Designing Digital Health Prototypes for Ibn Sina Hospital

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Designing Digital Health Prototypes for Ibn Sina Hospital

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Abstract

This project focused on the implementation of digital technologies in the Moroccan healthcare sector. It sought to assist the International University of Rabat in identifying and examining the role of digital health technologies and developing prototypes for the Ibn Sina Hospital in Rabat. UIR's newly founded Faculty of Medicine and new university hospital center was the inspiration behind the collaboration with this project. Two prototypes were developed for the surgical and sterilization departments at Ibn Sina Hospital to improve efficiency and streamline data flow processes. The prototypes consisted of a data flow system for the surgical management staff to aid in the analysis of surgical trends and a barcode inventory tracking system for the sterilization department to prevent lost or misplaced surgical instruments. Overall, the project presented specific technological solutions that can be further developed and implemented within other hospitals and health centers in Morocco, promoting a sustainable trajectory in the country's healthcare sector.

Executive Summary

In lower and middle income countries, healthcare systems are facing the challenge of utilizing digital technologies to their fullest potential. Morocco is considered a developing, low-income nation due to its low gross domestic product (GDP). While the quality of healthcare treatment delivered to Moroccan citizens is adequate, increasing access to healthcare resources has been an ongoing initiative within the country. Although the rural-urban divide in healthcare access is decreasing, introducing digital technologies may help accelerate the closing of this gap. Morocco's Ministry of Health has already begun including digital technology into its healthcare system by implementing a 2025 Digital Healthcare Plan. With the rapid innovation and implementation of digitization across the world as a result of the Covid-19 pandemic, there has been increased recognition of the potential for digital solutions to improve the ways healthcare is administered. A Covid-19 vaccine and exposure application, an appointment scheduling platform, and telemedicine have been widely implemented across Morocco, improving the access and quality of healthcare.

The rapid socio-economic growth of Morocco and need for digital infrastructure demonstrates the unsustainable trajectory of current healthcare practices. Despite the significant advances being made in the healthcare sector, there are some areas that could benefit from digitization; such as in creating a centralized, nation-wide electronic health record to simplify the process of transferring and accessing medical documents. The opportunity to integrate technology remains abundant and would be beneficial in many areas of the Moroccan healthcare sector. The Faculty of Medicine at The International University of Rabat (UIR), located in the capital of Morocco, is working on digital innovations to increase access and quality of digital health resources for the Moroccan public. The motivation for this project is to suggest modern digital solutions that could be implemented within UIR's newly constructed University Hospital Center to be completed in 2024. Through UIR and our sponsor, Dr. Ouassim Karrakchou, we were able to conduct a case study for digital technologies at the Ibn Sina Hospital, the largest public hospital in Morocco. Through interviews with the hospital's healthcare workers, we examined the current presence of digital technologies, developed an understanding of how processes could be improved, and then designed two prototypes for the surgical and sterilization departments. These prototypes aimed to alleviate ongoing efficiency concerns, such as helping to locate lost and misplaced instruments and to streamline data flow processes. These digital solutions could be further expanded and implemented within other hospitals and health centers in Morocco. The scope of our project allowed us to identify specific technological solutions that could be further developed by NGOs, private organizations,

or PhD students.

The project consisted of two phases:

1. Identifying possible digital health solutions for Ibn Sina Hospital.
2. Designing prototype(s) for Ibn Sina's surgical and sterilization departments.

Following our discussions with the key informants in phase one, we were able to identify two types of digital solutions that would be beneficial to Ibn Sina's surgical and sterilization departments. These solutions consisted of:

1. A data flow system for the surgical management staff to aid in the analysis of surgical trends.
2. A barcode inventory tracking system for the sterilization department to prevent lost or misplaced surgical instruments.

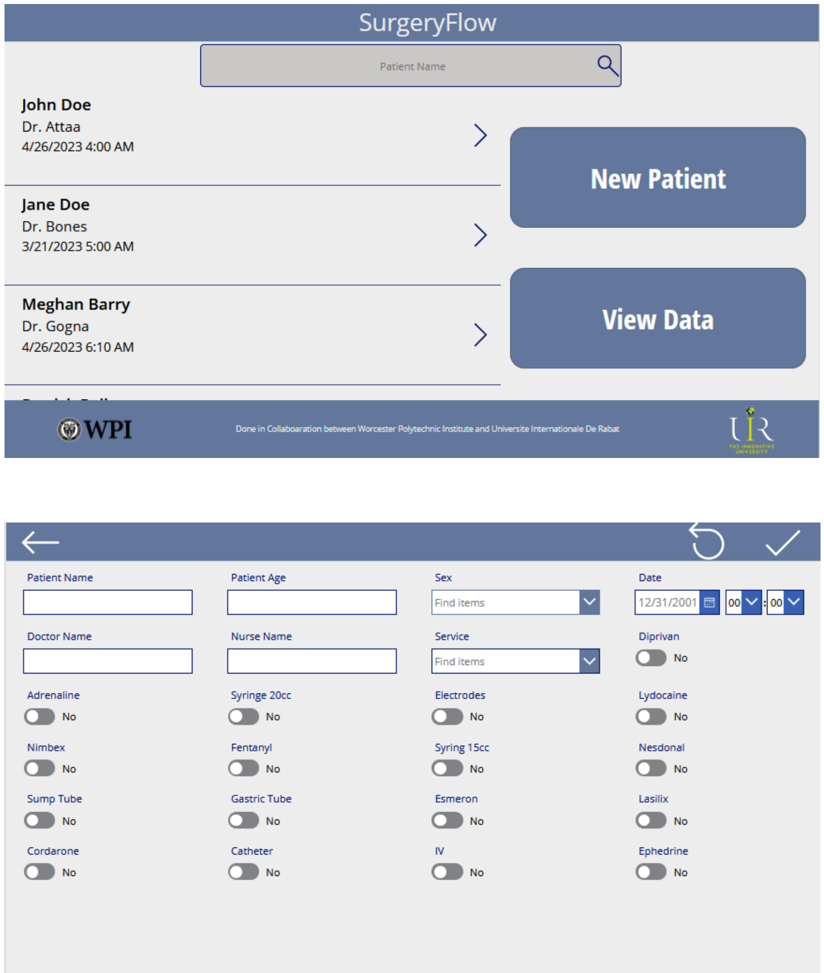
Deliverable 1: Surgical Analytics Data Flow

To begin the prototyping phase of the design process for the surgical analytics data flow, we first defined the design criteria, including: transferability, automation, exportation, and ease of use. The system must be **transferable** between users such as from the nurse or anesthesiologist to the operation room, this would **save time** and eliminate waste. The system should be **compatible with Excel** and the input fields need to be **exportable**, and in order to bypass manual input, the system should **automatically** populate the data into Excel as the forms are completed. For this system to be beneficial, the users need to see it as a more efficient solution, so the process should be **user friendly and easy** to use.

The system we decided to design in order to meet these criteria was a desktop application that would:

1. Contain electronic forms that mimic the paper ones
2. Automatically export data to Excel for analytics
3. Generate weekly, monthly, and annual reports for the department

The prototype built in PowerApps opens on a home screen where all filled out surgery forms can be seen and searched for based on patient names or date. Clicking on one the forms in the list shows all information that was imputed into that form and there is the option to edit the form from here which updates the corresponding data in the SharePoint list. Going back to the home screen, there is also an option to fill out a new form. The new form gets automatically added into the SharePoint list and organizes the data into the correct columns.



Figures 1 & 2. Home screen of the Surgery Flow app and a blank form created by the website. All patient forms are visible on the left hand side. The New patient button creates a new form to fill out as well and the View Data button launches the raw SharePoint. Data filled out in the blank form gets automatically added to the SharePoint list ready to be exported to excel.

The SharePoint list is updated every time a form is filled out and data can either be edited through PowerApps or directly in the list if necessary. The SharePoint list can then be exported to an Excel file with a single button press. Surgery staff will be able to collect and analyze all surgeries in a month or even in a year and keep track of inventory used without having to manually input data after every surgery which will save time and reduce errors.

Ibn Sina has options when implementing a surgery form system. Many softwares already exists with the ability to create forms that are saved into an Excel file when submitted. However, softwares like these often require a monthly or yearly fee to use depending on how many of the software features the user wishes to have access to. A more economical solution in the long term would be to create the software custom for the hospital. We were able to successfully create an app with the full functionality needed in a relatively short amount of time and with minimal technical expertise, so it is very feasible given the hospital's increased resources. Another advantage to this path would be that the software could be designed and integrated with the other hospital softwares in mind such as the custom platform that the hospital has already designed and integrated with GreenCube. This would allow it to be fully compatible and to be customized to the hospital's needs.

Deliverable 2: SmartScan Prototype

To begin the prototyping phase of the design process for the barcode inventory system, we first defined the design criteria. This included sterilizability, minimal contact, barcode scannability, a database, and logistics. To satisfy the needs of the department, these design criteria were an essential component to the prototype. The system must be **sterilizable** due to hospital standards and have **minimal contact** to avoid cross contamination. For instruments to be identifiable the system must be able to **scan barcodes** with unique identifiers for each tool. In order to track the sterilization process for each instrument, the system must have a **database** which logs all instrument **logistics** such as time, location, and its unique identifier. Time and location are important in determining when and where each instrument is throughout the sterilization process and the unique identifier for each instrument ensures all instruments are accounted for before and after they are used in surgery.

The system that we decided to design in order to meet these criteria consisted of three main components:

1. A way to engrave surgical equipment with identifying barcodes
2. A sterilizable platform that allows for contactless scan of instruments
3. A scanning application that scans barcodes and uploads to a database

Figure 3. Square piece of stainless steel metal with a laser engraved barcode for demonstration purposes.

To satisfy the instrument component of the prototype and to demonstrate the ability to scan engraved barcodes, we used a square piece of stainless steel metal and were able to laser engrave a unique barcode (**Appendix D**) at a local metal workshop in Rabat (**Figure 3**). The unique barcodes used for this prototype were generated using an online barcode generator called Cognex. Although we were not able to obtain actual medical instruments from the Ibn Sina hospital for demonstration purposes, this sample barcode shows the readability of the engraved data on metal.

Figure 4. Completed SmartScan platform constructed of plexiglass

To allow for contactless scanning we designed a **sterilizable platform** on which a device with the scanning application can sit. Our design was a bracket shaped box with three open sides, which allows for instruments to be passed underneath the scanner without touching the device. The top part of the bracket was designed to be large enough to hold an iPad and the camera hole large enough for an iPhone so the platform can satisfy a wide range of devices. It consisted of four components which were separately modeled in SolidWorks and then assembled together. The platform has a sliding mechanism that uses bolts and nuts which allows the height of the bracket to be adjusted depending on the size of the item being scanned. After modeling we utilized resources at the UIR technical center to build the physical prototype out of plexiglass.

Lastly, the SmartScan application was designed using Microsoft PowerApps to scan barcodes and upload information to the database. The application starts on a login page where the user chooses their login destination: admin or scanner. Upon choosing, the user can then perform different actions; on the admin side scans can be viewed and either approved or declined. On the scanner view, barcodes can be scanned and appended to a SharePoint List as well as a local Data Gallery.

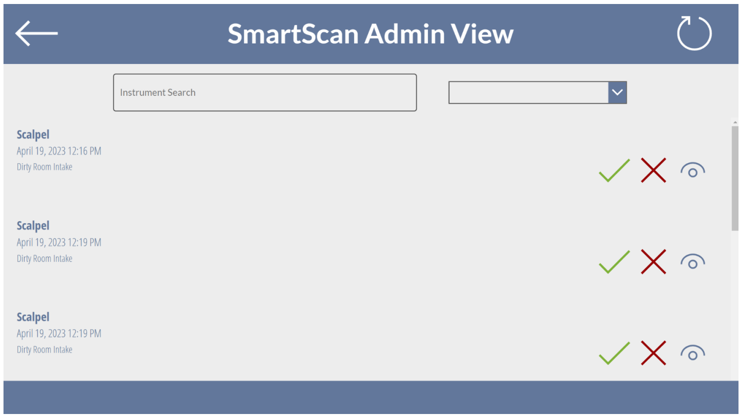


Figure 5. SmartScan Admin View. In the Admin View, the data gallery is synced with the 'Tracking Data' SharePoint List that is patched when an instrument is scanned, therefore it can be updated when a new item is added to the list.

On the admin view shown in **Figure 5**, the Data gallery has the SharePoint List 'Tracking Data' as its source as real time functionality is limited in PowerApps, adding a dynamic list bypasses that hurdle allowing it to be seen on multiple devices as the data is stored on the cloud rather than locally.

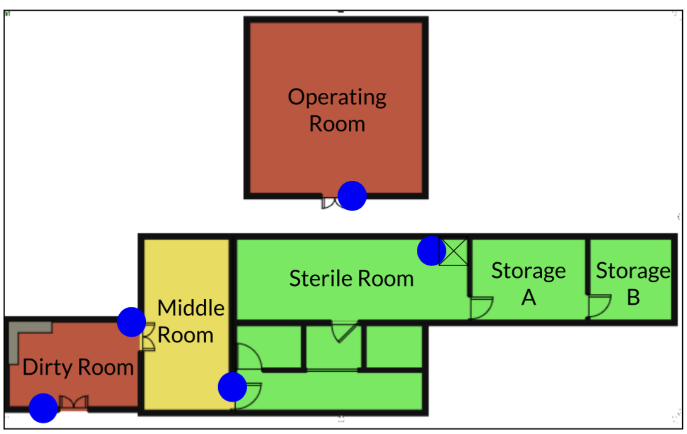


Figure 6. The layout of the sterilization area containing adapted checkpoints (blue).

Using the information gathered in phase one we were able to identify checkpoints that would allow for the best tracking of instruments, these checkpoints can be seen in Figure 6. Five scanners would be placed at the entrance and exit of each room that equipment is passed through. The sterilization technicians would complete the entire process as normal, but scan each instrument as it travels from room to room. When recommending our solution to the sizable scale of a hospital like Ibn Sina, our prototype would not be sufficient to fulfill the needs of the hospital. The idea of the SmartScan prototype is to showcase the thought process and ideas about how such a solution would be implemented. This prototype also served as a deliverable to our sponsor and our contacts at Ibn Sina hospital. Luckily there are existing companies that have engineered our envisioned solution to fit the needs of hospitals all over the world.

This project reveals that the implementation of digital technology has been shown to improve quality of care in the healthcare sector through the reduction of errors and the increase in efficiency that computers and the internet provides. The current motivation from the Moroccan Ministry of Health demonstrates the drive for overall improvement in the healthcare sector, this motivation begins with transformation of the public healthcare system. The purpose of this project was to aid the International University of Rabat in identifying and examining the role of digital health technologies and to develop prototypes for the Ibn Sina Hospital, with the vision that it will act as a catalyst for more digital technology in Moroccan healthcare.

The application of digital technologies in healthcare is a broad topic with endless opportunities that aim to improve the quality of care and facilitate current processes. The growing potential for developing countries to obtain digital technologies remains abundant and with the aid of governmental initiatives a future of more comprehensive healthcare is promising. With this potential in mind there is space for future research in the field of healthcare technologies which can be carried out by future WPI projects, especially in developing nations where the need for technological solutions remains present.

“There are no incurable diseases, only the lack of will. There are no worthless herbs, only the lack of knowledge” - Ibn Sina

Table of Contents

Chapter 1: Introduction 1
Chapter 2: Background 3
2.1 The International University of Rabat 3
2.2 Digital Healthcare in Developing Economies 3
2.3 The Potential for Digital Healthcare in Morocco 6
2.3.1 Access to Equitable Healthcare Resources in Morocco 6
2.3.2 Digital Infrastructure in Morocco 8
2.3.3 Medical Education and Training in Morocco 9
2.3.4 Underlying Factors of Moroccan Healthcare 9
2.3.5 General Access to Internet and Digital Services 10
2.4 Recent Innovations in Moroccan Healthcare 10
2.4.1 Telemedicine Infrastructure 11
2.4.2 Electronic Health Records 12
2.4.3 Governmental Health Initiatives in Morocco 12
2.4.4 Future Opportunities 13
2.5 The Ibn Sina Hospital 14
Chapter 3: Preliminary Investigation 16
3.1 Identifying Digital Health Solutions for Ibn Sina Hospital 16
Chapter 4: Surgical Analytics Data Flow 18
4.1 Current Surgical Record Keeping 18
4.2 Envisioned Automated System 18
4.3 Designing a Surgical Analytics Data Flow 19
4.4 SurgeryFlow Prototype 19
4.5 Conclusion and Recommendations 21
Chapter 5: Sterilization Inventory Tracking 23
5.1 Existing Sterilization Process 23
5.2 Envisioned Sterilization Solution 24
5.3 Designing a Barcode Inventory Tracking System 25

5.4 SmartScan Prototype 27
5.4.1 Instrument Engraving 27
5.4.2 SmartScan Platform 28
5.4.3 SmartScan Application 28
5.5 Conclusions and Recommendations 31
Chapter 6: Final Conclusions 34
Bibliography 35
Appendices 38
Appendix A: Interview Consent Form in English and French 38
Appendix B: Department Interviews in English and French 40
Appendix C: Demonstration Tool barcodes 42
Appendix D: SmartScan Code And SharePoint Lists 43
Appendix E: Surgery Dataflow list 46

List of Figures

Figure 1. Distance rural and urban patients travel (Boutayeb., 2016). 4

Figure 2. Illiteracy rates between men and women in rural and urban areas. 7

Figure 3. Map of technologies that fall under digital healthcare. 13

Figure 4. Rendering of the new Ibn Sina Hospital to open in 2026. 15

Figure 5. SurgeryFlow- Home screen. 20

Figure 6. SurgeryFlow- Form data screen. 20

Figure 7. Surgery Flow- Empty form screen. 21

Figure 8. Surgery Flow- Completed form screen. 21

Figure 9. Surgical instrument travel cycle. 23

Figure 10. Surgical instrument travel cycle with adapted checkpoints. 24

Figure 11. Block diagram of SmartScan modules. 26

Figure 12. SolidWorks design for the SmartScan device platform. 26

Figure 13. Example of a surgical instrument engraved with a unique identifying code. 27

Figure 14. Square piece of stainless steel with barcode. 27

Figure 15. Laser cutter machine used to cut out pieces of the platform. 28

Figure 16. Photo of the completed SmartScan platform constructed of plexiglass. 28

Figure 17. Photo of the completed SmartScan platform constructed of plexiglass. 28

Figure 18. SmartScan- Login homescreen. 29

Figure 19. SmartScan- Admin login screen. 29

Figure 20. SmartScan- Sterilization checkpoint login screen. 29

Figure 21. SmartScan- Admin view screen. 30

Figure 22. SmartScan- Sterilization checkpoint view screen. 30

Figure 23. SmartScan- Coding block flow diagram. 31

Figure 24. Map of sterilization area. 31

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4.4 SurgeryFlow Prototype	Zachary Gogna	All

4.5 Conclusion and Recommendations	Zachary Gogna	All
Chapter 5: Sterilization Inventory Tracking	Meghan Barry	All
5.1 Existing Sterilization Process	Helga Becka	All
5.2 Envisioned Sterilization Solution	Helga Becka & Meghan Barry	All
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Chapter 1: Introduction

Digital healthcare, also known as eHealth, refers to the use of digital technologies to improve the delivery of healthcare services. It has demonstrated the potential to transform healthcare by providing more efficient and effective services to patients, improving communication between providers and patients, increasing access to treatment, and advancing the quality of care (WHO, 2021). The Covid-19 pandemic, which greatly reduced face-to-face care worldwide, accelerated the implementation of digital solutions to deliver comprehensive and accessible treatment. Digital health solutions include virtual care, remote monitoring, artificial intelligence assisted diagnosis, and applications of *Internet of Things (IoT)*, such as smart wearables and radio frequency identification chips (*RFID)*. These technologies create a continuum of care with proven potential to enhance health outcomes by improving medical diagnosis, data-driven treatment decisions, digital therapeutics, clinical trials, and self-management of care as well as creating more evidence-based knowledge, skills, and competence for professionals to support healthcare (WHO, 2021).

In lower and middle income countries, healthcare systems continue to face the challenge of utilizing digital technologies to their fullest potential. Morocco is considered a developing, low-income nation due to its low gross domestic product (GDP) (Fourtassi, 2020). While the quality of healthcare treatment delivered to Moroccan citizens is adequate, increasing access to healthcare resources has been an ongoing initiative within the country (Roder-DeWan et al., 2019). Although the rural-urban divide in healthcare access is decreasing, introducing digital technologies may help accelerate the closing of this gap. An additional stress on the country's healthcare system is the low human resources index of 1.65 health staff per 1000 persons, which is 3.5 times lower than the WHO threshold (Fourtassi, 2020). Incorporating more digital technology within Morocco's health sector may help to alleviate this stress and make processes more efficient by utilizing valuable digital resources.

Morocco's Ministry of Health (MMoH) has already begun including digital technology into its healthcare system by implementing a 2025 Digital Healthcare Plan. With the rapid innovation and implementation of digitization across the world as a result of the Covid-19 pandemic, there has been increased recognition of the potential for digital solutions and infrastructures to improve the ways healthcare is administered. A Covid-19 vaccine and exposure application, an appointment scheduling platform, and telemedicine have been widely implemented across the country, improving the access and quality of healthcare.

The rapid socio-economic growth of Morocco and need for digital infrastructure demonstrates the unsustainable trajectory of current healthcare practices. Despite the significant advances being made in the healthcare sector, there are some areas that could benefit from digitization; such as converting to a centralized, nation-wide electronic health record to simplify the process of transferring and accessing medical documents. The opportunity to integrate technology remains abundant and would be beneficial in many areas of the Moroccan healthcare sector.

The Faculty of Medicine at The International University of Rabat (UIR), located in the capital of Morocco, is working on digital innovations to increase access and quality of digital health resources for the Moroccan public. Through UIR and our sponsor, Dr. Ouassim Karrakchou, we were able to work with Ibn Sina Hospital, the largest public hospital in Morocco. Through interviews with healthcare workers at the Ibn Sina hospital, we examined the current presence of digital technologies, developed an understanding of how processes could be improved, and then designed two prototypes for the surgical and sterilization departments. We use a design oriented report structure, in which we dedicate individual chapters for the sterilization and surgical departments where we discuss our design approach, the results, and our conclusions for each solution. These prototypes aimed to alleviate ongoing concerns of efficiency, such as helping to locate lost instruments and to streamline data flow processes. These digital solutions could be further expanded and implemented within other hospitals and health centers in Morocco to benefit various departments and stakeholders.

Chapter 2: Background

This chapter provides an overview of the existing Moroccan healthcare system and the role that digital healthcare technologies could have in the near future. First, we provide an overview of our sponsor, the International University of Rabat, and of Dr. Ouassim Karrakchou who is directly supervising this project. We begin our discussion by taking a closer look at digital healthcare on a global scale, examining how it's evolving and what it means for developing countries like Morocco. Although Morocco is making strides in constructing new healthcare initiatives, there are still some challenges to overcome before digital healthcare can be integrated fully. Some of the factors we discuss are access to the internet, equitable healthcare resources, and the training of healthcare professionals. We then examine potential solutions for integrating healthcare technologies within the Ibn Sina Hospital. With a focus on improving efficiency, we aim to provide insights and recommendations that could serve as a model for other healthcare institutions in Morocco and beyond.

2.1 The International University of Rabat

The International University of Rabat (UIR) is a private university of more than 5,500 students that was opened in 2010. It has four main colleges spread over a 30 hectare campus; the College of Engineering and Architecture, College of Management, College of Humanities, and College of Health. The UIR's mission statement is "to produce and transmit knowledge and values for future societies." The vision of UIR is to be a world class African university and to achieve this, they focus on a "strong international dimension, with an exposure to the world's most prestigious universities." Our main contact, Dr. Ouassim Karrakchou, recently joined the University as an assistant professor in September of 2022. He received his PhD from the School of Electrical and Computer Engineering at the University of Ottawa and his Masters Degree in Telecommunications Engineering from the Institut National des Sciences Appliquées de Lyon (INSA Lyon), France. Dr. Karrakchou has conducted notable research in the field of internet architecture, information-centric networks, software-defined networking as well as cloud computing structure.

2.2 Digital Healthcare in Developing Economies

Over the last decades, developing economies such as those of North Africa have made noticeable progress improving certain socioeconomic and health indicators such as life expectancy, literacy, per capita income, and access to healthcare (Boutayeb et al., 2011). The advances in the healthcare sector have been significant and there is an ongoing effort that aims for further development of healthcare services in these developing countries. Still, much can be done toward overcoming healthcare disparities between various socioeconomic groups. Healthcare inequities are prominent between urban and rural areas and differing economic groups.

Many times, access to healthcare in rural areas becomes challenging due to the distance necessary to reach healthcare facilities, the insufficient number of beds, or shortage of medical personnel. People with lower incomes face these types of disparities, while richer populations have easier access to healthcare services (Boutayeb et al., 2011). Similarly, healthcare in Morocco varies widely depending on location. Considering that more than 30% of rural dwellers have to travel at least 10 kilometers to the nearest health center, there are prevalent healthcare disparities present among the rural and urban populations of Morocco (**Figure 1**).

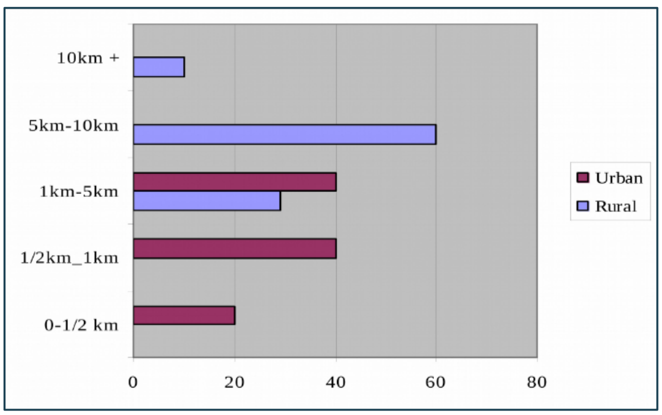


Figure 1. The distance rural and urban patients travel to reach the nearest health facility (Boutayeb., 2016).

Since the internet was made public in the early nineties in Morocco, everyday citizens have had access to a variety of online information including information on health topics (Ossebaard, 2016). Digital health solutions open the opportunity for self-care, management, and participation of the patient in their personal health. Considering the access of public information, the range of health information and education has the power to reach a substantial portion of the population.

Digital healthcare technologies use information and communication technology or ICT (Al Kuwaiti, 2018). ICT includes:

- Electronic health records
- Telemedicine visits, messaging
- Web based analysis
- AI assisted software

- Remote monitoring sensors

The adoption of these tools offers the potential to improve the quality of care delivered to patients while also increasing patient-centered medical ideology. In 2020, the World Health Organization adopted the WHO Global Strategy on Digital Health, which strives to connect the latest breakthroughs in innovation and digital health (World Health Organization, 2021). An integral part of this global strategy is to be supportive of equitable and universal access to quality health services.

The vision of connected healthcare extends beyond digitalized patient records and telemedicine; it aims to add an interconnected human perspective on patients' health. Personal health technologies are beginning to play a larger role in the lives of millions and integrated personal health and wellbeing applications are making their way into users' personal healthcare treatments. The availability of new technology like personal health devices, which could be evolved to collect data such as blood glucose levels or cardiac monitoring (Rghioui, 2018). Sensors and wearable technology can be deployed within clinical settings to allow for the remote tracking of a patient's condition and the transmission of data to providers in real time. The use of digital health technologies in this way would promote a long term and sustainable trajectory for healthcare sectors focused on preventative care and population health rather than chronically ill patients.

In 2019, the Coronavirus pandemic abruptly shifted the delivery of healthcare treatment to patients worldwide. As doctor visits were postponed and elective and less urgent treatments were canceled, the world of face-to-face medical care was greatly reduced. The pandemic greatly accelerated the acceptance and incorporation of these new technological tools and, although they already existed, they had not been used as purposefully, rapidly, and with such intentionality (Shah, 2020). One of the main advances that was made available in many countries as a means to avoid in-person consultations and still receive proper medical attention was telemedicine. Telemedicine provides services such as telehealth and e-visits, which are beneficial even in the post-COVID era due to their practicality, efficiency, and cost-effectiveness (Shah, 2020). Providing continuous training for the medical personnel is necessary in order to be up-to-date with the most current advances of telemedicine and other digital solutions.

Alongside the development of telemedicine, fostering the creation of electronic health record (EHR) systems is something that developed countries have been able to implement (Serbanati, 2011). The situation in developing countries regarding EHR systems is somewhat different; even though there is a continuous effort for the implementation of EHR systems, there are still many regions where challenges persist.

Although digital health holds the power to revolutionize care across the world, its success is limited due to complications in the implementation process. Implementation of EHRs often fails due to the lack of consideration for socio-economic factors, who the main users are, and accessibility of the new system (Ossebaard, 2016). When making dramatic shifts in healthcare systems that have been present for decades, such important considerations must be made to increase the sustainability and success of the technology.

There has been continuous progress in implementing digital health systems in developing countries, especially after the COVID-19 pandemic reemphasized the need for digital solutions. Platforms such as telemedicine and mobile health have been widely adopted in these countries in the last three years; however, there are still some major obstacles that prevent the effective implementation of digital health solutions in remote locations such as insufficient digital infrastructure, insufficient funding, high cost of telecommunication systems, etc. (Fagherazzi et al., 2020).

2.3 The Potential for Digital Healthcare in Morocco

Morocco boasts a developing healthcare system that is evolving to fit the needs of the Moroccan public by increasing its digital infrastructure, funding, and addressing current limitations. In general, Moroccan healthcare is provided via public health centers at roughly 150 hospitals across the entire country with only around 12,000 healthcare providers. Separate from these hospitals there are five main university hospitals used for training new physicians and are located in Marrakesh, Fes, Oujda, Rabat, and Casablanca.

When it comes to the private sector, there are around 360 private clinics, however, these are mostly concentrated in the Rabat-Sale-Kenitra and Casablanca-Settat regions, the more urban areas of Morocco (Brown et al., 2019). This disparity has caused several accessibility issues for the citizens living in rural areas; 30% of the population has to travel over 10 km to the nearest healthcare facility. Another issue that arises from the rural-urban division is the partitioning of the healthcare staff, which is skewed heavily towards the more urban areas (Boutayeb, 2006).

2.3.1 Access to Equitable Healthcare Resources in Morocco

While social and health conditions in North African countries have been substantially improved over the last few decades, these improvements have not always been equally shared between all socioeconomic groups. However, progress is being made; from 1980 to 2010 Morocco achieved a 61% increase in the human development index (Boutayeb, 2011). While there has been a push to increase literacy, there is still a large imbalance in literacy rates among different groups in Morocco. Particularly this appears in the difference between rural and urban as well as between male and female populations (Figure 2). A study done in 1999 found that urban literacy was twice that of rural areas and a rich urban male was found to be 7.4 times more likely to be literate than a poor rural female, showcasing just how big of a differential is at play (Boutayeb, 2011).

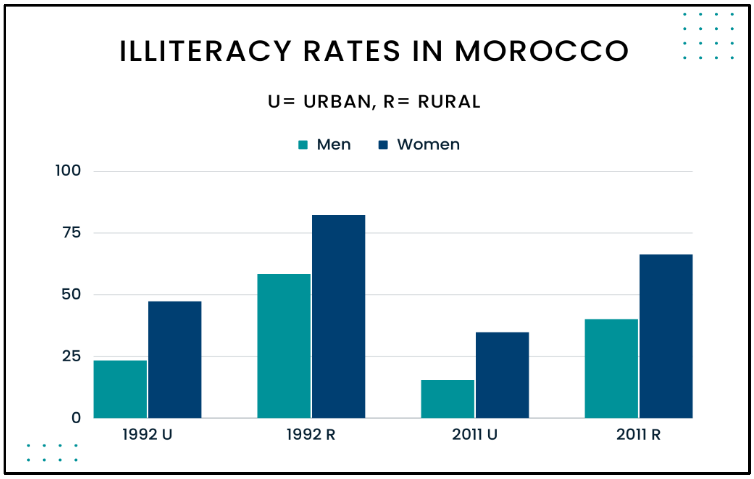


Figure 2. Illiteracy rates between men and women in rural and urban areas

In more recent years these figures have seen a dramatic shift. The literacy rate among the adult population has increased to 71.71% as reported by UNESCO and the government has begun focusing specifically on raising female literacy rates. Their efforts have already begun to pay off as it was reported by the High Commission for Planning that female literacy was at 53.9% in 2019 up from 39.6% in 2004. The relevance of literacy rates among the population correlates to the human development index, which indicates the achievements in three key social factors: standard of living, education, and healthcare (WHO, 2023). The increase of the HDI within Morocco over the last decade, shows that progressive initiatives are making a difference in the accessibility of public resources to the population.

The number of inhabitants per physician is 6,362 in rural areas such as Taounate compared to 380 in Rabat, and the number of beds in public hospitals per 100,000 inhabitants is 31 in the rural area of Berkane, and 444 in Rabat. These statistics show the existing inequity of available resources among various demographics. Fortunately, the government of Morocco is aware of these inequalities and has outlined plans to improve this in the "HEALTH 2025 PLAN" published by the Ministry of Health. In this document, they outline the plan to increase the number of beds and encourage more health professionals to work in rural health centers. In 2022, the Moroccan Government allocated and spent $2.4 billion for the healthcare sector, and they are set to increase that to a budget of $2.6 billion, a roughly $400 million budget increase (Brown, 2019).

Despite awareness of the issue of inequality in Morocco and the government being committed to making changes, there are still challenges that remain. Many solutions are still in the planning or outlining phase and haven't been implemented. One example of this is that the MMoH proposed legislation in 2015 for new graduates to work in underserved areas for two years, but the law was very unpopular with healthcare workers and ended up being discarded.

2.3.2 Digital Infrastructure in Morocco

The COVID-19 pandemic has allowed Morocco to focus on its digital infrastructure especially in the healthcare field. The wide expanse in deployment of these devices was remarkable and important in helping navigate the pandemic. Morocco continues to pursue Sustainable Development Goal Three (SDG3) of ensuring healthy lives and promoting well-being of its government initiatives. One example was the setup of controlled systems to mitigate the COVID-19 crisis, which included the development of a vaccination passport. This passport was accessible and showed the vaccinations a person had received. This implementation has been possible due to the efforts of expanding internet access to the majority of the country with wide access to 3G, and 4G cellular networking, as well as the capability of its national grid to provide stable electricity to the entire country (Bennacer, 2022).

The Moroccan government has increased the funding of its Ministry of Health (MoH) and has been working towards a digital transformation. Currently only 35% of basic public services are accessible online. Predating the pandemic, the MoH started implementing an online appointment system that enables people to make doctors' appointments, get health advice and minimize waiting time. With the Covid-19 crisis and the measures taken to handle it, the Ministry adopted a citizen-centric strategy and communicated with the public on a daily basis through the Ministry's social media accounts. Furthermore, a patient-centric strategy was also launched that introduced a digital platform allowing for a remote Covid-19 self-diagnosis making the treatment process reactive and efficient.

Three months after the first case of Covid, the MoH presented the tracking app "Wiqaytna", which notified users in case of contact with positive Covid-19 cases. The app was popular at the beginning but several social media users started warning people against the app due to misunderstanding of the way it works or believing it would give the Moroccan government access to users' personal data. According to several news articles, the Moroccan National Commission for the Protection of Personal Data Protection (CNDP) received over 1,500 complaints and made an announcement clarifying there were no data privacy issues and that the application does not store personal information. This incident illustrates some of the issues within the Moroccan civic culture and a pervasive distrust of the government (Nachit, 2020).

2.3.3 Medical Education and Training in Morocco

Medical education in Morocco, while good, is struggling due to staffing shortages and inconsistent requirements for teacher qualification. There have been some changes and reforms proposed to the medical education system in Morocco so that students can gain a more nuanced education and hands-on experience in the medical field. One particular concern is the lack of adequate training for medical teachers. Every specialist can apply to become an assistant professor after passing a recruiting exam, but there is no requirement for training as medical educators, nor mandatory programs of faculty development. To overcome this problem, many faculties started a university diploma on medical pedagogy for their teaching staff but enrolment is not mandatory, nor financed by the institution, which is a real limiting factor. It has been established that medical education cannot improve in quality without adequately trained teachers and without regular assessment to track and correct inadequacies (Fourtassi, 2020, Shah, 2020).

2.3.4 Underlying Factors of Moroccan Healthcare

The annual population growth rate in Morocco has decreased from 2.2% to 1.2% between 1970-2018, at the same time the prevalence of chronic illnesses has increased the demand for healthcare that meets population's needs. These healthcare demands were met 70% by the public hospitals run by the MoH, and the rest was by a relatively expensive private sector that can only be afforded by a small subset of Moroccan citizens living in the main urban areas (Fourtassi, 2020).

The distance that has to be traveled to receive healthcare is a concern for those living in more rural areas where 30% need to travel a distance of at least 10 kilometers to reach their nearest health center and in general 42% of the population has to travel more than one hour to reach the nearest healthcare center. It was also noted that only 62% of the Moroccan population is granted health insurance: covering employees, low-income individuals, and students in higher education (Fourtassi, 2020).

Morocco suffers from a lack of human resources as it has a health staff concentration of 1.65 per 1000 persons, which is roughly 3.5 lower than the minimum threshold according to the WHO (4.45 per 1000). This can be attributed to Morocco's low healthcare expenditure per GDP of 5.8% that is below average for both WHO countries and OECD countries at 6.8% and 8.9% respectively. Recently, however, Morocco's healthcare expenditure allocation has been increasing. In 2022 the allocated budget to the healthcare sector in general was $2.4 billion and has been increased by $400 million for 2023 to meet National Health Plan 25 (Fourtassi, 2020; Brown, 2021).

2.3.5 General Access to Internet and Digital Services

Digital health implementation is usually harder in developing countries due to several factors including but not limited to:

- Lack of ICT infrastructure
- Stable electric power supply
- Logistic and cultural issues
- Lack of efficient data collection resources

Morocco on the other hand does not struggle with many of these issues for a few reasons. Widespread digital and information infrastructure is important and available in Morocco; as it has extensive fiber optic, 3G, 4G, and ongoing 5G deployment. Electricity is stable and extends to most of the country including some of the most rural and remote areas. Recently, a digital development agency (ADD) was created and tasked with accelerating and mitigating the transformation to digital transcription of public services (El Otmani Dehbi., 2021).

This digital shift is necessary for Morocco to achieve its goals. The strength of the existing IT-infrastructure promotes the establishment of information systems in public hospitals and electronic medical records, which are essential nowadays with increasing value and improved quality of global healthcare.

A final point that must be considered concerns preserving individual data privacy, the expanded usage of digital health data requires a higher level of data security and proper handling of personal health information. Although the security structure needs to be re-evaluated by government authorities, an interesting test of data privacy is the use of blockchain based vaccine passport with two access levels for general users (the public) and admins (doctors and the government). Telemedicine is also a major component of the MoH Digital Development Strategy 2025, which focuses on the implementation of assisted living technologies to aid those with chronic illnesses and improve their overall Quality of Life (Bennacer, 2022).

2.4 Recent Innovations in Moroccan Healthcare

Morocco has made advancements in healthcare in recent years, but there are still areas that need improvement, especially when it comes to providing equal access to quality healthcare in urban and rural areas. The national government, particularly the Ministry of Health, and private non-profit organizations are exploring the use of technology in healthcare to improve public healthcare. One particular problem of the past, which is being addressed, is the disparity in healthcare quality between different socioeconomic groups and between rural and urban inhabitants. The technologies discussed below can perhaps address some of these issues.

2.4.1 Telemedicine Infrastructure

Telemedicine is one promising application of technology in the healthcare field. Telemedicine aims to overcome barriers specific to Morocco such as:

- Inadequate roads /transportation
- Language barriers
- Limited healthcare staff

However, there are other limitations that can still affect implementation, such as limited funding, the range of internet access, general bureaucracy, and cultural differences in the acceptability of medicine. A lack of standardization and interoperability between different digital health systems, and a lack of digital infrastructure and technological expertise in some parts of the country has held back development (El Otmani Dehbi 2021). Despite this, some big initiatives have been done in the telemedicine space such as when the MoH launched a free medical "tele-advice" digital platform (www.tbib24.com) in which doctors representing all medical specialties participated during the COVID lockdown for the benefit of the public (El Otmani Dehbi 2021). Likewise, in 2005 the Faculty of Medicine in Casablanca launched its Medical Informatics Laboratory with the objective of promoting research and developing quality in the field of biomedical data processing and health, improving research methodology in medical informatics application, and integrating new technologies into medical education and biostatistics (Bennani et al, 2012).

While most of the progress made so far is in testing and theorizing about proposed frameworks and is far from a real implementation, the work being done is the essential first step that can point to what challenges are most pressing and how best to build an effective telemedicine Infrastructure specific to Morocco. And it has been determined that in order for a proposed telemedicine framework to function, there needs to be government assistance specifically from the Agence Nationale de Réglementations des Télécommunications or ANRT, which is in charge of issuing laws on Telecommunications at the national level (Bennani et al, 2012). Getting the support of the major telecom operators in the country to fund pilot operations and getting industrial computer manufacturers to make the hardware is crucial. Additionally, using government aid to promote telemedicine in academics has proven to be very important. Of course, this research has been extremely crucial since it has begun the conversation of the benefits of this tech in the sectors that are most necessary to ensure its success and with this groundwork Morocco can begin to build actual services that will immeasurably benefit the general population.

2.4.2 Electronic Health Records

Individual public medical centers are also making progress on their own to improve their services with digital solutions. The implementation of electronic health records (EHRs) is mostly happening in university medical centers, which are the largest and most advanced public healthcare centers in Morocco (Parks 2019).

The five main challenges of implementing EHRs:

1. Selection of an EHR service
2. Weak bargaining power when buying the technology
3. Lack of interoperability standards
4. Insufficient human and financial resources
5. Missed cooperation and collaboration opportunities (Parks 2019)

Despite the inefficient adoption of EHRs, they have been able to help institutions transition away from the use of paper documents, thus speeding up patient wait times and allowing for more comprehensive care. Since there are studies that point out mistakes made by previous individual implementations, the integration of new systems can be done much quicker and more efficiently avoiding the mistakes made previously.

2.4.3 Governmental Health Initiatives in Morocco

Despite the many challenges facing Morocco's healthcare sector, the government is committed to making improvements and implementing new laws and plans. Data protection has seen much improvement in healthcare. For example, the Morocco Ministry of Health (MOH), and Commission for the Protection of Personal Data Protection (CNDP) have signed a contract agreement in 2021 to support the healthcare sector's compliance with protecting personal medical data (Bennacer 2022). The goal of this contract is to protect the privacy of individuals by dividing those who can access and verify medical data into two parts, authorized and unauthorized entities, to ensure personal information privacy. This policy has already been used specifically with COVID-19 in the tracking of vaccine information for citizens. The personal data protection act (09-08 act) protects individuals' privacy through limiting the disclosure and use of personal and sensitive data by the data controllers in any data processing operation (Mounia 2015).

The Ministry of Health also put out a plan to improve healthcare in Morocco by 2025. In it, they divided the plan into 3 pillars, which were in turn broken into 25 axes made up of 125 individual actions. The three pillars were to organize and develop the supply of care in order to improve access to health services, strengthen national programs for health and the fight against diseases, improve governance and optimize the allocation and use of resources.

2.4.4 Future Opportunities

Further improvement of the healthcare sector can build upon existing digital solutions after developing them within the context of a hospital department. Digital healthcare solutions extend beyond the e-health record and encompasses technologies such as portable vaccine passports, medication-event monitoring systems (Yang et al, 2022), adherence monitoring, radio frequency identification or RFID chips, remote patient monitoring, and wearable technologies.

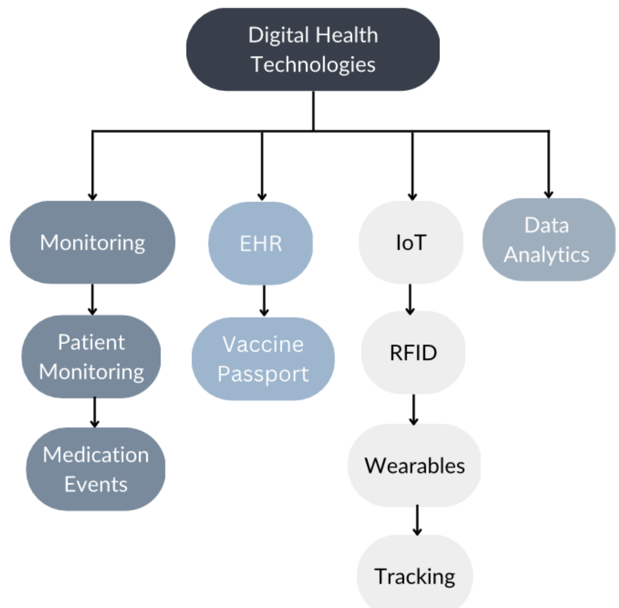


Figure 3. Map of technologies that fall under digital healthcare

One possible solution could be to build upon the covid-19 vaccine passport that has already been implemented across Morocco, and develop it further to include other vaccines, allergies, blood type, diseases, known conditions, etc. This would make all important health information readily accessible for any emergency.

In Morocco, smart pill boxes were created with a medication-event monitoring system (MEMS) to track patient adherence to tuberculosis treatment (Yang et al., 2022). This technology could be extended to track adherence of other treatments or even daily medication, especially for patients prone to forgetfulness.

Another possible solution that can be assessed and then potentially implemented within hospital departments is the use of RFID chips, as they are relatively inexpensive and could be used for various purposes. For instance, the chips can be placed in medical instruments to ensure proper sterilization. This solution could be implemented within surgical departments to track the sterilization process of the medical equipment.

A portable health monitor could facilitate a nurse's job, especially because in many Moroccan hospitals, one single nurse is responsible for simultaneously taking care of many patients in different rooms. Having a digital solution such as a monitor that notifies the nurse about patients' needs, could be beneficial and feasible within Moroccan hospitals.

Many citizens already possess wearable technology such as smart phones and smart watches that track physical data such as, heart rate, blood oxygen levels, electrocardiograms, and sleep metrics. Finding a way to integrate or share wearable technology data with healthcare providers would supply physicians with important information about trends and activity they may not be aware of. Incorporating everyday personal technology into health allows for a more complete patient health summary.

2.5 The Ibn Sina Hospital

The Ibn Sina University Hospital Center, also called CHU Ibn Sina, is the largest public hospital in Rabat Morocco. This health center was built in 1954 and named after the Persian polymath Ibn Sina (also known as Avicenna in the west) who wrote the *Book of Healing* and is considered the father of early modern medicine. CHU Ibn Sina includes 10 hospitals and healthcare institutions that each contain multiple specialty groups. The large capacity of the hospital is shown by their 2,347 beds, in which they also provide 328,730 medical consultations and 30,054 surgeries each year (*Hôpital Ibn Sina)*.

During our time in Morocco, we worked with the primary Ibn Sina hospital which contains six departments:

1. Medical diseases and surgeries in adults
2. Nuclear medicine
3. Internal medicine
4. Reconstructive and aesthetic surgery
5. Dialysis and kidney transplantation
6. Lithotripsy

For our project, we specifically worked with the surgery departments as well as the sterilization area that supplies these departments with instruments and equipment.

Due to the large size and outreach of CHU Ibn Sina they have greater access to digital health technologies such as electronic health records and other softwares. They utilize multiple softwares to manage patient data; Green Cube, Millensys, and a custom platform. Green Cube is an electronic health record platform that has multiple functionalities used for patient record-keeping, documentation, scheduling purposes, and accessing radiographic images. Millensys is another platform that is used for keeping their radiology images which is integrated with Green Cube. The custom platform was created specifically for Ibn Sina to be integrated with Green Cube and is used to manage patient laboratory results and data.

With the aforementioned plans in expanding digital healthcare in Morocco. The hospital is also undergoing major renovations to match the expected growth of healthcare digitization, via a brand new 130,293 square meter facility that will cost around $155 million and is planned to be completed in 2026 (Figure 4).

Figure 4. Rendering of the new Ibn Sina Hospital to open in 2026.

Chapter 3: Preliminary Investigation

This project examines digital technologies that have the potential to improve the quality of healthcare in Morocco. Our research took place in Rabat, Morocco from March 11 to May 5, 2023. During our collaboration with the University and their affiliated resources, we focused our attention on the surgical department and sterilization area at Ibn Sina Hospital to identify specific technological solutions that could be further developed by NGOs, private organizations, or PhD students.

The project consisted of two phases:

1. Identifying digital health solutions for Ibn Sina Hospital
2. Designing prototype(s) for Ibn Sina's surgical and sterilization departments

In this chapter we present the methodology for phase one; this led to the identification of two specific technological applications which are discussed in detail in the chapters that follow.

3.1 Identifying Digital Health Solutions for Ibn Sina Hospital

The first phase was to gain an overall understanding of the current methods and practices used within the surgical and sterilization departments of the Ibn Sina Hospital. Dr. Ouassim Karrakchou helped set up interviews with staff at the Ibn Sina Hospital. Our exchanges with both the sterilization and surgical departments began with a tour of their facility and an overview of the existing processes, followed by a brief introduction to our project and team and a review of our consent form (**Appendix A**). These key informants then expressed their interest in our project and shared how they envisioned digital technology could help. These conversations were open-ended to let the experts guide the discussion based on what they felt is most relevant with only some general questions (**Appendix B**) to initiate the conversation. Interviews were informal and often deconstructed, detailed notes were taken of the interviewee's responses. This helped us to gather important information which we used when constructing our prototypes in phase two.

Following our discussions with the key informants, we were able to identify two types of digital solutions that would be beneficial to Ibn Sina's surgical and sterilization departments. These solutions consisted of:

1. A barcode inventory tracking system for the sterilization department to prevent lost or misplaced surgical instruments.

2. A data flow system for the surgical management staff to aid in the analysis of surgical trends.

We concluded that both solutions would be beneficial for the hospital to implement, and ultimately decided to pursue prototypes for both. To begin, we prioritized the sterilization tracking system because it provided better demonstrative value. While prototyping this solution we also worked on designing the data flow system.

In phase two we designed and developed two prototypes for the surgical department and the sterilization department, which are discussed in detail in the next two chapters, respectively.

Chapter 4: Surgical Analytics Data Flow

In this chapter we investigate the surgical department of the Ibn Sina hospital in which we review how records are transferred and stored for analytical purposes. We first discuss how the process exists currently, then what our suggested solution would look like. The design process describes our design criteria and the use of Microsoft PowerApps to create an automated prototype for streamlining the existing processes. Lastly, we review our prototype and its features and make recommendations .

4.1 Current Surgical Record Keeping

One department we were able to investigate was the surgical department of the Ibn Sina hospital. Through our interview with Mr. Houcine, the manager of the surgical department, we learned that the process of preparing the operating room and record keeping of each operation is **performed manually**. Before each surgery, a **paper form** is filled out by anesthetists and nurses who list all the necessary equipment and medications needed for the surgery and is **given to the OR** to be prepared for the operation. Following the procedure, other relevant information such as the name of the doctor who performed the surgery, and the surgery's start and end time, are also added to the paper form. Once the form is complete, the **information is manually entered** into **Microsoft Excel** and saved there for statistical analysis and monthly audits. At the end of each month, detailed reports are generated and sent to the hospital administration for inventory purposes as well as for them to plan adequate strategies for the future.

4.2 Envisioned Automated System

Mr. Houcine along with two surgical secretaries expressed that the main issue with the current record keeping system at the surgical department is entering all the information manually into Excel. A more **automated process** would be much more **efficient** for them as it would eliminate the need for manually sorting the information and entering it into the corresponding fields in Excel. Since they already have computers set up in the operating room, a possible solution would be to create a **digital version** of the paper form, such as an online interface that would be able to generate reports and **automatically export the data** into Excel. That way nurses and anesthetists could simply fill out the electronic version of the form and have the information exported within minutes.

4.3 Designing a Surgical Analytics Data Flow

To begin the prototyping phase of the design process for the surgical analytics data flow, we first defined our design criteria, including:

1. Transferability
2. Automation
3. Exportability
4. User Friendly

To satisfy the needs of the department, these design criteria were an essential component to our prototype. The system must be **transferable** between users such as from the nurse or anesthesiologist to the OR, this would **save time** and eliminate waste. The system should be **compatible with Excel** and the input fields need to be **exportable**, and in order to bypass manual input, the system should **automatically** populate the data into Excel as the forms are completed. For this system to be beneficial, the users need to see it as a more efficient solution, so the process should be **user friendly and easy**.

The system we decided to design in order to meet these criteria was a desktop application that would:

1. Contain electronic forms that mimic the paper ones
2. Automatically export data to Excel for analytics
3. Generate weekly, monthly, and annual reports for the department

4.4 SurgeryFlow Prototype

The prototype was built using Microsoft PowerApps and has multiple functionalities. On the home screen (**Figure 5**) a staff member is able to see all surgery forms sorted by date and also search for specific forms using keywords in the search box. They may choose to click on one of the filled forms which takes you to a new screen (**Figure 6**) and shows all information that was imputed into the form. One also has the option to edit the form from here which updates the corresponding data in the SharePoint list (**Figure 8**). Going back to the home screen, there is also an option to fill out a form (**Figure 7**). Inputting data into the fields here creates a new item in the SharePoint list and puts the data into the corresponding columns (**Appendix E**). The SharePoint list is updated every time a form is filled out and data can either be edited through PowerApps or directly in the list if necessary. The SharePoint list can then be exported to an Excel file with a single button press. Surgery staff will be able to collect and analyze all surgeries in a month or even in a year and keep track of inventory used without having to manually input data after every surgery which will save time and reduce errors.

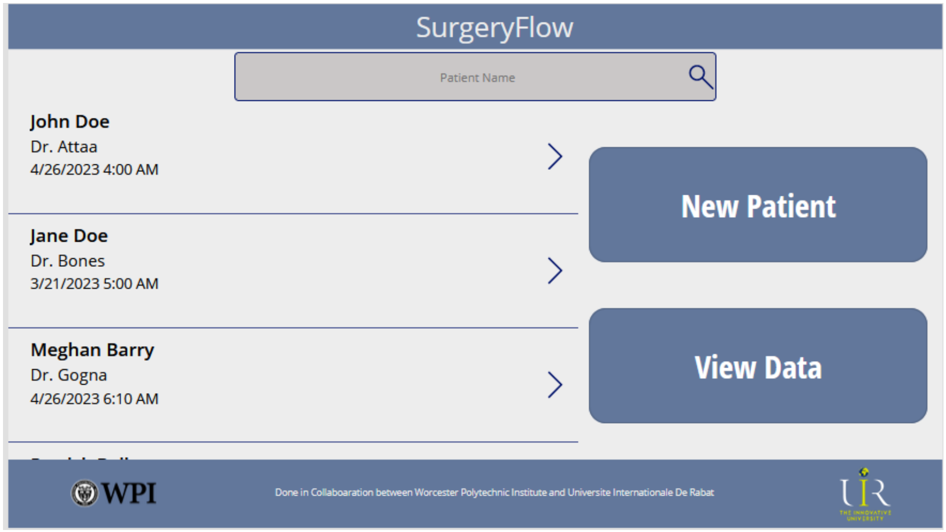


Figure 5. Home screen of the Surgery Flow app. All patient forms are visible on the left hand side. The New patient button creates a new form to fill out as well and the View Data button launches the raw SharePoint. Clicking on any of the filled out forms in the list lets you see the full filled out form.

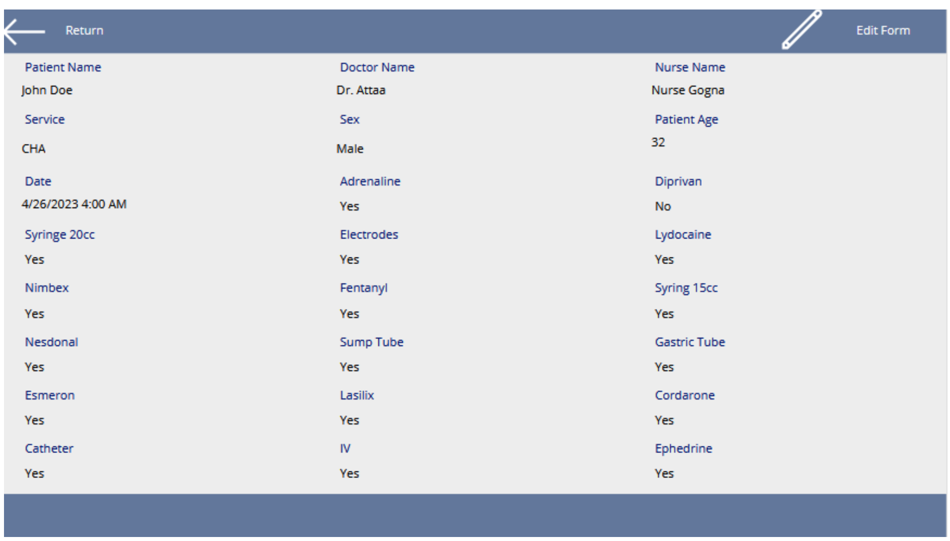


Figure 6. Form data screen which shows the information in a selected completed form. To edit the completed form a user would click on the edit form button in the top right corner. Or if they wish to go to the home screen they may click the return button in the top left.

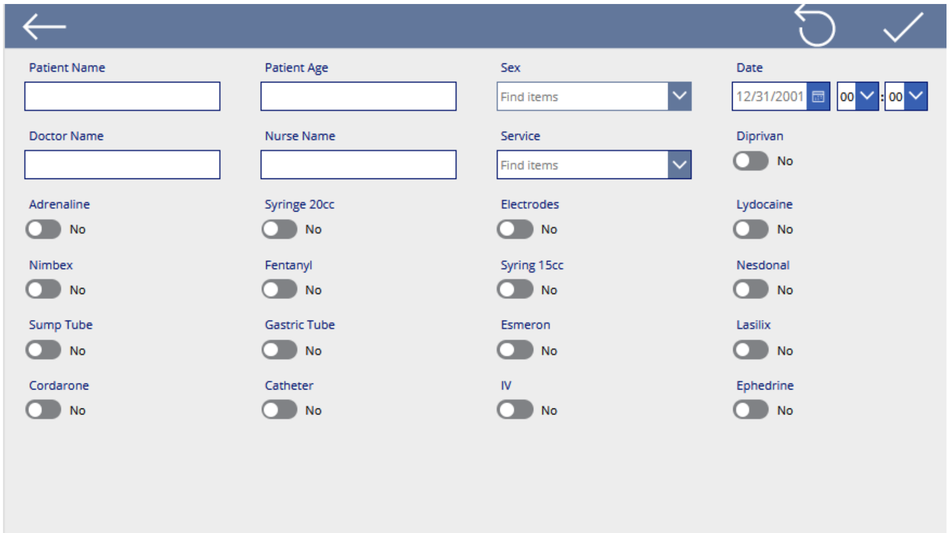


Figure 7. Empty form screen a user generates after clicking the New Patient button. Information such as the patient's name, age, their service can all be filled in and the supplies used in the surgery can also be checked off. To submit the form a user would click on the check mark in the right hand corner.

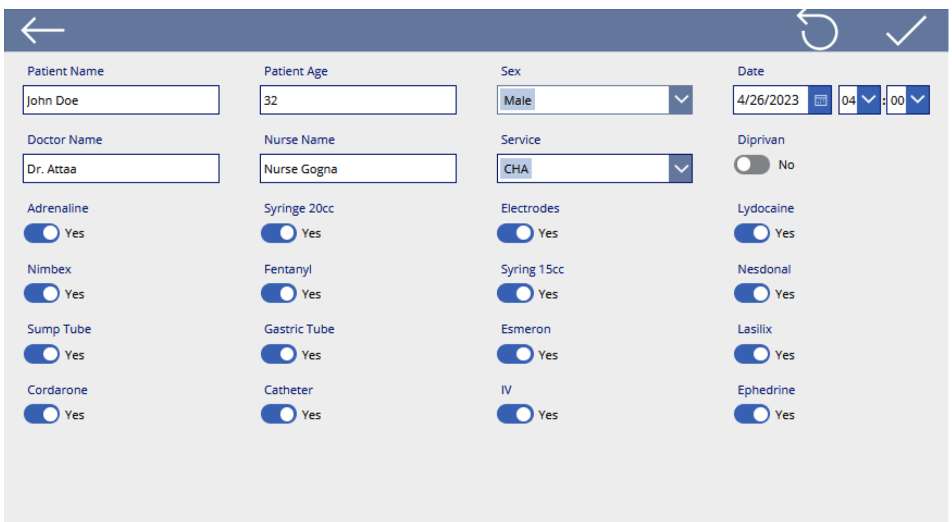


Figure 8. The completed form. All forms are able to be edited after being submitted by going through the data view screen and clicking “edit”. This will populate a form with all the information as it was previously filled out and can easily be changed by editing the form and clicking the submit button again.

4.5 Conclusion and Recommendations

Implementation of this type of technology would be relatively simple within the process framework that already exists. The only significant change in the procedure would be the transfer from paper forms to electronic forms that would be available on a computer. The operating rooms already have computers, therefore the hospital would have to install the software they intend to use and make sure the computers have access to the internet or the hospital's internal system.

Ibn Sina would have the choice to either purchase software that already exists or have it custom designed to their specifications. Currently, many companies have software available for purchase that allows users to create and send online forms and then have the data uploaded to an Excel file such as FormSmart. However softwares like these often require a monthly fee to use and in the case of FormSmart this can range from $120-$360 depending on how many of the software's features the user wishes to have access to. A more economical solution in the long term would be to create custom software for the Ibn Sina hospital. Our prototype demonstrates that this can be done in a relatively short amount of time and with minimal technical expertise. Another advantage to this path would be that the software could be designed and integrated with the other hospital softwares in mind, such as the custom platform that the hospital has already designed and integrated with GreenCube. This custom solution would allow it to be fully compatible and to be customized to the hospital's needs.

Chapter 5: Sterilization Inventory Tracking

In this chapter we investigate the sterilization department of the Ibn Sina hospital in which we review the current sterilization process and our proposed solution for tracking instruments. The sterilization process goes over the current methods as well as the suggested barcode scanning solution. The design process describes the use of Microsoft PowerApps to develop an application, and the synchronization to a SharePoint list and an Excel table.

5.1 Existing Sterilization Process

Figure 9. Flow of instruments in the sterilization process

Another area of investigation in phase two was the sterilization department. The manager, Mr. Fathi, gave us a tour of the department and a detailed explanation of the sterilization processes. The processes of sterilizing medical equipment follow global standards that ensure maximum sterility and Ibn Sina hospital is no exception to that. The department follows a detailed process for ensuring the cleanliness of their equipment. This process is separated into different rooms, the "**dirty room**", "**intermediate room"**, and "**sterile room**".

Used equipment enters the **dirty room** to be **decontaminated,** which involves removing any bodily fluids and tissues. The instruments are then transported to the **intermediate room** where they are **packaged** and **prepared** for sterilization. Then instruments are **sterilized** in the **sterile room**.

Sterilization follows two different techniques:

1. An **autoclave,** which uses steaming in a high temperature and pressure environment to kill microbial growth.
2. A low-temperature, low-pressure technique that uses **vaporized hydrogen peroxide**.

Finally, the sterile equipment is **labeled**, wrapped, and put in the **stockroom** before leaving for surgeries. The stockroom has an **equipment elevator** built-in that connects to the operating room to minimize contamination along the way. To comply with standards, steam integrators are placed in the sterilizer along with the instruments for every cycle. These integrators verify the sterility of the equipment by indicating whether or not the cycle was exposed to the correct temperature and pressure. Paper archives of these integrators are kept for liability reporting and inspection purposes. **Figure 9** depicts the sterilization process that the instruments go through.

5.2 Envisioned Sterilization Solution

Mr. Fathi shared some of his ideas on ways that instrument and equipment inventory could be optimized by using a **digital system**. The two main concerns he had were **missing instruments** and the **wrong equipment** being packaged into the surgical boxes. One way that a digital system could be used to help is by using **barcodes**. In this method all surgical equipment would be labeled with a unique barcode and scanned at multiple checkpoints throughout the sterilization process; these checkpoints are shown in **Figure 10** below. Each time an instrument is scanned, the data would be logged into a program that shows **which instrument, what location**, and **who scanned it**. Such a system would help to locate instruments by viewing where it was last scanned, it would also eliminate errors in packaging as instruments would be scanned and verified prior to packaging.

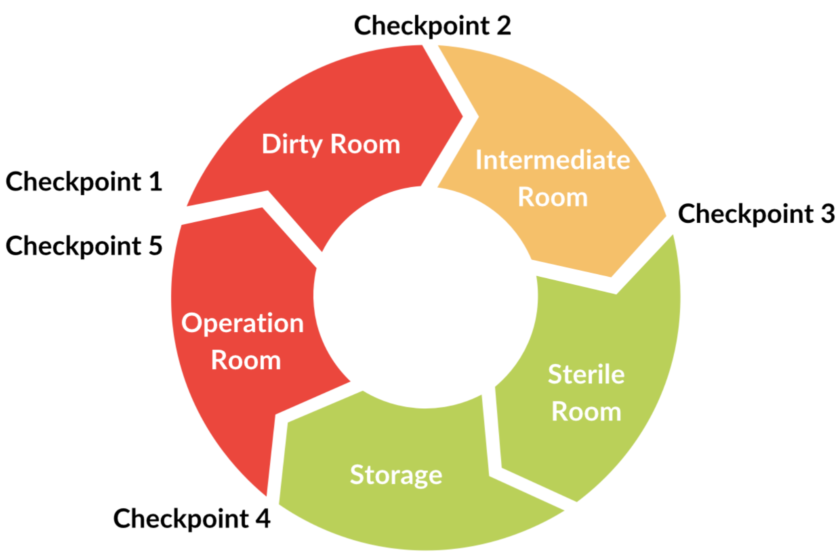


Figure 10. Where instruments travel adapted with scanning checkpoints.

In our discussion with Mr. Fathi, he shared that the sterilization department handles more than 3,000 surgical instruments in total, which makes tracking inventory challenging. With this information in mind, we began our design process of a barcode inventory tracking system. In the sections that follow we discuss our design criteria and their reasoning, followed by our prototype deliverable.

5.3 Designing a Barcode Inventory Tracking System

To begin the prototyping phase of the design process for the barcode inventory system, we first defined our design criteria.

This included:

1. Sterilizability
2. Minimal contact
3. Barcode Scannability
4. Database (Integrable, Real Time updating)
5. Logistics (Timestamp, Location of Scan, instrument ID)

To satisfy the needs of the department, these design criteria were an essential component to our prototype. The system must be **sterilizable** due to hospital standards and have **minimal contact** to avoid cross contamination. For instruments to be identifiable the system must be able to **scan barcodes** with unique identifiers for each tool. In order to track the sterilization process for each instrument, the system must have a **database** that logs all instrument **logistics** such as time, location, and the unique identifier. Time and location are important in determining when and where each instrument is throughout the sterilization process and the unique identifier for each instrument ensures all instruments are accounted for before and after they are used in surgery.

The system that we decided to design in order to meet these criteria consisted of three main components:

1. A scanning application that scans barcodes and uploads to a database
2. A sterilizable platform that allows for contactless scan of instruments
3. A way to engrave surgical equipment with identifying barcodes

To design the **barcode scanner application**, we utilized Microsoft PowerApps, a software and design development environment useful for making design mockups and prototypes for mobile applications. We developed a diagram that demonstrates the components of the app as well as the interactions between them, and can be seen in **Figure 11** below. We started with a login page for both admin and non-admin users that contains each of the scanner locations. Then barcode reader modules were added and named “scan instrument”, coded so that upon scanning of a barcode, it records who scanned, what was scanned, and when it was scanned on the app directly.

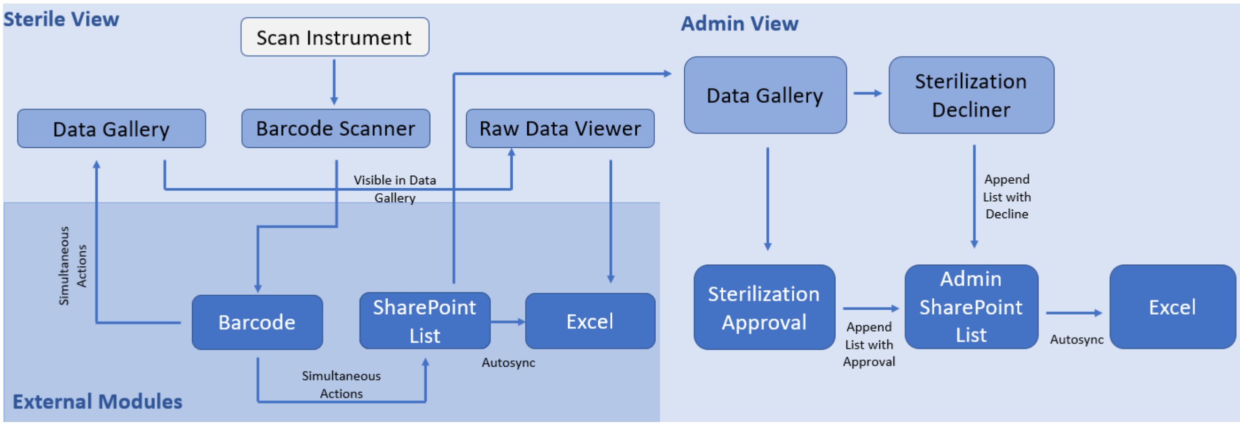


Figure 11. The interaction between different modules within the app and external data. The app is divided into Admin and Sterile view to showcase the two different user groups.

This direct display was achieved by utilizing a vertical gallery with a data source of the collected Barcode scanning data, which ensures the collection of real time barcode data. Through PowerApps' features, we created and connected a SharePoint list that would be updated with the barcode data upon scanning. To achieve **minimal contact** the user has to interact with the app only when logging in for the first time and when ending the scanning session; once barcode scanning is initiated, it runs continuously until it is manually halted.

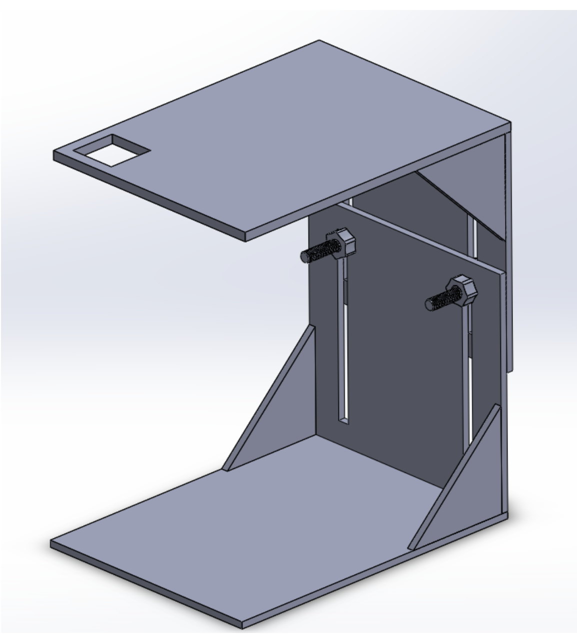


Figure 12. SolidWorks design for the device platform.

In order to make the scanning system have minimal contact, we designed a **sterilizable platform** on which a device with the scanning application can sit. Our design was a bracket shaped box with three open sides that allows for instruments to be passed underneath the scanner without touching the device. The top part of the bracket was designed to be large enough to hold an iPad and the camera hole large enough for an iPhone so our platform can satisfy a wide range of devices. It consisted of four components that were separately modeled in SolidWorks and then assembled together. The platform has a sliding mechanism that uses bolts and nuts, which allows the height of the bracket to be adjusted accordingly depending on the size of the item being scanned. This design can be seen in **Figure 12**.

Lastly for the system to be complete, the **surgical instruments** must be engraved with the unique identifying barcodes (**Figure 13**). The purpose of engraving the barcodes into the surgical instruments is to ensure the barcodes' durability through the sterilization process. Paper barcodes or stickers would not stay attached to the instruments due to the high heats and pressures used by the sterilization machines. Fortunately surgical tools are made out of stainless steel due to its strength and corrosion resistance, which means they can easily be engraved using a laser engraver. In order to do this a unique barcode for each instrument must be created and fitted to the dimensions of the instrument. Additionally, the barcode must be readable by the scanning application.

Figure 13. Example of a surgical instrument engraved with a unique identifying code.

5.4 SmartScan Prototype

Accounting for the design criteria discussed previously, we began to construct the prototype that served as a deliverable to our sponsor. To make this design into a functional prototype we utilized our resources within the UIR technical center and worked closely with Mr. Mohamed El Ouahabi, the lead technician.

5.4.1 Instrument Engraving

Figure 14. Square piece of stainless steel metal with a laser engraved barcode for demonstration purposes.

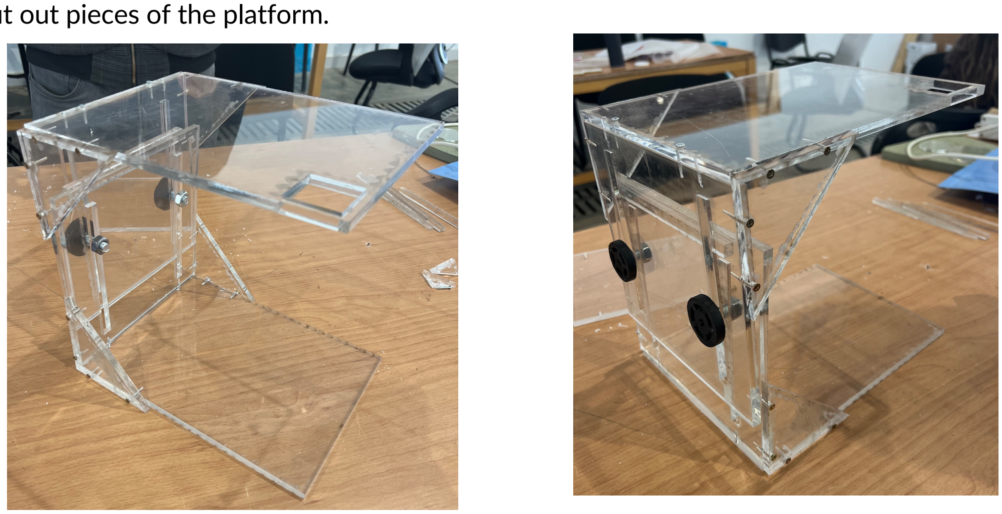
To satisfy the instrument component of the prototype and to demonstrate the ability to scan engraved barcodes, we used a square piece of stainless steel metal and were able to laser engrave the unique barcodes (**Appendix D**) at a local metal workshop in Rabat (**Figure 14**). The unique barcodes used for this prototype were generated using an online barcode generator called Cognex. Although we were not able to obtain actual medical instruments from the Ibn Sina hospital for demonstration purposes, this sample barcode shows the readability of the engraved data on metal.

5.4.2 SmartScan Platform

After modeling the SmartScan Platform in SolidWorks, we utilized our resources at the UIR technical center to build our physical prototype. Ideally, we would have chosen stainless steel as the material for our prototype due to its durability and sterilization capabilities; however, for demonstration purposes, we decided to use plexiglass as it was readily available to us at the UIR. Plexiglass is a thermoplastic that can resist relatively high temperatures and pressures and would still be sterilizable, though a metal like stainless steel would be the better option, especially for the long-term.

Figure 15. Laser cutter machine used to cut out pieces of the platform.

The four different parts of the platform were laser cut (**Figure 15**) according to our design dimensions, and then assembled together using screws. Bolts and nuts were used to adjust the height of the platform. Four triangular shaped pieces were added on both sides to provide extra support and to ensure that the platform would hold the weight of the scanning device. The fully constructed SmartScan platform can be seen in **Figures 16 and 17** below.



Figures 16 & 17. Completed SmartScan platform constructed of plexiglass.

5.4.3 SmartScan Application

This section explores in depth the SmartScan application outlined in **Figure 11**, with screenshots of each of the pages. The application starts on a login page where the user chooses their login destination: admin or scanner. Upon choosing, the user can then perform different actions; on the admin side scans can be viewed, approved or declined. On the scanner view, barcodes can be scanned and appended to a SharePoint List as well as a local Data Gallery. Outlined below is an application walkthrough using screenshots of all views to clarify the process.

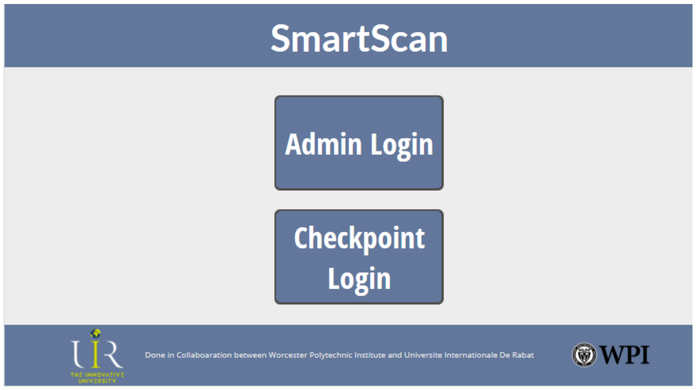


Figure 18. SmartScan Login area. Admin Login directs to the admin side for viewing and authenticating scans, whereas the sterile login allows scanning of instruments.

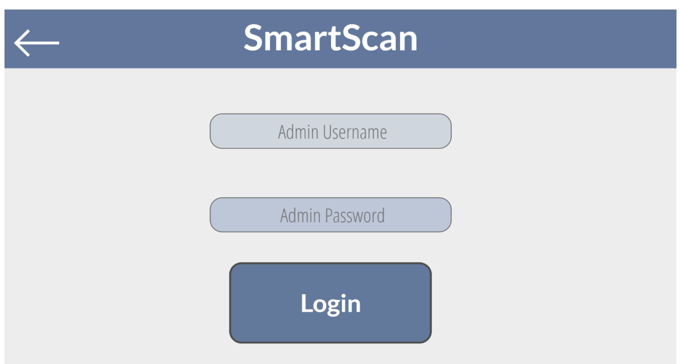


Figure 19. Admin Side Login page, using specific admin credentials hardcoded into the Login button.

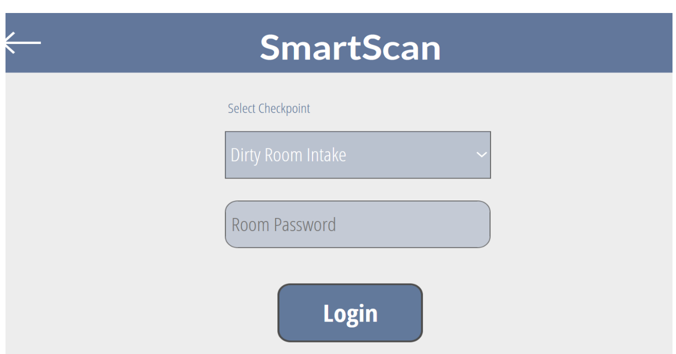


Figure 20. Checkpoint Login. Choice of room from a dropdown menu (Dirty room, Middle Room, Sterile room, Surgery In, or Surgery Out) each with a unique password linked to a SharePoint list. (**Appendix D)**

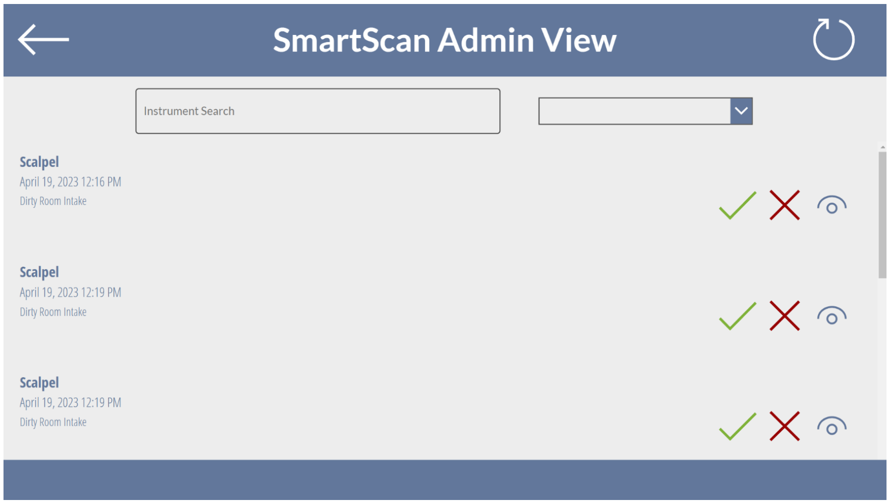


Figure 21. SmartScan Admin View. When either of the checkmark or cross is pressed, the tracking page will be updated with the item's approval status. In the Admin View, the data gallery is synced with the 'Tracking Data' SharePoint List that is patched when an instrument is scanned, therefore it can be updated when a new item is added to the list.

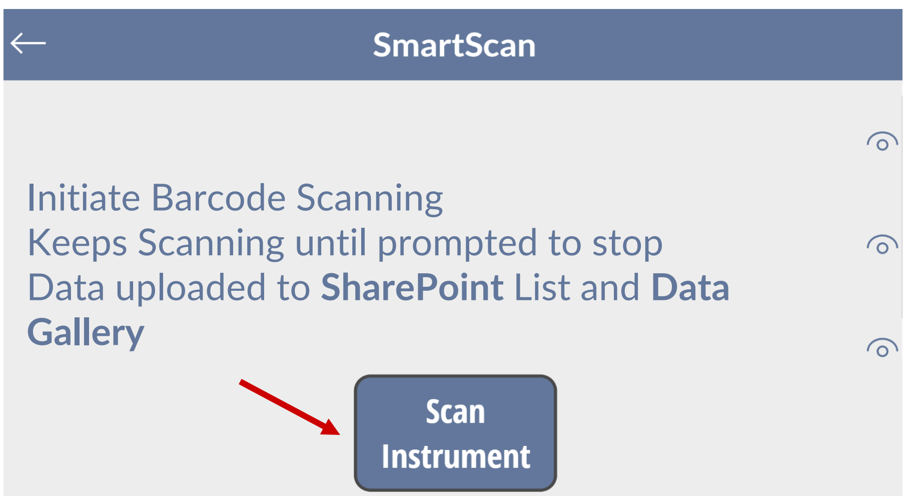


Figure 22. SmartScan Checkpoint View. Scanning occurs on this page. Upon scanning the data gallery is updated with the read values, and simultaneously, a SharePoint is updated with the data. Again we utilize the 'Patch' function. The module is also initialized to reselect the Barcode scanner after a scan is done which causes a loop; this achieves the minimal contact aspect of the application as scanning will occur automatically.

On the admin view shown in **Figure 21**, the Data gallery has the SharePoint List 'Tracking Data' as its source as real time functionality is limited in PowerApps, adding a dynamic list bypasses that hurdle, allowing it to be seen on multiple devices as the data is stored on the cloud rather than locally. Below is a diagram that showcases the functionality of the scanning feature in **Figure 22** using the same patch function used in **Figure 21**.

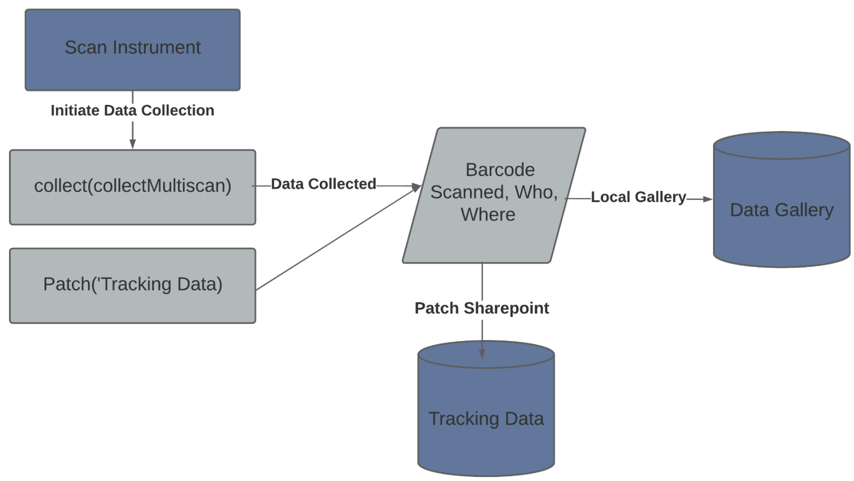


Figure 23. SmartScan barcode scanner flow diagram showcasing the main coding blocks. When the first scan is initiated, it first goes into collect mode to collect the data to be stored in the collection 'collectMultiscan' that stores it in a local gallery. After that it is able to patch this new information to a SharePoint accessible via the cloud **(Appendix D)**.

5.5 Conclusions and Recommendations

For our prototype to be complete, we needed to lay out where scanners would be placed throughout the sterilization process. Using the information we gathered from Mr. Fathi, we were able to identify checkpoints that would allow for the best tracking of instruments (see **Figure 10** for checkpoint location). Scanners would be placed at the entrance and exit of each room that equipment gets passed through. **Figure 24** below shows the layout of the sterilization department. For the doors that connect two rooms together, only one scanner would be used. There would be a total of five scanners that would be placed, at the entrance to the dirty room (red), at the entrance to the intermediate room (yellow), at the entrance to the sterile room (green), as well as at the elevator located in the sterile room that connects to the operating room, and at the exit of the operating room.

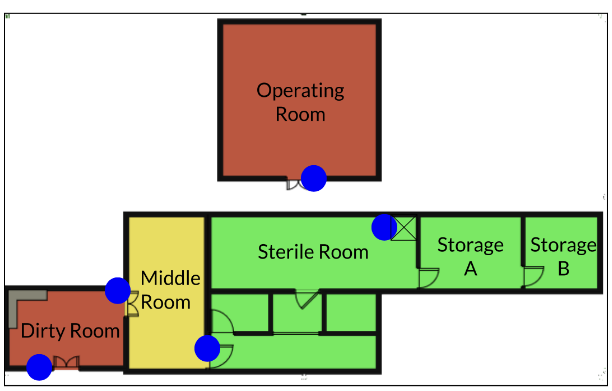


Figure 24. The layout of the sterilization area containing adapted checkpoints (blue).

Once scanners are placed at these checkpoints, the sterilization technicians would complete the entire process as normal, but scanning each instrument as they travel from room to room. In our discussion with Mr. Fathi, the main challenge he envisioned was people adapting to the new process. As with any change, implementation is always an adjustment but our solution causes minor changes to the user's routine and the technicians should be able to quickly adapt. Mr. Fathi also noted that because Ibn Sina is a teaching hospital, they often have new technicians coming in. This constant stream of new employees can be seen as a positive thing because the sterilization process is taught and reinforced regularly and if the new technicians are taught with the adapted checkpoints, adherence becomes less of a concern.

As for the logistics when recommending our solution to the sizable scale of a hospital like Ibn Sina, our prototype would not be sufficient to fulfill the needs of the hospital. The idea of our SmartScan prototype is to showcase the thought process and ideas for how such a solution would be implemented. This prototype also served as a deliverable to our sponsor and our contacts at Ibn Sina hospital. Luckily there are existing companies that have engineered our envisioned solution to fit the needs of hospitals all over the world.

The most feasible approach would be for the hospital to purchase one of these systems from a company such as Becton Dickinson. This company provides a surgical instrument management system called *Impress*. This system manages inventory, people, and processes with various levels of functionality. It tracks inventory at all touchpoints - from decontamination through sterilization and storage to the OR and patient level, and collects detailed data about the facility's systems and processes. The *Impress* system includes tracking software, instrument engraving, and scanners, as well as technical support.

If the hospital were to create their own instrument management system, our SmartScan prototype demonstrates that this can be accomplished with very little technical knowledge. If the hospital had a system developed, such as the custom software for managing lab data, they could add personalized features and functions that would extend the system's capabilities beyond what we have proposed.

To engrave the 3,000+ instruments of the surgical department, Ibn Sina would have two options. The first would be to purchase a laser engraver. A laser engraver from a traceability solutions company such as Telesis, costs roughly 251,000 MAD and one can expect to engrave about six instruments per hour. For a workday of eight hours, one would be able to engrave about 240 instruments a week, and it would take about 12.5 weeks to engrave all 3,000 instruments. Also accounting for the salary of the operator (28 MAD/hr) (ERI), is an additional 2,800 MAD. With the total of these costs being 253,800 MAD, it would cost about 85 MAD per instrument to be engraved. The second option to engrave the instruments would be to outsource the engraving to a private vendor, which can cost anywhere between 30-100 MAD depending on the size and material of the surgical instrument.

To complete the custom solution, Ibn Sina would also need to purchase scanners for each scanning checkpoint. Scanners range anywhere from 1,000-10,000 MAD per scanner which would be an additional cost of up to 50,000 MAD. In total, the custom instrument management system could cost upwards of 350,000 MAD depending on the engraving and chosen scanners, not including the cost of software development.

Chapter 6: Final Conclusions

The implementation of digital technology has been shown to improve quality of care in the healthcare sector through the reduction of errors and the increase in efficiency that computers and the internet provides. The current motivation from the Moroccan Ministry of Health demonstrates the drive for overall improvement in the healthcare sector, this motivation begins with transformation of the public healthcare system. The purpose of this project was to aid the International University of Rabat in identifying and examining the role of digital health technologies and to develop prototypes for the Ibn Sina Hospital, with the vision that it will act as a catalyst for more digital technology in Moroccan healthcare.

This is possible through either the adoption of the proposed prototypes or simply by sparking conversation and providing inspiration to leaders in Moroccan healthcare. It is the hope of this project that in the next few years digital technology will become more commonplace in the healthcare sector. This may happen through increased government programs but more likely it will be through individual initiatives of those who are able to identify problems and create working solutions.

The application of digital technologies in healthcare is a broad topic with endless opportunities to improve the quality of care and facilitate current processes. The growing potential for developing countries to obtain digital technologies remains abundant and with the aid of governmental initiatives a future of more comprehensive healthcare is promising. With this potential in mind there is space for future research in the field of healthcare technologies that can be carried out by future WPI projects, especially in developing nations where the need for technological solutions remains present.

"There are no incurable diseases, only the lack of will. There are no worthless herbs, only the lack of knowledge" - Ibn Sina

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Appendices

Appendix A: Interview Consent Form in English and French

Hello,

We would like to thank you for choosing to participate in this interview. Today we would like to have a small chat with you surrounding your work at Ibn Sina. We also want to discuss a little about digital technologies, and your perspective and knowledge about them and how you could utilize or use them.

Your participation in this interview is completely voluntary and you are not required to answer any questions you feel uncomfortable with. Your opinions and perspectives are extremely valuable to us and will contribute to the advancement of our research about digital healthcare.

We would like to ask for your permission to take notes on what you say, or audio/video record your statements during our chat. We will only use this information for the purposes of analysis and reporting of the study results and all of those will be terminated after using them.

This interview will take around an hour to complete. Your time is very valuable to us, and we thank you for taking the time to participate. Especially during Ramadan and with your busy work schedules, we know how hard it is and we appreciate that.

We want to ensure that all of your confidentiality is maintained throughout the interview. Therefore, your responses will be kept anonymous, and any quotes used in the final report will not be attributed to you unless you explicitly grant us permission to do so.

If you are willing to go through with the interview, please sign this document and return it to one of us. Please don't hesitate to come forward to us with questions or concerns.

Sincerely,

MO23 Digital Healthcare Team

________________________________ _________________

Signature Date

Bonjour,

Nous tenons à vous remercier d'avoir choisi de participer à cet entretien. Aujourd'hui, nous aimerions avoir une petite conversation avec vous concernant votre travail chez Ibn Sina. Nous voulons également discuter un peu des technologies numériques, de votre point de vue et de vos connaissances à leur sujet et de la manière dont vous pourriez les utiliser.

Votre participation à cet entretien est entièrement volontaire et vous n'êtes pas tenu de répondre aux questions avec lesquelles vous vous sentez mal à l'aise. Vos opinions et points de vue nous sont extrêmement précieux et contribueront à l'avancement de nos recherches sur les technologies numériques de la santé.

Nous aimerions vous demander la permission de prendre des notes sur ce que vous dites et d'enregistrer vos réponses pendant l'entretien. Nous n'utiliserons ces informations qu'à des fins d'analyse et de rapport des résultats de l'étude et l'enregistrement sera supprimé une fois vos réponses transcrites.

Cet entretien prendra environ une heure à compléter. Votre temps nous est très précieux et nous vous remercions d'avoir pris le temps de participer. Surtout pendant le Ramadan et avec vos horaires de travail chargés, nous reconnaissons à quel point c'est difficile et nous apprécions votre coopération.

Nous voulons nous assurer que toute votre confidentialité est maintenue tout au long de l'entretien. Par conséquent, vos réponses resteront anonymes et les citations utilisées dans le rapport final ne vous seront pas attribuées à moins que vous ne nous en donniez explicitement la permission.

Si vous êtes prêt à passer l'entretien, veuillez signer ce document et le retourner à l'un d'entre nous. N'hésitez pas à nous faire part de vos questions ou préoccupations.

Sincèrement,

MO23 Digital Healthcare Team

________________________________	_________________________
La signature	La date

Appendix B: Department Interviews in English and French

Introduction: Hello, we are a team of American students working on a project about digital healthcare technologies. We are going to ask you a few questions about your role at Ibn Sina Hospital. The goal of these questions is to understand the current practices in place within the department and your perspective towards the role of digital health technology. We are looking to understand any limitations a type of technology may have and the perspectives of healthcare workers. You may choose not to answer a question or stop the interview at any time and we will keep your identity anonymous if you wish. With your permission, we would like to record this interview for note taking purposes but we will delete the recording once we have transcribed your responses.

Goal/Objective: To understand stakeholders' perspectives on the type of digital technology we plan to recommend and any limitations that may be present.

Questions:

1. What is your name and what is your role within the hospital?
2. What do you know about digital health technologies?
3. What areas of the hospital do you believe would benefit most from digital improvement?
4. Are you aware of any ongoing efforts to implement more technology within the hospital?
5. What are the current methods that you use within your role? Can you explain the process of equipment sterilization before and after surgery? Can you explain to us some of the current practices within the department?
6. What do you think are the main areas where technology could make your role or the department more efficient?
7. What digital technologies are you interested in implementing in your department, and why?
8. What are the main issues you face when interacting with current methods, if any?
9. How often do you interact with technology in your role?
10. Do you see technological solutions as a positive thing, why or why not? And do you have any concerns about integrating more technology in your workplace?
11. Do you foresee any challenges when trying to implement or use a new type of technology?

Introduction: Bonjour, nous sommes une équipe d'étudiants américains travaillant sur un projet sur les technologies numériques de la santé. Nous allons vous poser quelques questions sur votre rôle à l'hôpital Ibn Sina. L'objectif de ces questions est de comprendre les pratiques actuelles en place au sein du département et votre point de vue sur le rôle de la technologie numérique de la santé. Nous cherchons à comprendre les limites qu'un type de technologie peut avoir et les perspectives des travailleurs de la santé. Vous pouvez choisir de ne pas répondre à une question ou d'arrêter l'entretien à tout moment et nous garderons votre identité anonyme si vous le souhaitez. Avec votre permission, nous aimerions enregistrer cet entretien à des fins de prise de notes, mais nous supprimerons l'enregistrement une fois que nous aurons transcrit vos réponses.

Objectif: Comprendre les points de vue des parties prenantes sur le type de technologie numérique que nous prévoyons de recommander et sur les éventuelles limites.

Des questions:

1. Quel est votre nom et quel est votre rôle au sein de l'hôpital ?
2. Que savez-vous des technologies numériques de la santé ?
3. Selon vous, quels secteurs de l'hôpital bénéficieraient le plus de l'amélioration numérique ?
4. Êtes-vous au courant des efforts en cours pour mettre en œuvre plus de technologies au sein de l'hôpital ?
5. Quelles sont les méthodes actuelles que vous utilisez dans votre rôle ? Pouvez-vous expliquer le processus de stérilisation du matériel avant et après la chirurgie ? Pouvez-vous nous expliquer certaines des pratiques courantes au sein du ministère?
6. Selon vous, quels sont les principaux domaines dans lesquels la technologie pourrait rendre votre rôle ou le service plus efficace ?
7. Quelles technologies numériques souhaitez-vous mettre en œuvre dans votre département, et pourquoi ?
8. Quels sont les principaux problèmes auxquels vous faites face lorsque vous interagissez avec les méthodes actuelles, le cas échéant ?
9. À quelle fréquence interagissez-vous avec la technologie dans votre rôle ?
10. Voyez-vous les solutions technologiques comme une chose positive, pourquoi ou pourquoi pas ? Et avez-vous des inquiétudes quant à l'intégration de plus de technologie dans votre lieu de travail ?
11. Prévoyez-vous des défis lorsque vous essayez de mettre en œuvre ou d'utiliser un nouveau type de technologie ?

Appendix C: Demonstration Tool barcodes

Forceps-01

The image above is a Code-128 type barcode created for free on the website Cognex. The barcode was placed on the prop Forceps during the demonstration.

Scalpel-01

The image above is a Code-128 type barcode created for free on the website Cognex. The barcode was placed on the prop Scalpel during the demonstration.

Appendix D: SmartScan Code And SharePoint Lists

```
Collect(
    collectMultiScan,
    {
        ScannedItem: (BarcodeScanner1.Value),
        WhoScanned: Dropdown1.SelectedText.Value,
        WhenScanned: Now()
    }
);
Patch(
    'Tracking Data',
    Defaults('Tracking Data'),
    {
        Title: User().FullName,
        'Barcode Scanned': (BarcodeScanner1.Value),
        Checkpoint: Dropdown1.SelectedText.Value,
        When: Now()
    }
);
Refresh('Tracking Data');
Select(BarcodeScanner1);
```

OnScan code for barcode scanner. The process has multiple steps:

1. The **Collect** command tells the app to collect barcode data into 'collectMultiScan' a collection item that is as our data gallery source. It collects what the scanned item is via reading the scanned barcode value, who scanned it by accessing which room was chosen on login, and finally when it was scanned by logging the precise time it was captured.
2. The **Patch** function; tells the app to **append** the SharePoint list called 'Tracking Data' , what follows the curly brackets are the columns to be appended and what they are appended to, we can see that the values match that in the MultiScan collection to ensure no data differences occur.
3. Then it **refreshes** the list, and restarts the process by **selecting** the barcode scanner again to run it.

```
Patch(
    'Tracking Data Admin',
    Defaults('Tracking Data Admin'),
    {
        Title: "Admin",
        'Approval Status': {Value: "Approved"},
        'Barcode Scanned':BarcodeScanner1.Value,
        Who: Dropdown1.SelectedText.Value,
        When:Now()
    }
);
```

OnSelect code for the check mark in the admin view. Contrasting the OnScan module this code only utilizes the patch function. Here the **Patch** function tells the app to **append** the SharePoint list called 'Tracking Data Admin' , a list on the admin side with approval status. What follows the curly brackets are the columns to be appended and what they are appended to. All but one column is identical to the OnScan which is the approval status; formatted differently as the data input is a **record** rather than text.

```
If(
    !IsBlank(Username.Text = "admin" And PasswordIn.Text = "password"),
    Navigate('Admin View'),
    Navigate('Home Page')
);
Reset(Username);
Reset(PasswordIn);
```

OnSelection Code for the Admin side login. Hardcoded admin username and password. If Password and username matches it navigates to the Admin view, if not it goes to the home page. The If statement has syntax as such: logical test, true value, else value. The logical test here is the !IsBlank statement which is an expression to check for the inputted text; the true and else values are the navigate to admin and home pages respectively.

```
If(
    !IsBlank(
        LookUp(
            'Sterile Rooms Login',
            Rooms = Dropdown1.SelectedText.Value And Password = TextInput1.Text
        ).Rooms
    ),
    Navigate('Sterile View'),
    Navigate('Home Page')
);
Reset(TextInput1);
```

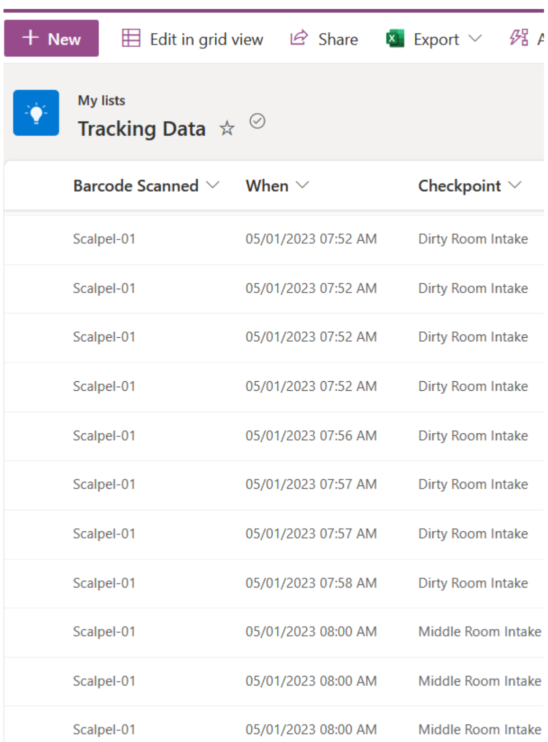
OnSelection Code for the Checkpoint side login. The If statement has syntax as such: logical test, true value, else value. The logical test here is the !IsBlank statement which is an expression to check for the inputted text; the true and else values are the navigate to checkpoint and home pages respectively. In here the logical condition uses a lookup to search the SharePoint list “Sterile Rooms Login” for the correct combination of Room and Password.

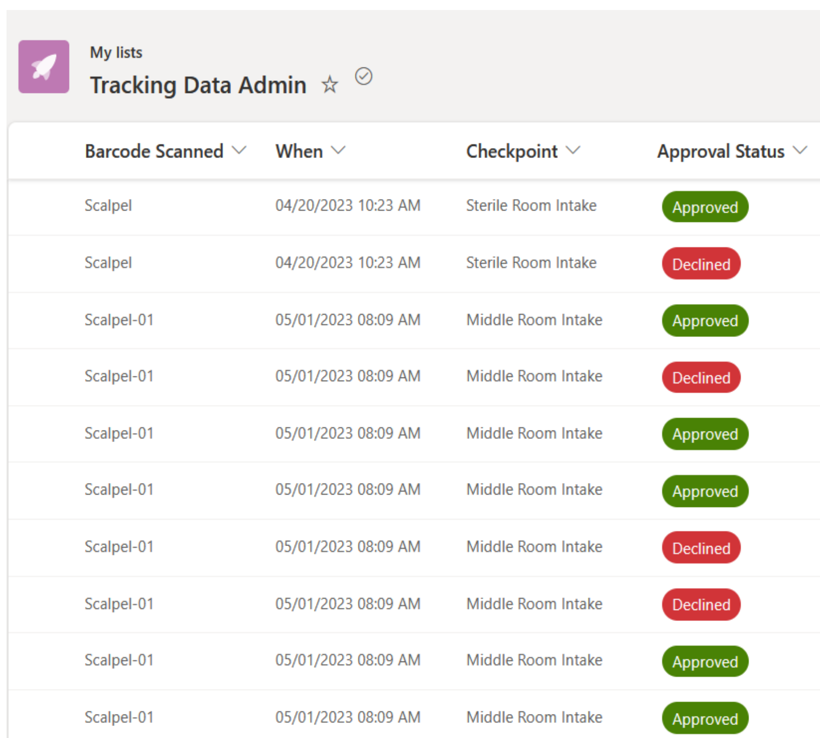
Rooms	Password
Dirty Room Intake	123
Middle Room Intake	123
Sterile Room Intake	123
Surgery Intake	123
Surgery Outake	123

SharePoint of Rooms and their respective passwords. In an earlier version we had the passwords set to different values, however it caused some confusion with demonstrating so we opted for uniform passwords to ensure a uniform scanning process.

```
If(//condition testing
    Dropdown2.SelectedText.Value = Blank(),// If None chosen on dropdown menu, display all Tracking Data items
    'Tracking Data',
    Filter(
        'Tracking Data',
        StartsWith(
            'Barcode Scanned',
            TextInput2.Text
        ),
        Checkpoint = Dropdown2.SelectedText.Value
    )
)
```

Admin View Data Gallery code, the code utilizes an if statement, where the logical test is to check if the checkpoint filter is blank, and if it is the entire data from the "Tracking Data" List will be shown. Otherwise the true value would be to Filter the data set using the 'StartsWith' command that finds all the items that start with the condition specified; in this application we are searching the 'Barcode Scanned' column in the list for items that begin with the text inputted in the search bar **(Figure 21).** The checkpoint filter is added onward after the conditional search, as it needs to be included in the Filtering statement.

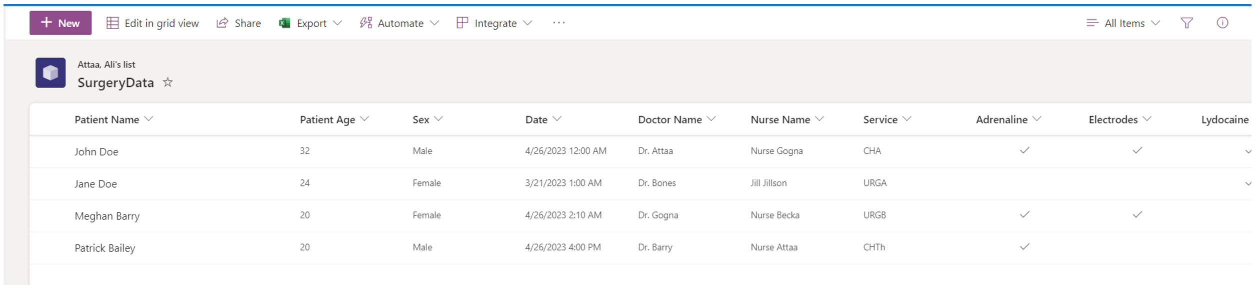




'Tracking Data' showing data of What, when and where items are scanned

'Tracking Data Admin' showing data of What, when where items are scanned, and approval status

Appendix E: Surgery Dataflow list



+ New | Edit in grid view | Share | Export | Automate | Integrate | ··· | All Items

Attaa, Ali's list

SurgeryData ☆

Patient Name	Patient Age	Sex	Date	Doctor Name	Nurse Name	Service	Adrenaline	Electrodes	Lydocaine
John Doe	32	Male	4/26/2023 12:00 AM	Dr. Attaa	Nurse Gogna	CHA	✓	✓	✓
Jane Doe	24	Female	3/21/2023 1:00 AM	Dr. Bones	Jill Jillson	URGA			✓
Meghan Barry	20	Female	4/26/2023 2:10 AM	Dr. Gogna	Nurse Becka	URGB	✓	✓	
Patrick Bailey	20	Male	4/26/2023 4:00 PM	Dr. Barry	Nurse Attaa	CHTh	✓		

Above Image is of the SharePoint list that the surgery data flow app uploads too. Every time a form is changed or filled out the list gets updated with the changes made or the new data added. To upload the data to excel all the staff must do is press the export button which gives an option to create an excel sheet with all the data. Below is a part of the exported excel file from the SharePoint.

Patient Name	Patient Age	Sex	Date	Doctor Name	Nurse Name	Service	Adrenaline	Electrodes	Lydocaine	Nimbex	Fentanyl	Nesdonal	Syringe 15cc	Sump Tube
John Doe	32	M	4/26/2023 0:00	Dr. Attaa	Nurse Gogna	CHA	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Jane Doe	24	F	3/21/2023 1:00	Dr. Bones	Jill Jillson	URGA	No	No	Yes	No	Yes	No	Yes	Yes
Meghan Barry	20	F	4/26/2023 2:10	Dr. Gogna	Nurse Becka	URGB	Yes	Yes	No	Yes	Yes	Yes	No	Yes
Patrick Bailey	20	M	4/26/2023 16:00	Dr. Barry	Nurse Attaa	CHTh	Yes	No	No	Yes	Yes	Yes	Yes	Yes