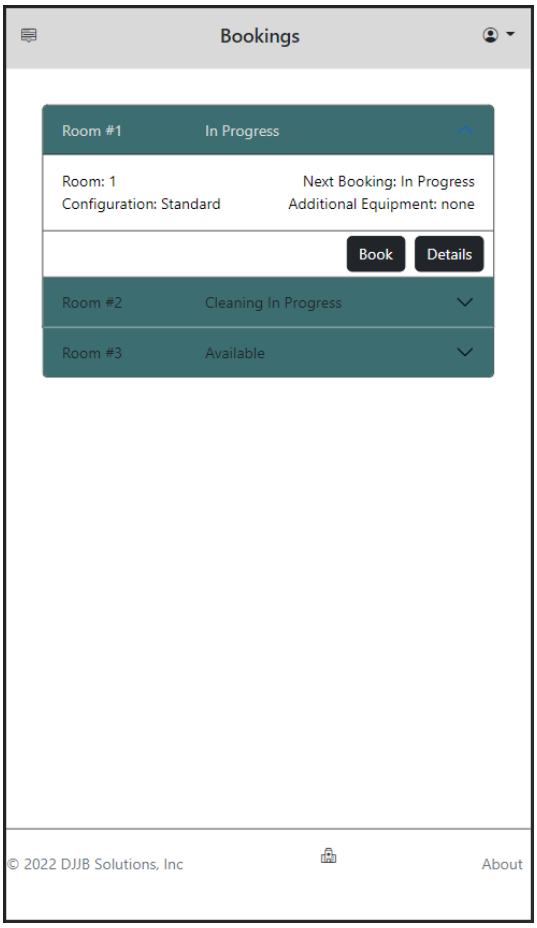
There are multiple avenues which the information is displayed depending on the user and their access level. The main avenue for information will be the door unit screen which will show current booking and status. Administrators will need a booking screen to make the operating theatre bookings. Cleaners will need a cleaning screen to see room utilisation patterns. Finally, hospital managers need a statistics screen to view overall theatre statistics and cleaning performance. Based on feedback and group discussions changes were made in the eveolution from low fidelity to high, most noticeable is the remove on the search bar in most of the pages. These were removed as it was unclear what a user would be searching for in these various contexts.



Bookings

The bookings screen shows a list of within the hospital with more detailed information available if needed. Controls are also available view greater room details or to book the room.

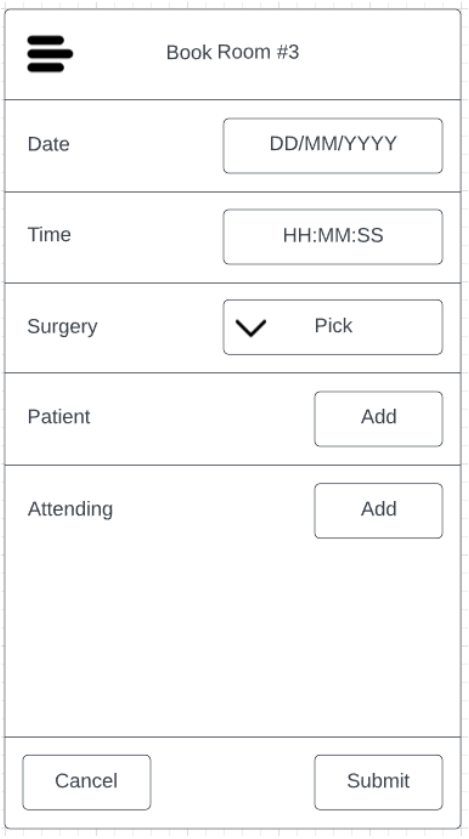


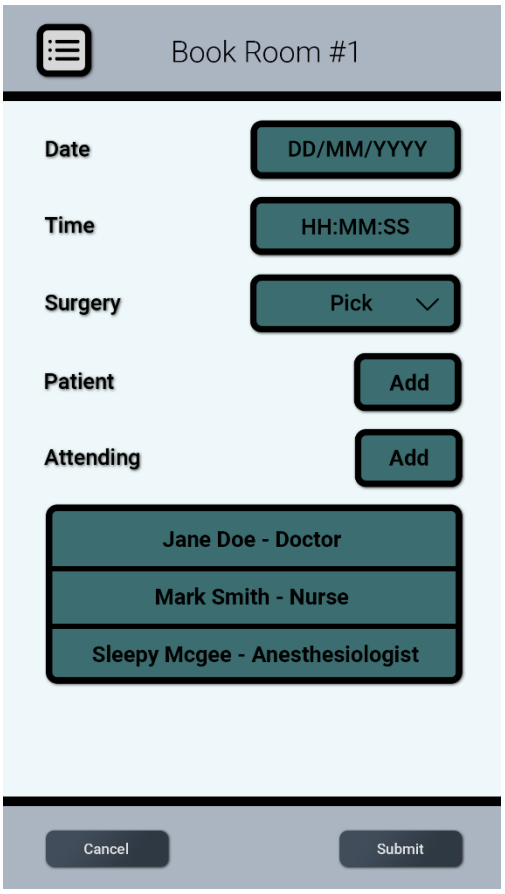


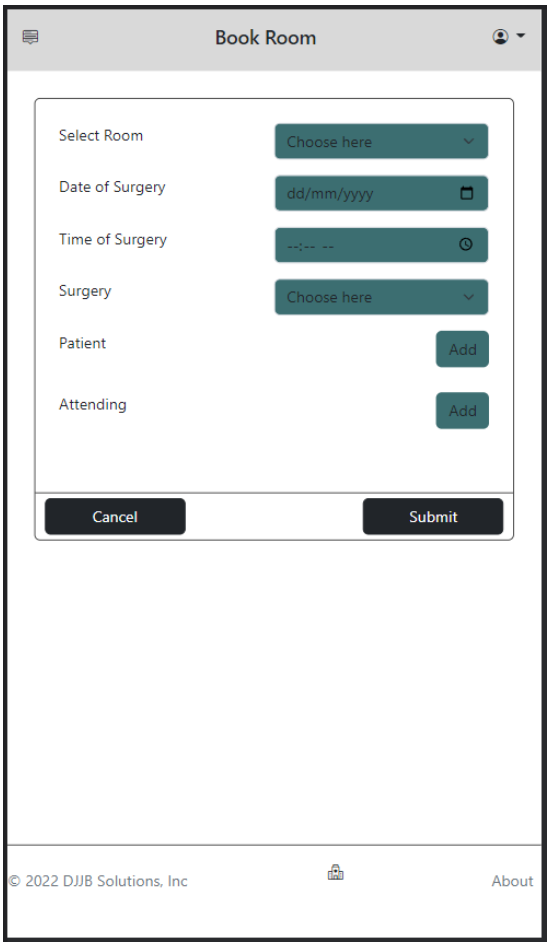
Book Room

The book room page is a standard form control with inputs for standard form controls like date, time and selection.

This form was not modified as feedback was positive through all rounds.



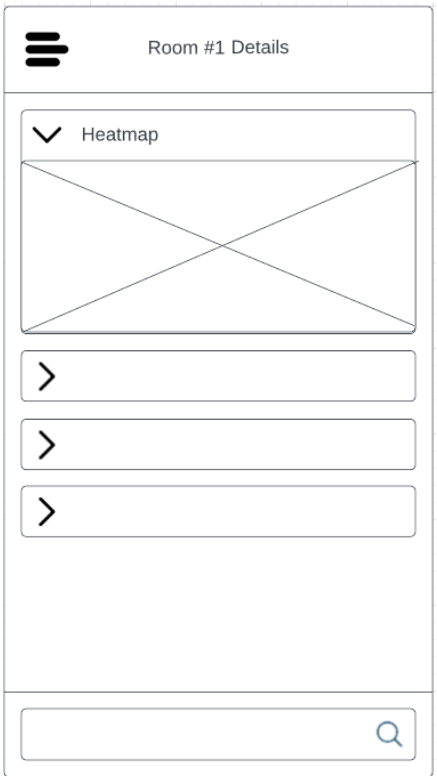


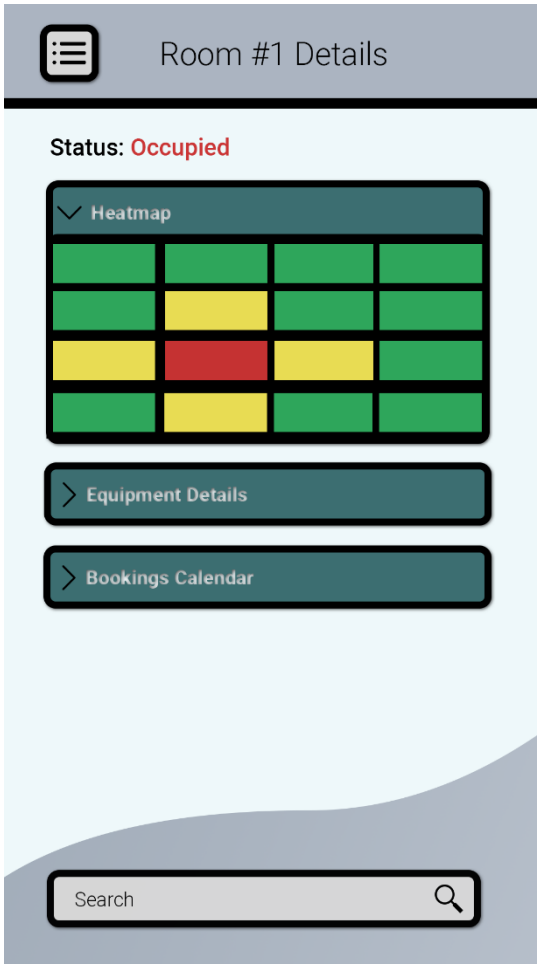


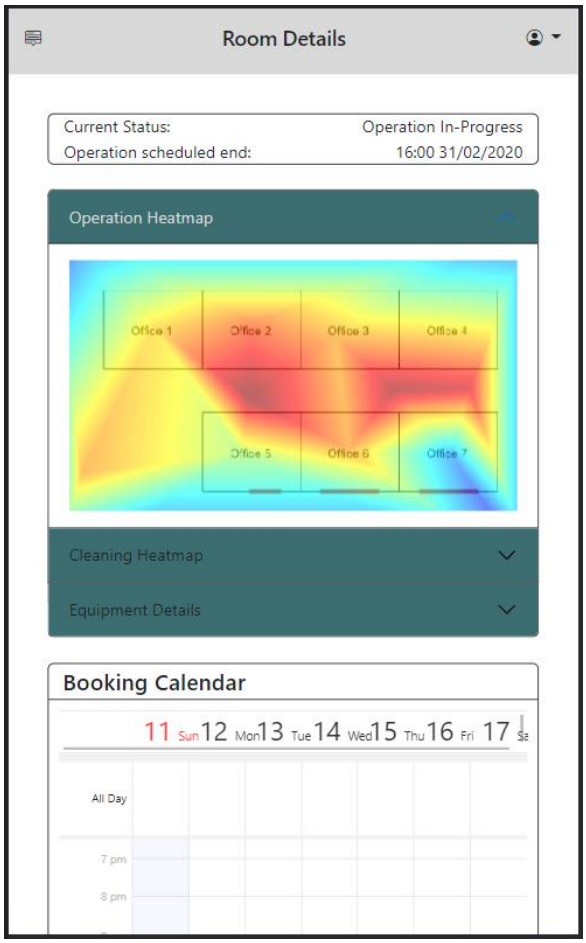
Room Details

The Room details page provides different room specific information to each role such as the operation heatmaps for cleaners and cleaning heatmap for managers.

A booking calendar is display out side of site standard accordians due to feeback indicating a desire to have immediate access to the most valuable information relating to specific rooms.



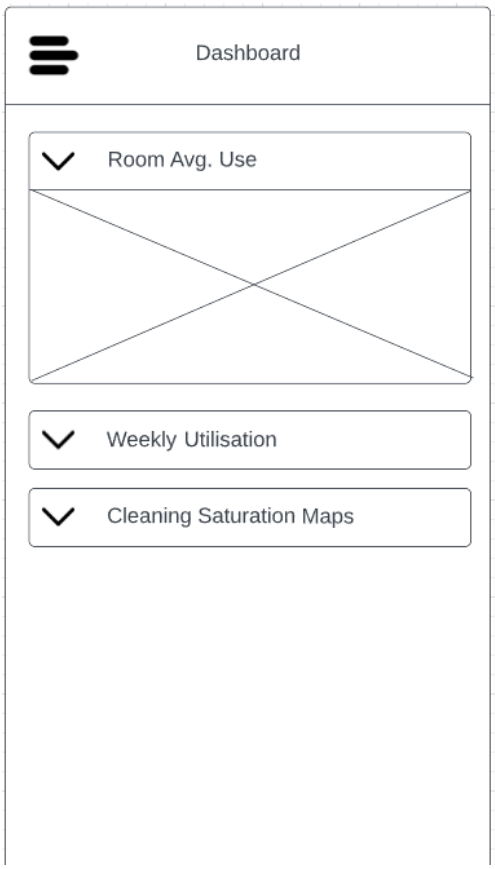


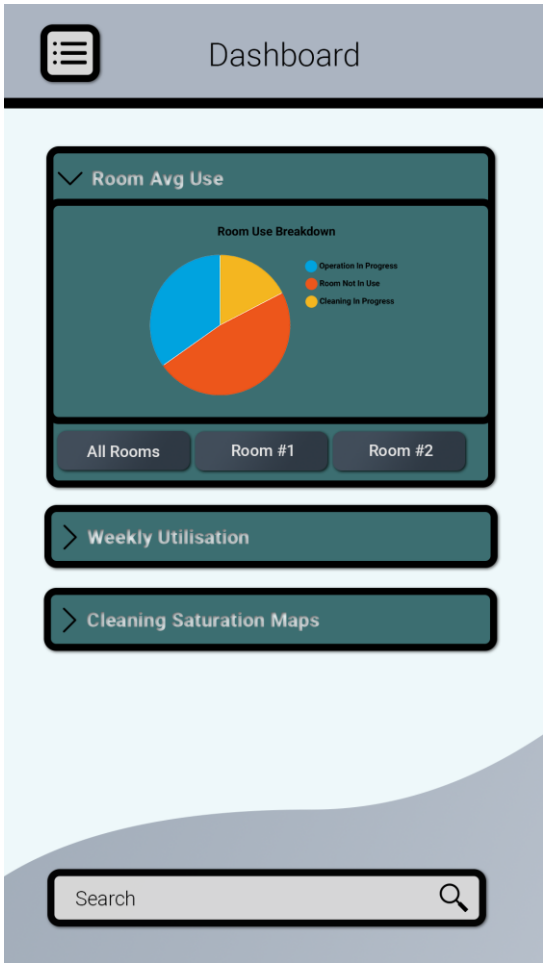


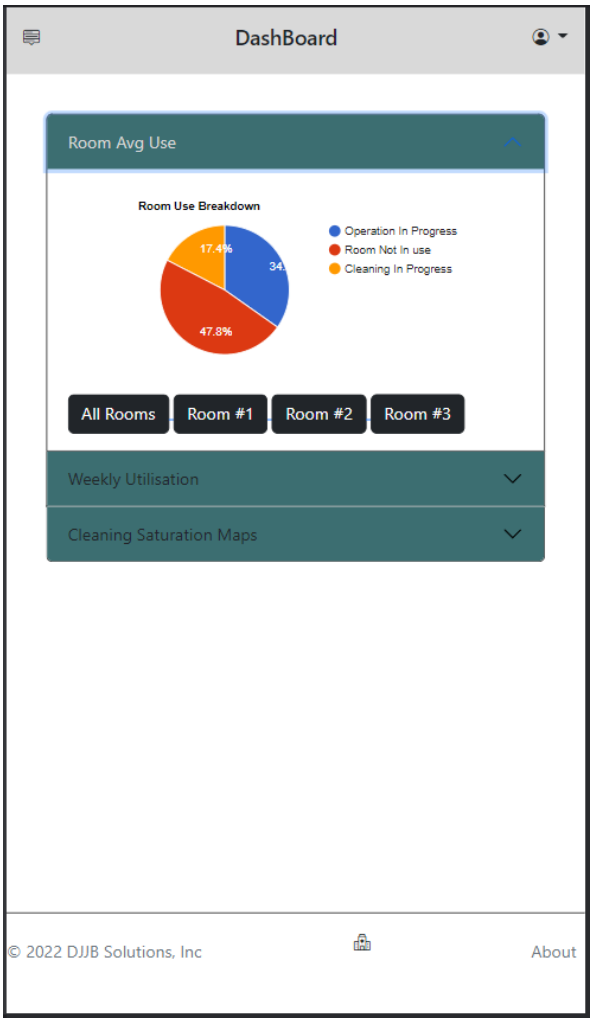
Statistics

The Dashboard page provides access to data collected and collated by the system such as

- Average surgery time
- Average cleaning time
- Average down time
- Weekly throughput
- Missing item list
- (Review Cleaning of the Room via heatmap)







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