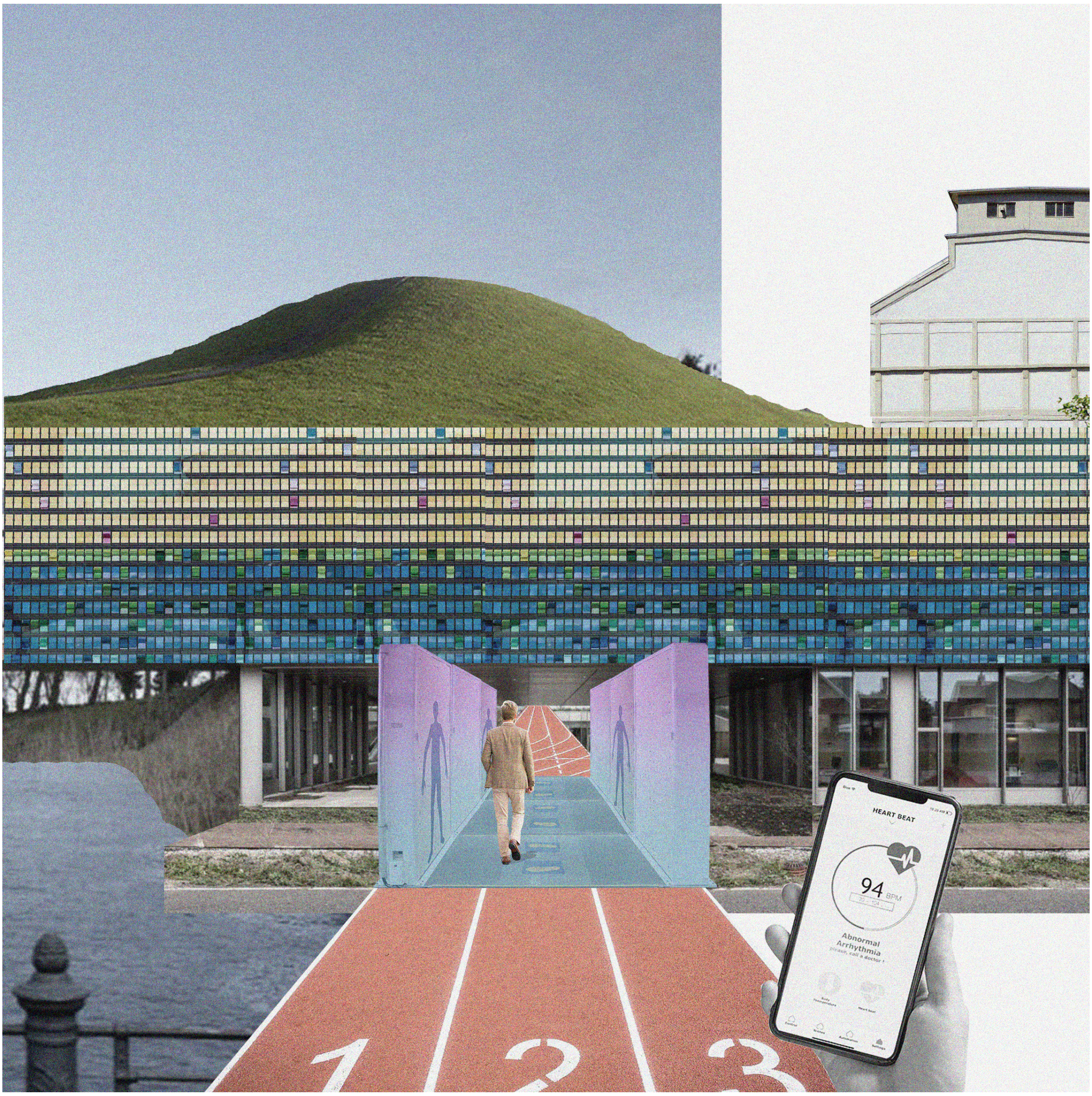


COMPLEX PROJECTS

TWIN ANATOMY

Hospital of a Human Data Twin

Project Book

Sumeet Joshi

TUDelft

2023-2024

COMPLEX PROJECTS

Berlin studio
Bodies & Building

Studio
AR3CP010
AR4CP010

Student
Joshi Sumeet (5823498)

Chair
Kees Kaan

CP studio coordinator
Hrvoje Smidihen

Main Tutor
Olindo Caso

Building Technology Tutor
Jan van de Voort

Third Tutor
Martin Grech

Research tutor
Georg Vrachliotis

INDEX

INTRODUCTION

01

Thesis topic

Experiences within a city emerge from a dialogue between its inhabitants and the buildings situated in the urban landscape. As daily users, we often navigate through different buildings, each providing space, light, and shelter for specific activities. The design of these buildings is rendered by specific needs of the bodies (users in this case) correlated to movement, measures, safety, and security, thus influencing the overall experiences of the activities. In our current information-centric society, where data holds a pivotal role, bodies are perceived as data producers regulating the demand for the buildings to be more efficient and functional at the same time. Consequently, these dynamics are contributing to the increased complexity in designing public buildings. Hospitals, as highly specialized and function-specific structures, are significantly impacted by the information society.

The focus of the graduation project is the development of a hospital tailored for a concept known as the 'Human Data Twin'. This project is based in Berlin and seeks to delve into the effects of digitalization in healthcare, specifically examining how datasets and artificial intelligence (AI) influence the architectural design and functions of hospitals. The term 'Human Data Twin' refers to a unique concept that requires further exploration, emphasizing the fusion of digitalization, healthcare, and innovative design principles in our project

The project holds significant relevance in the current context, drawing inspiration from near-future predictions of technological advancements in healthcare. The envisioned transformation from generalized to personalized and percision medication, facilitated by data science and technology, forms the crux of the project. By doing so, the project is poised to spark discussions around the imperative nature collaborating with technologies like Artificial Intelligence that will reflect change in the hospital functions, processes and design. This discourse will also shed light on ethical challenges and considerations inherent in such advancements. In a broader sense, the project aspires to establish guidelines for designing hospitals of the digital future.

Figure 1: (left)
The Oakland Municipal Auditorium is being used as a temporary hospital with volunteer nurses from the American Red Cross tending the sick there during the influenza pandemic of 1918, Oakland, California, 1918.
(Photo by Underwood Archives/Getty Images)

The poised problem

A century apart, two global pandemics share a common thread—seasonal viruses transmitted through breath, coughs, and sneezes. Despite the vast strides in medical innovation and information dissemination, millions of lives have been lost in both instances. This poignant parallel underscores the persistent challenges in combating infectious diseases and highlights the ongoing urgency for global health preparedness.

As per the Oxford Dictionary, a 'Hospital' is defined as an institution that provides medical and surgical treatment along with nursing care for sick or injured individuals. In this traditional hospital model of 'cure and care', individuals seek medical attention only when afflicted by illness, injury, or diseases. Hospitals play a crucial role in cities, serving as spaces for recovery, rehabilitation, and even the rejuvenation of human life, but all within its institutional boundaries *(figure. 3)*. The health datasets of individuals collected by hospitals are primarily used to understand the patient's medical history and address any immediate medical conditions. However, the health datasets hold the potential for much broader applications in information society, offering possibilities for holistic care preventing diseases, disorders, and undiagnosed deaths.

Despite Germany's worldwide reputation for advanced medical care, a recent study highlights that a substantial portion of deaths in the country is primarily attributed to progressive diseases caused due to changes in body metabolism. The onset of the COVID-19 pandemic also underscored the limitations of the 'cure and care' model, leading to significant loss of lives—both due to the acute illness of the virus and delays in detection, reporting and diagnosis. Hospitals that once used to be social institutions known for care are now merely perceived as healing machines.

Figure 2: (right)
Staff members spray disinfectant at a residential community to prevent the spread of COVID-19 in Yuhua District, Shijiazhuang, north China's Hebei Province, Jan. 24, 2021. (Xinhua/Zhu Xudong)

Today, data is produced, processed, and consumed at every step. Individuals are placing a greater emphasis on their health and are willing to equip themselves with Internet of Things (IoT) devices, such as health watches or other body sensors, to keep track of their well-being. A study from 2021 shows that German health apps recorded a new high of 2.4 million downloads per quarter. Howver the health data generated by the IOT's does not have a recevier's end which can analyse, study and respond back with valued information *(figure. 4)*.

The demand for personalized healthcare and big data generation presents an opportunity for hospitals to establish a smart healthcare system, transitioning from a 'cure and care' to a 'care first' model, extending assistance beyond institutional boundaries.

Modern data management and Artificial Intelligence (AI) enable a comprehensive diagnostic approach, encompassing descriptive analytics for reviewing medical records, diagnostic analytics to analyze current conditions, predictive analytics for forecasting patient risks, prescriptive analytics suggesting treatments, and discovery analytics exploring unknown medical trends[1].

Technological strides now allow the digitization of the human body, forming a Human Data Twin (HDT) in cyberspace synced through an implanted IoT device. The HDT conducts real-time simulations, optimizations, and evaluations, providing personalized suggestions to empower individuals in making informed decisions, enhancing health performance, and extending life expectancy.

This healthcare transformation not only reshapes personal well-being but prompts a reevaluation of hospital architecture, signaling the emergence of institutions designed for the information age that recognise the interplay between data-driven healthcare advancements and evolving societal needs.

1. Mohamed, K. (2018). Health Analytics Types, Functions and Levels: A Review of Literature. Data, Informatics and Technology: An Inspiration for Improved Healthcare, 137-140.

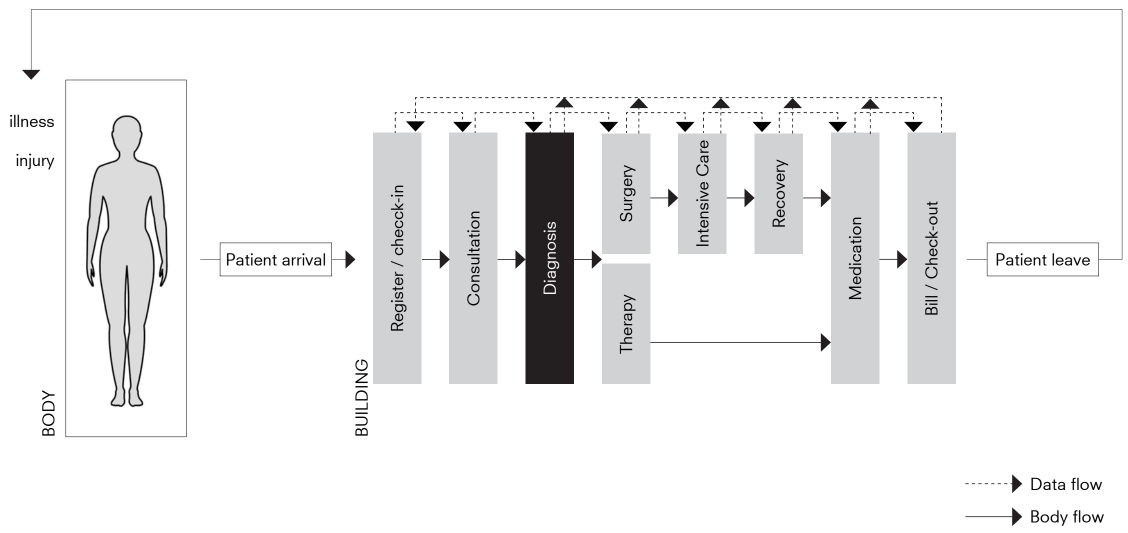


Figure 3: Cure & Care Model; *graphic by author*

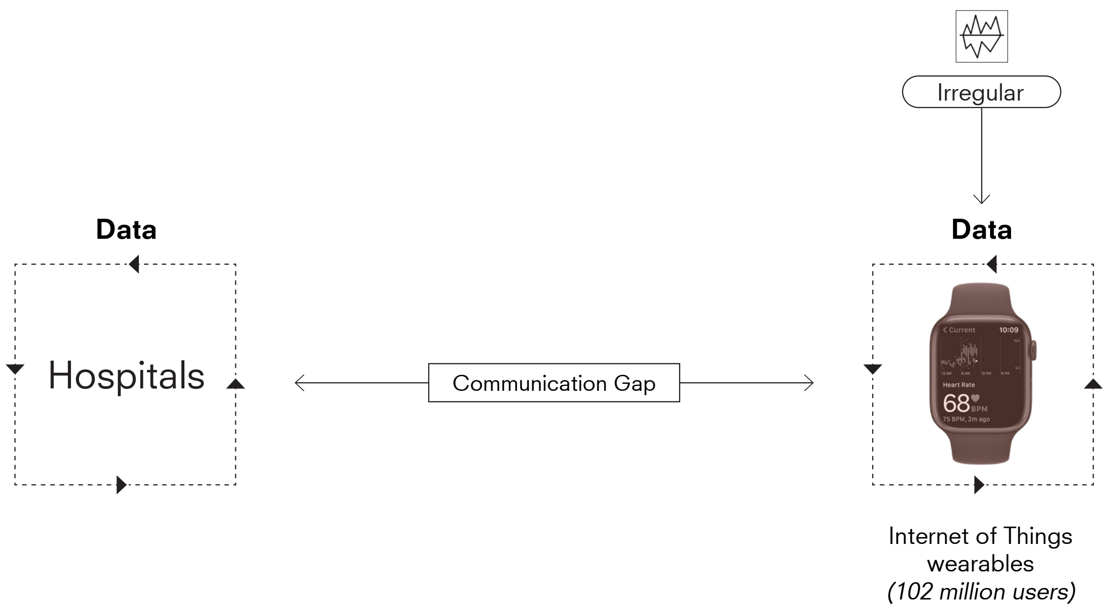


Figure 4: Health data communication gap; *graphic by author*

Research Question

Hospitals, as public buildings, establish connections with people in ways unparalleled by other structures. The architecture of a hospital directly influences its functionality, exerting a profound impact on the delicate balance between life and death. In the contemporary information society, where the body is conceptualized more as a collection of data for tracking individuals' health, the pendulum shifts decisively toward life.

The transformative approach to healthcare through digitization has extensive implications, potentially necessitating the creation of new spaces within the hospital. Research indicates that the Artificial Intelligence revolution in medicine introduces new dynamics to spatial relations in the diagnostic process, where AI is likely to play a key role. The architectural design of hospitals also calls for reappraisal, presenting an opportunity to promote health, physical activities, and mental well-being of the society. The findings culminate into a research question:

How does the digitization of the human body in the information society, impact the architectural and spatial design of hospitals?

In this context, architecture investigates changes in form, functions, spaces, configurations, while spatial design responds to alterations in processes, arrangements, interactions, and flows.

RESEARCH FRAMEWORK

02

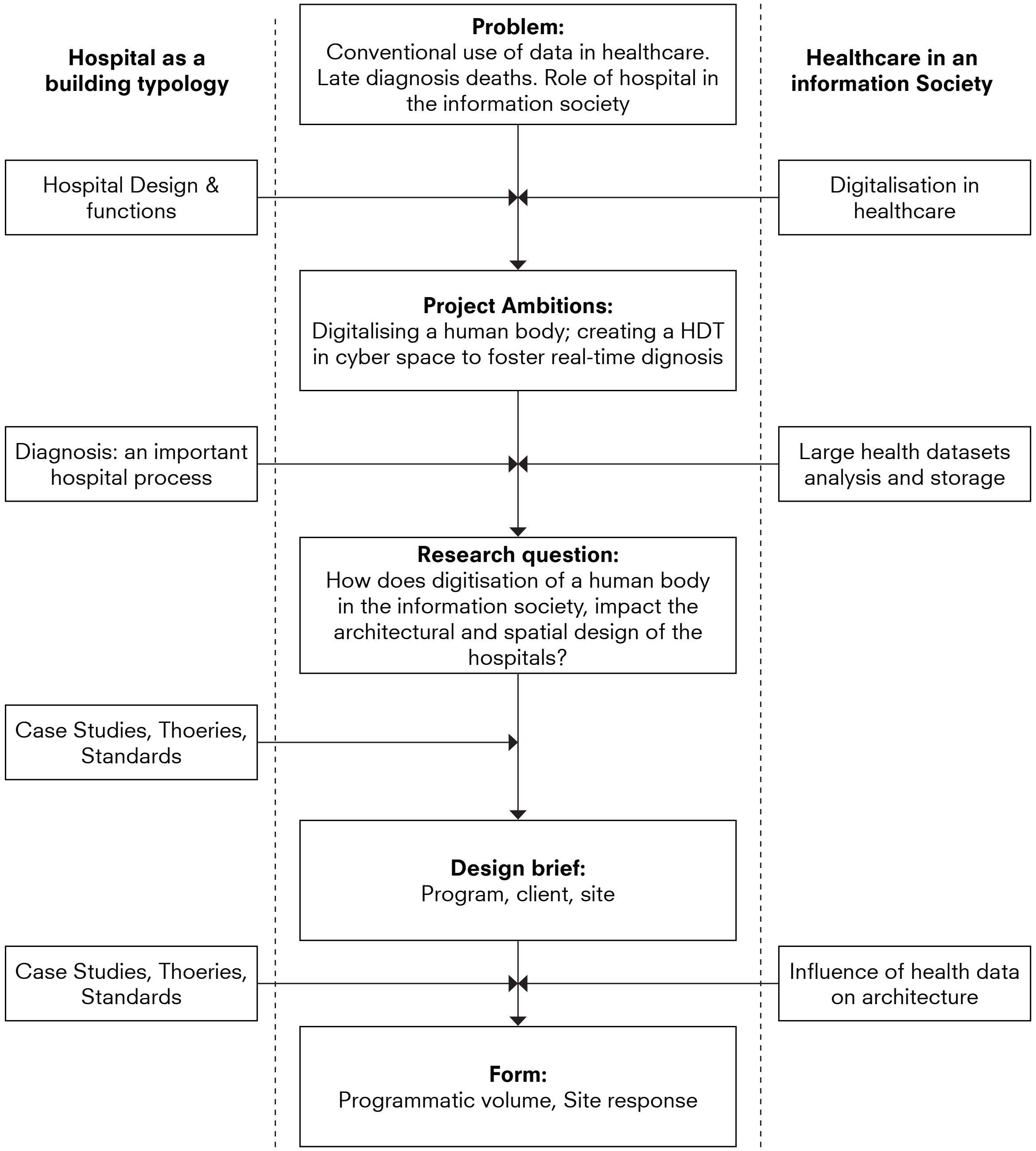


Figure 5: Diagram for Theoratical Framework; *graphic by author*

Theoratical framework

The research employs two lenses during the literature review to investigate:

1. Hospital as a building typology: This lens is utilized to understand hospital processes and functioning, examining the design evolution in terms of form, flows and efficiency.

2. Healthcare in an information Society: This lens explores the impact of digitalization and data on the functioning of public buildings.

In the book, "Hospitals: A Design Manual," the author describes the distribution of healthcare facilities, where centralization and decentralization strategies could be employed to create a hospital network, preventing the demolition of existing hospital buildings[1].

The theoretical framework *(see figure. 4)* aims to adopt methodological approach to understand the hopsital typlogoy from a city lens to the building scale.

Relevance

1. Early diagnosis: Studies show that late diagnosis and delays in reporting cause 75% of fatalities for cancer and other diseases.

2. Expert patients: With the rise of the Internet of Things, individuals are equipped with wearables that help them stay well-informed about their bodies. Studies show a rise in health download apps and an increase in telemedicine consultations.

3. Digital health care: The German Federal Ministry of Health is driving the digital transformation of healthcare system. The large health datasets will be governed by the government for security and an open data society, aligning with the goals of the Federal Ministry of Digital Infrastructure.

1. Wagenaar, C. e. (2018). Hospitals : A Design Manual. Walter de Gruyter GmbH. Retrieved from http://ebookcentral.proquest.com/lib/delft/detail.action?docID=5155807.

Research Methods

The graduation studio works simultaneously with both individual research and group research. A prevalent theme of digitalization is discussed and explored within the group, with the aim of formulating a digital strategy for Berlin. The research conducted by both the group and individuals mutually enhances each other's work, contributing to a shared outcome.

Program

Literature study

The literature study aims to gain deeper understanding of the key spaces, medical inventory used for diagnosis and treatments *(see figure. 6)*. It further aims to study different flows of varied users in a hospital evaluate the impact of digitalisation on it. The research also seeks to grasp the concept of the Human Digital Twin and the efficiency it can bring to the medical process.

Additionally, the study involves an examination of German and European guidelines for hospital buildings and current developments in information society.

Furthermore, within the group vision, there is an exploration of data centers and the role they play in an urban city, with the objective of identifying potential strategic changes for data centers. One proposed change is their inclusion in public buildings as architectural elements.

Case study

Benchmakring case studies will be undertaken to develop a progam for the hospital project, which wil also help gain a better understanding of the the spatial planning, and traffic flows in a hospital.

Key space study

The functions in hospital buildings are specific and require dedicated spaces. A thorough understanding of key spaces, such as operating rooms, examination rooms, and patient rooms, will be undertaken to implement necessary changes in this project. A key assessment of diagnostic processes, equipment, and functions will be carried out to gain better insights into these procedures, as the project primarily focuses on diagnosis.

Client

The project is envisioned as a public-private partnership to ensure equal authority over the data produced within the building. The client search will conducted over the internet and also by contacting the private partners to know more bout the technological advancements. The clients will be identifined based on the following requirements:

1. Technology for the future of medicine:
Identifying pioneering companies dedicated to advancing Human Digital Twin (HDT) technology.

2. State owned hospital group:
Given the need for widespread availability, a state-owned hospital group is sought to ensure affordability and accessibility of the services.

3. Data security:
To align with open data objectives and ensure responsible data usage, the involvement of a federal ministry is deemed necessary.

Client Ambitions

As architects, we mostly design buildings for clients. This is why we need to understand the client and bring their ambitions to the table. This approach not only helps to generate interesting ideas for the project but also ensures that the design is functional for its typology .

Site

Mapping

A GIS mapping of specific datasets for Berlin will be layered to align with the three group site criteria for the urban vision. Additionally, three individual building typology criteria will be defined, and map layers for each will be produced. Based on the defined parameters, and superimposition of parameters layers, the three sites will be identified.

Site visit

A visit to all of the identified sites will be conducted during the studio excursion to Berlin. Photo documentation and mapping of site activities will be carried out.

Site analysis

The identified site will be analyzed in terms of its urban position, land use, connectivity to existing transport nodes, and current conditions. Given Berlin's rich historical presence, the site's history will also be examined to gain more insights into its usage. Based on this analysis, a strategy will be proposed for the site's development.

RESEARCH

03

Religious & Charitable institutions

Asklepiea 350 BC

Temple of Aesculapius at Epidaurus, Greece

Xenodochium 325 AD

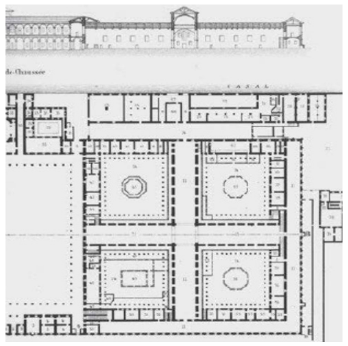
Care of the Sick, Domenico di Bartolo, Roman

Hotel-Dieu 816 AD

'Hotel-Dieu', France

Public institutions

Civilian hospital 1400-1700

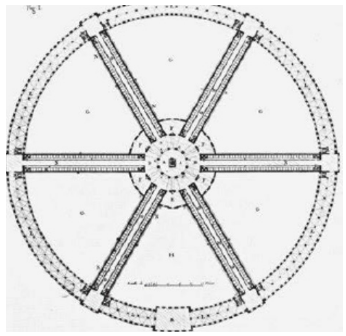


Ospedale Maggiore, Milan

Teaching hospital 1400-1700

Charite Berlin, Germany

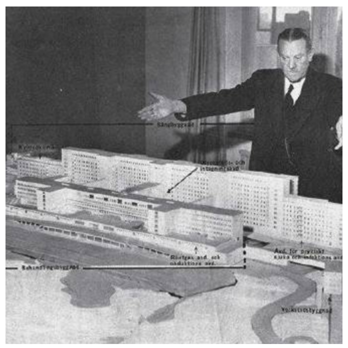
Machine a Guerir 1700-1900



Proposal for Hotel Dieu, Antoine Petit

Machines & Medicine & Innovation

Hospital flows 1930



Sodersjukhuset, Stockholm

Speciality hospital 1940

Paimio Sanatorium, Alvar Aalto

Hospital flexibility 1970

Hvidovre hospital, Denmark

Figure 5: Evolution of Hospitals; *graphic by author*

Hospital as a Public Service

Throughout their millennial history, hospitals have served diverse functions, functioning as shelters for the poor, hostels for pilgrims, hospices for the elderly and marginalized, and healing centres for both acute and chronic illnesses. These institutions held a crucial position in communities, evident in the presence of a hospital in each city and a town. The hospital model, initially evolved during the Christian age in Europe, was disseminated worldwide by Christian missionaries since the sixteenth century, establishing itself as a public and charity institutions and finally as independent buildings[1].

In the Middle Ages, hospitals served as vital social institutions, focusing on the care of the impoverished who fell ill. Providing basic necessities such as food and shelter, these hospitals, although symbolic and adorned with art, offered limited treatment options. Despite their grandeur, they functioned more as almshouses than advanced medical centers.

It was only in the late 19th century that hospitals transformed into providers of top-notch medical care. This shift was spurred by advancements like Röntgen's X-ray machine in 1897, compelling patients to seek treatment directly at these evolving medical institutions. With every medical invention, the complexity of flows and processes in hospital became crucial to consider. This also affected the building form of the hopsital, which progrssed towards more effciency. Sodersjukhuset, in Stockhlom was one of the first hospital to grow vertical with an intention to categoires flows in a hospital. Soon enough, these complexes started becoming, monotonous machines for treatments, while moving away from the aspect of patient care.

This created a prevailing trend that indicates a decreasing lifespan of a hospital as they enter in the information society, posing challenges that require a reassessment of the future of hospital typology *(figure. 6)*. In the coming decades, the conventional hospital as we currently recognize it could potentially cease to exist, and the connotation of the term might undergo significant transformations[2].

1. Riva , M. A., & Cesana, G. (2013). The charity and the care: the origin and the evolution of hospitals. European Journal of Internal Medicine, 24, 1-4. doi:https://doi.org/10.1016/j.ejim.2012.11.002

2. Wagenaar, C. e. (2018). Hospitals : A Design Manual. Walter de Gruyter GmbH. Retrieved from http://ebookcentral.proquest.com/lib/delft/detail.action?docID=5155807.

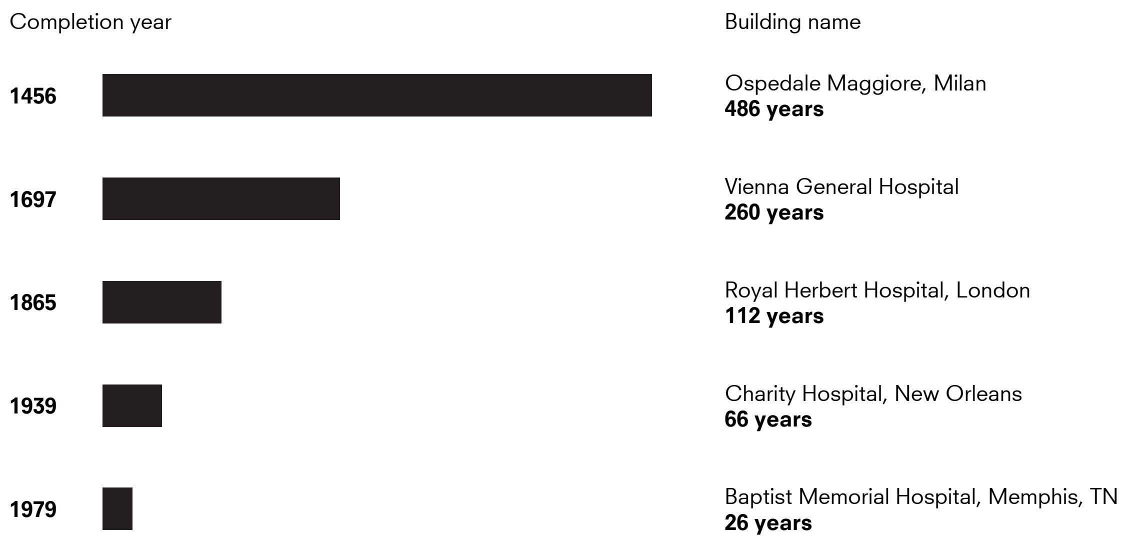


Figure 6: Life of a hospital; *graphic by author*

Healthcare in Information Society

Today, the hospital is regarded as a cornerstone of modern medicine. While the lifespan of hospitals may be on a downward trend, medical innovations continue to rise. With each medical discovery, the hepsital processes and functions. With every new breakthrogh, different treatements, scopes and medcial information doubles up, that requires a deeper study of things. Technologies are developed to bring effcieny and preceision in human taks. However, each of these technology is carefully crafted to do particular task only. For example, to diagnose a heart, a Electrocardiogram is required, where as to diagnose other internal body organs or bones, a medical ultrasound or a MRI is required. But today, with the evlution of AI, the technologies can be developed with an intention to solve multiple taks at one, using a machine learning algorithm. The advent of the AI revolution, impacting various sectors, is also significantly influencing healthcare. Hospitals play a pivotal role in the healthcare system, designed to improve public health. This improvement is ultimately gauged by statistical data derived from diagnoses and other parameters used to define the quality of life and life expectancy.

Currently, this data is utilized exclusively within the healthcare system, focusing on curing diseases first and then addressing patient care. However, in today's information society, where data serves as the language of information, there is an opportunity to transition from patient-centered care to involving patients in their own care. With the proliferation of Internet of Things (IoT) devices, such as Apple devices collecting real-time data like ECG, patients can be better informed. However, the wearables can produce irregular data, the "Twin Anatomy" emphaises the implatation of a sync device (IoT) and the human body to acquire constant and regular data.

The analysis and monitoring of this data can provide personalized feedback to users, and this is where AI can streamline the process. GPT-4, for instance, can respond to medical queries from both patients and professionals, generate summaries or reports from medical records, aid doctors or nurses in clinical decisions, ultimately empowering individuals, and democratizing access to medical knowledge[1]. In the data based flow, a hopsital empowers itself and the users to care first and then cure if nedeed, instead of focusing of the traditional model of cure and care (*figure. 7).*

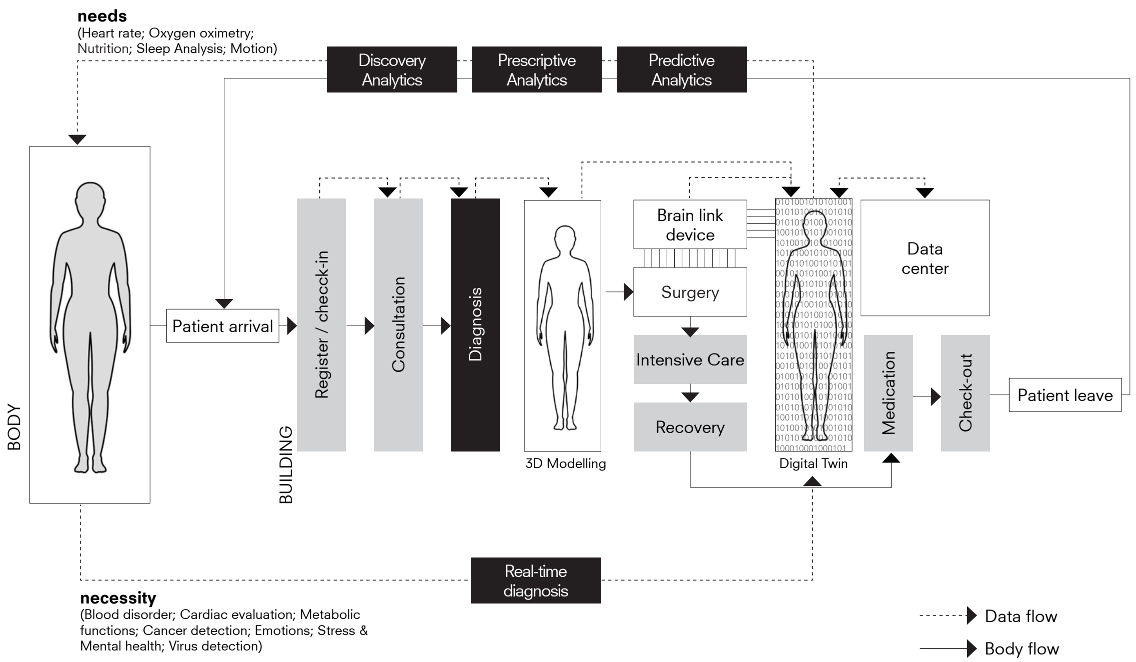


Figure 7: Care First Model; *graphic by author*

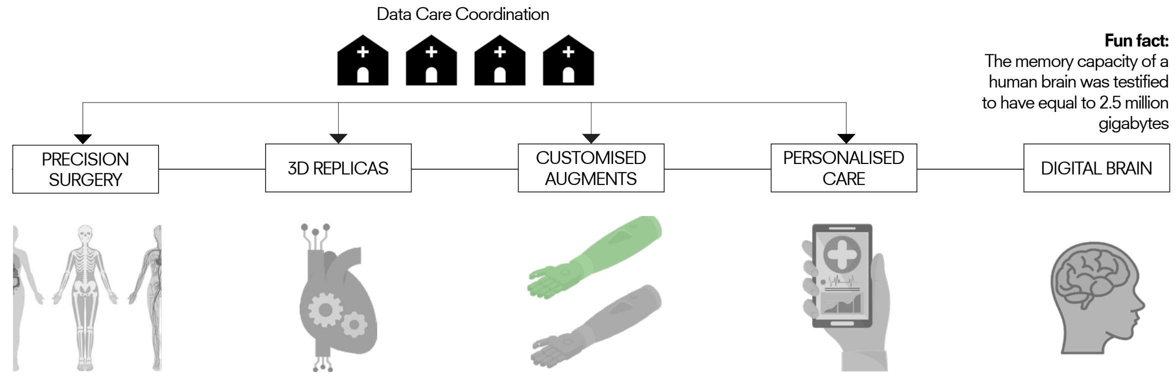


Figure 8: Possibilities of Digitising a Human Body; *graphic by author*

This shift has the potential to redefine the role of hospitals, providing precision medicine and prioritizing preventive care to avert the onset of diseases.

Medical possibilites

Digitizing the human body opens up a vast array of possibilities for various medical and technological processes (*figure. 8)*. Here are some of the key applications:

Precision Surgey: Before surgery, detailed 3D printed models of a patient's anatomy can be created. These models allow surgeons to plan and practice procedures with a high degree of precision, reducing risks and improving outcomes.

3D Replicas: Digital body data can be used to create 3D bioprinted organs for transplantation. This technology holds the potential to address organ shortages and provide perfectly matched organs for patients, reducing the risk of rejection.

Customised Augments: Exact replicas of skin tissues and other body parts can be created using 3D printing technology. This allows for the production of highly customized prosthetics that fit and function better than traditional options.

Personalised Care: Digital body data enables personalized healthcare management in terms of nutrition and fitness. Real-time monitoring and analysis help in creating customized diet and exercise plans, promoting overall wellness and preventive care.

Digital brain: The human brain's memory capacity is estimated to be equivalent to 2.5 million gigabytes. Digitizing brain memory can provide extensive data storage solutions, potentially allowing for the preservation and transfer of personal memories and cognitive functions.

All of this digital data can be shared and exchanged with other hospitals through the Twin Anatomy Institute. This institute would act as a central hub for data care coordination, ensuring seamless and secure sharing of patient data. This exchange of information would facilitate collaborative care, enhance research opportunities, and improve healthcare delivery across institutions

1. Lee, P. a. (2023). The AI revolution in medicine: GPT-4 and beyond. Pearson.

Human Data Twin

In the near future, an innovative technology called the "Human Data Twin (HDT)" will revolutionize healthcare sector, by creating a digital replica of an individual's biological and physiological data within cyberspace. As discussed in pervious sections, the concept of Human Data Twn can revolutionise the way diagnosis is performed, enabling us to predict, prescribe and prevent for the future. The goals of HDTs in healthcare include: Improved patient outcomes, Enhanced drug development and efficacy, Reduced healthcare costs, Increased understanding of disease mechanisms.

This cyber twin will require continuous input of health data, including metabolic and physical changes, to provide real-time diagnoses and health insights.

Metabolic Changes:
Blood and Mental Health
For the Human Data Twin to accurately reflect an individual's metabolic changes, it will need constant updates on various health parameters. This includes data from blood tests, such as glucose levels, cholesterol, and other biomarkers, as well as indicators of mental health, such as neurotransmitter levels and hormonal balance. To facilitate this continuous data flow, individuals will need to undergo a synchronization device implant surgery (*figure. 9*). This implant will serve as a communication link between the person's body and their cyber twin, enabling seamless data transfer and real-time monitoring.

Physical Changes:
Bones, Tissues, and Organs
Equally important to the metabolic data are the physical changes occurring in a person's body. These include alterations in bones, tissues, and organs. For the Human Data Twin to function effectively, it must be equipped with up-to-date information on these physical changes (*figure. 10*). Currently, imaging techniques like CT scans and MRI are used to gather this data. However, the frequency and necessity of these scans pose significant challenges.

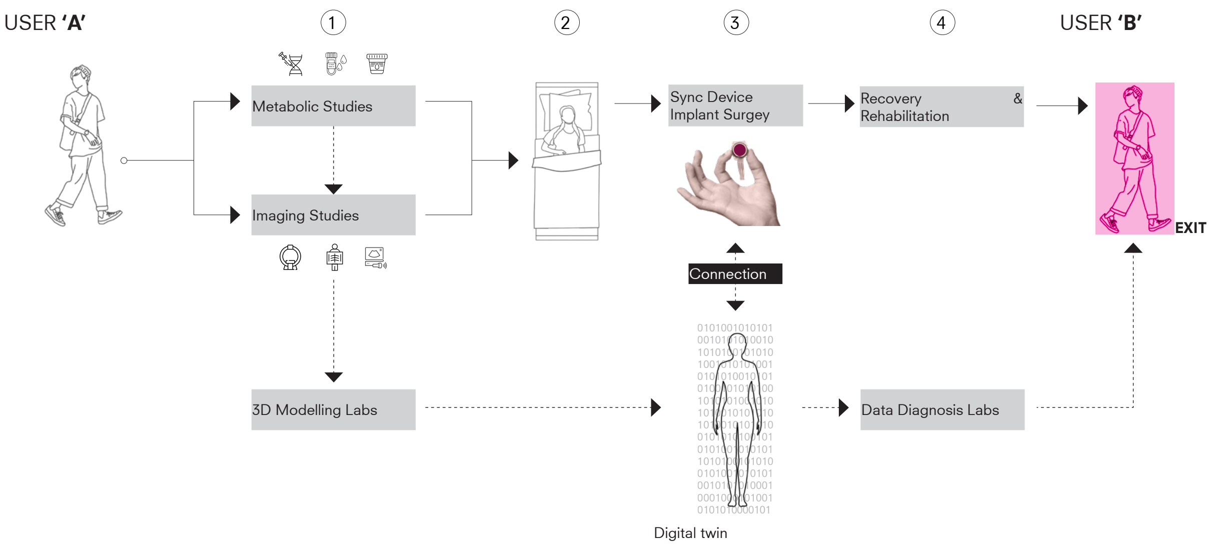


Figure 9: An iterative process diagram; *graphic by author*

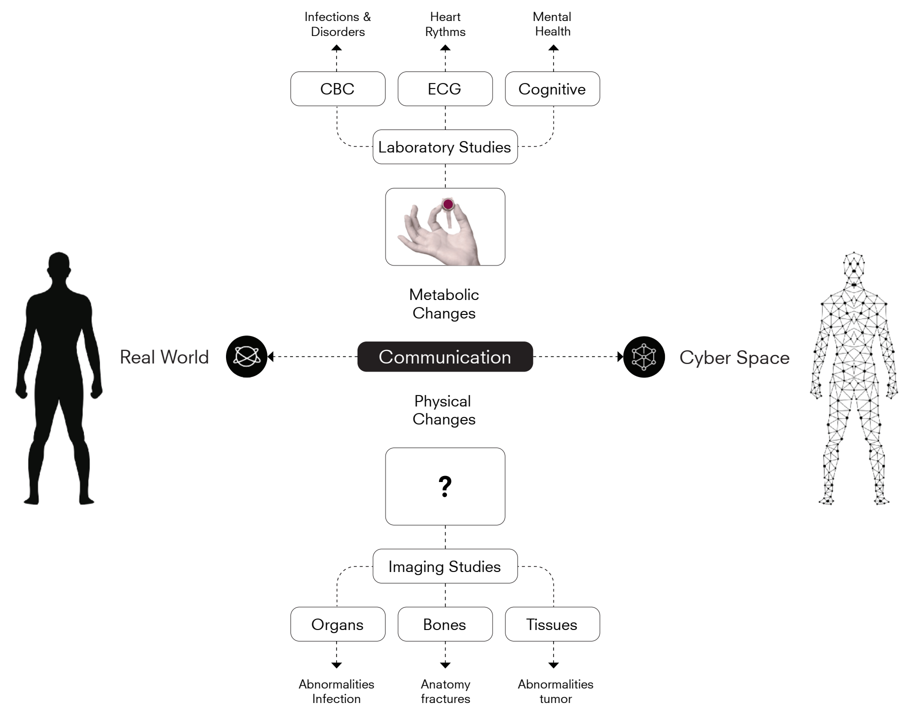


Figure 10: Human Twin Connection Diagram; *graphic by author*

Imaging Techniques and Public Access
The advanced imaging techniques required to monitor physical changes, such as CT scans and MRIs, are often privatized and protected by medical institutions *figure. 11)*. Despite their critical role in the Human Data Twin technology, the cost and limited accessibility of these machines can hinder the frequent use needed for accurate real-time diagnosis. Therefore, there is an urgent need to re-evaluate the design and deployment of these imaging technologies.

To meet the demands of the Human Data Twin technology, CT scans, MRIs, and other essential imaging tools should be made more accessible. This could involve integrating these technologies into the public healthcare domain, reducing costs, and ensuring they are available for frequent use. Additionally, redesigning these machines for more efficient and user-friendly operation can further support the widespread implementation of the Human Data Twin.

The project is a hospital building that could facilitate the communication between a Data Twin in cyber world and Body in real world. By addressing these challenges and making the necessary technological advancements, the Human Data Twin can become a powerful tool in personalized healthcare, offering real-time diagnoses and comprehensive health insights that can significantly improve medical outcomes and overall well-being.

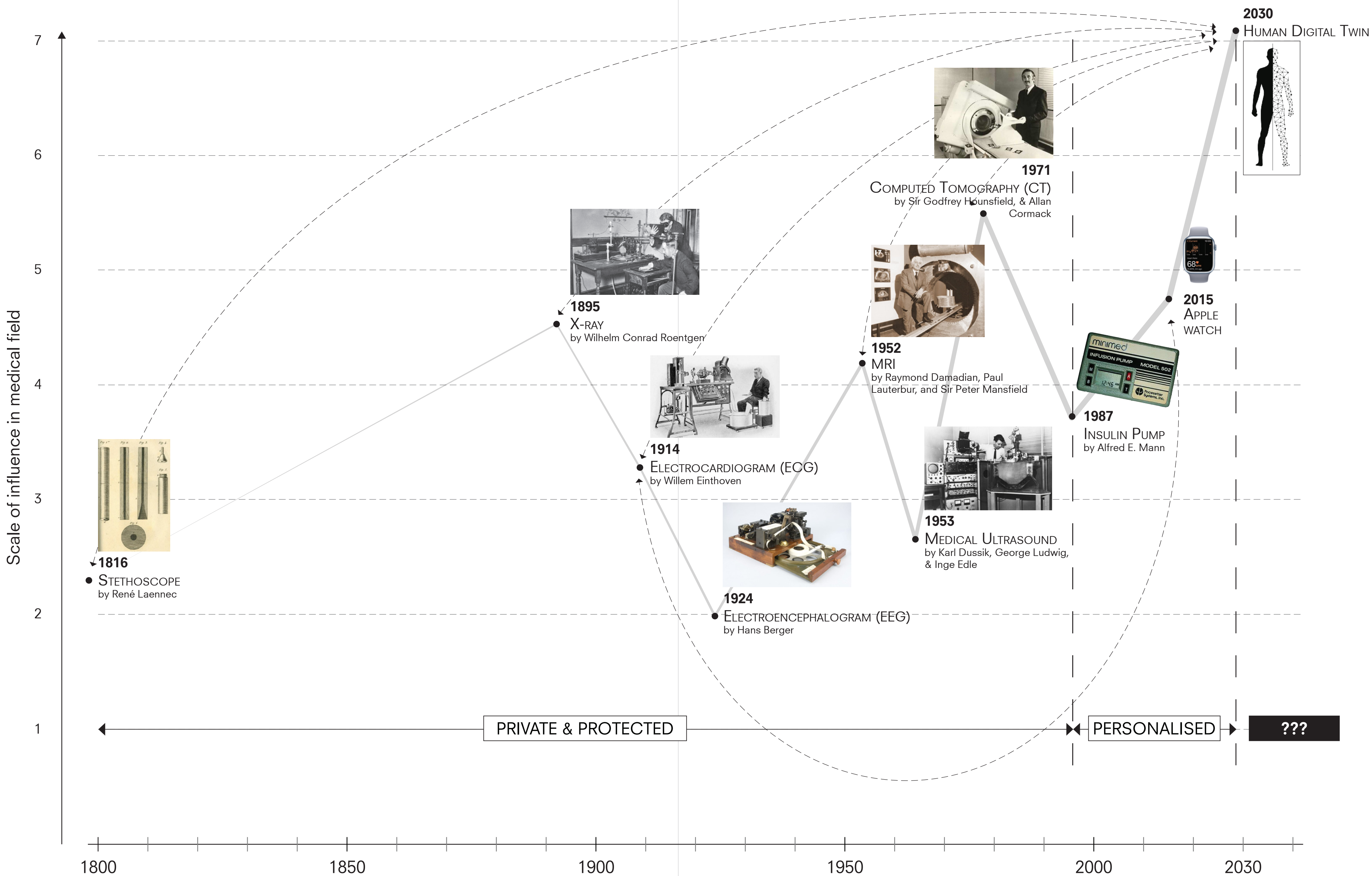


Figure 11: Breakthrough inventions for diagnosis; *graphic by author*

DESIGN BRIEF

04

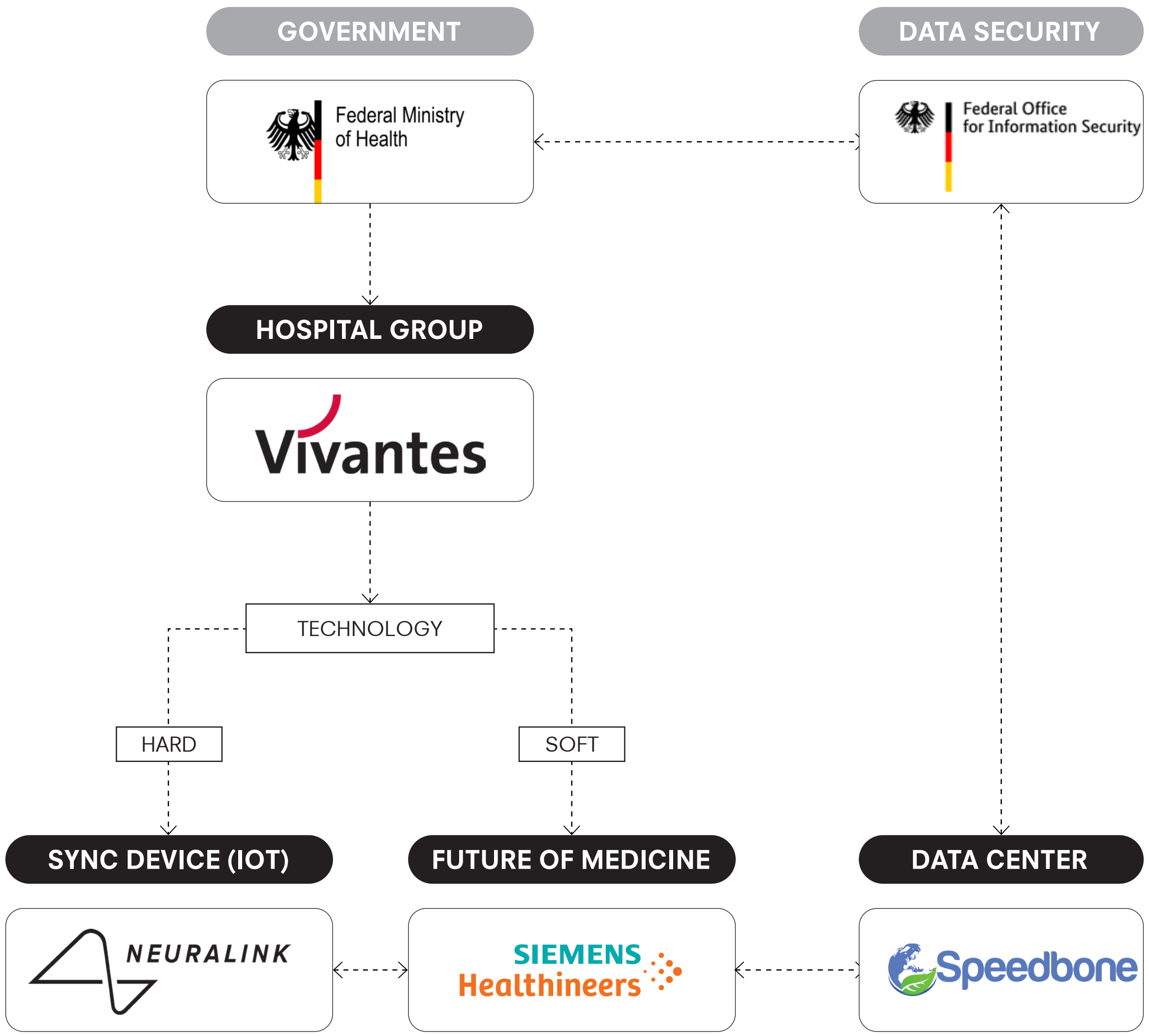


Figure 12: Client relation diagram; *graphic by author*

Client

The Federal ministry of Health together with the Fedral ministry of Information security in Germany, are willing to realise the project. Since its government initiative, the main client would be the state own hopsital group. A client heirarchy tree is show in *figure. 12.*

1. Hospital group:
Vivantes hospital Group is a state-owned healthcare company operating hospitals in Berlin. The company currently runs 10 hospitals with a total capacity of about 6,000 beds and more than 17,000 employees. A state-owned hospital group will allow for cost control of the new medical services.

2. Future of medicine:
The potential client to approach for the technology would be Siemens, who already have initiated research in Human Data Twin. The company specializes in developing and manufacturing medical devices, diagnostic equipment, and healthcare information technology. Siemens Healthineers is known for its innovative solutions in the fields of medical imaging, laboratory diagnostics, and advanced therapies.

3. Sync device (IOT):
The potential client to approach for the IOT device would be Neuralink. The company's resarch specialises to enable direct communication between the human brain and external devices, fostering advancements in the field of neuroscience and potentially addressing neurological conditions.

4. Data Center:
The large health datasets needs to be stored on campus for improved latency and reliability. Speedbone GmbH is a German Company located in Berlin. It provides internet services and colocation racks for other private companies. The company runs of a 100% energy from water, wind and sun.

4. Data Security:
Bundesamt für Sicherheit in der Informationstechnik or BSI in Germany is the national cybersecurity agency responsible for ensuring information security at the federal level. The involvement of a federal ministry as a client will become crucial in securing the health data and also to facilitate a open data society.

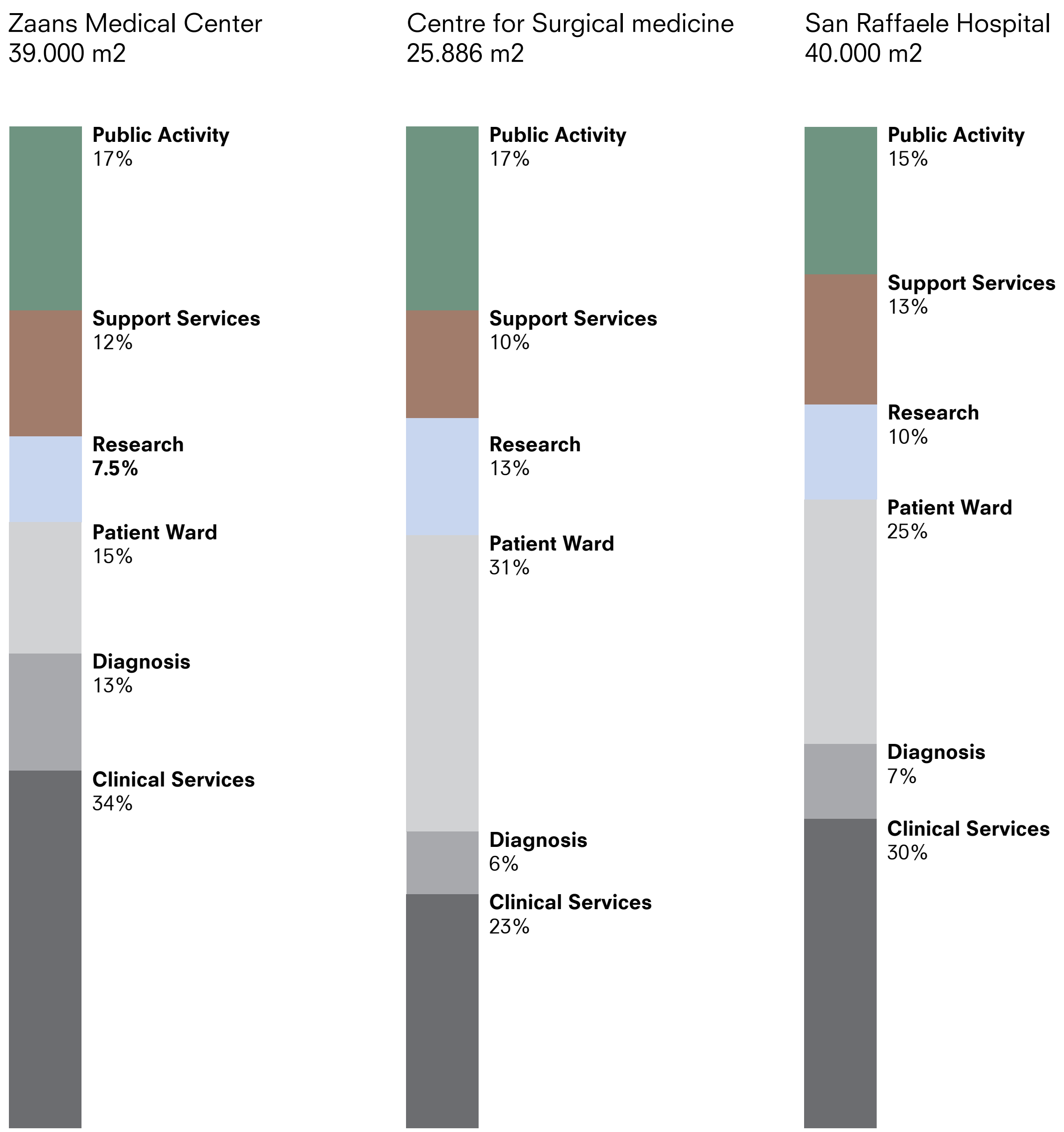


Figure 9: Case study program relation; *graphic by author*

Program

Hospitals are typically categorized based on their bed capacity: a large-sized hospital, often referred to as a Medical Complex, has more than 500 beds; a medium-sized hospital, known as a general or specialty hospital, falls within the range of 100 to 500 beds; and a small-sized hospital, resembling a clinic, has fewer than 100 beds.

To achieve this, three case studies focusing on a medium sized hopsital are conducted, with the goal of examining the percentage volume distribution of various spaces within a hospital building. Special attention is given to determining the proportion of the diagnosis department within the overall building program. The comparative analysis across these case studies aims to establish a new benchmark for the proposed hospital, providing clarity on its spatial organization.

Program bar

The building programs are categorised into four areas:

1. Public spaces: This includes the public movement area along with other amenities such as cafes, restaurants, shops, or additional facilities like a library or a playroom.

2. Support services: This category encompasses back-of-house functions, administration, storage, logistics, and other related spaces.

3. Research areas: The case studies were also selected based on academic or medical research requirements. This category contains office spaces and research labs.

4. Medical services: These constitute the core spaces of a hospital and are further classified into patient ward, diagnostic services, and clinical services.

As previously mentioned, each case study underwent a detailed examination, revealing that diagnostic services constituted a relatively small part of the program *(figure 13)*. This revelation was attributed to the specialization of diagnosis laboratories, each dedicated to specific body parts or organs, ranging from urology and genetic testing to ophthalmology and radiology. Given this specialization, not all laboratories are housed within a single hospital, as hospitals typically focus on specific medical specialties and hence the diagnosis requiremnts in a single hospital building would be less.

However, the advent of big data analytics and the potential for comprehensive health diagnosis through a Human Data Twin (HDT) introduce novel opportunities for digital diagnostics. This emerging field necessitates the creation of dedicated spaces within the healthcare facility. Specifically, areas for data collection, storage, and processing become integral components, akin to a data center's requirements.

In developing these digital diagnostic spaces, various stages of data management must be considered. This includes data cleaning to ensure accuracy, data integration for comprehensive insights, data mining to extract valuable patterns, data fusion for a holistic perspective, and advanced analytics such as data visualization. Ths brings to the last addtion of a key space in the program bar:

5. Data Center: This includes, the data storage, which is crucial for storing and analysing the health datasets.

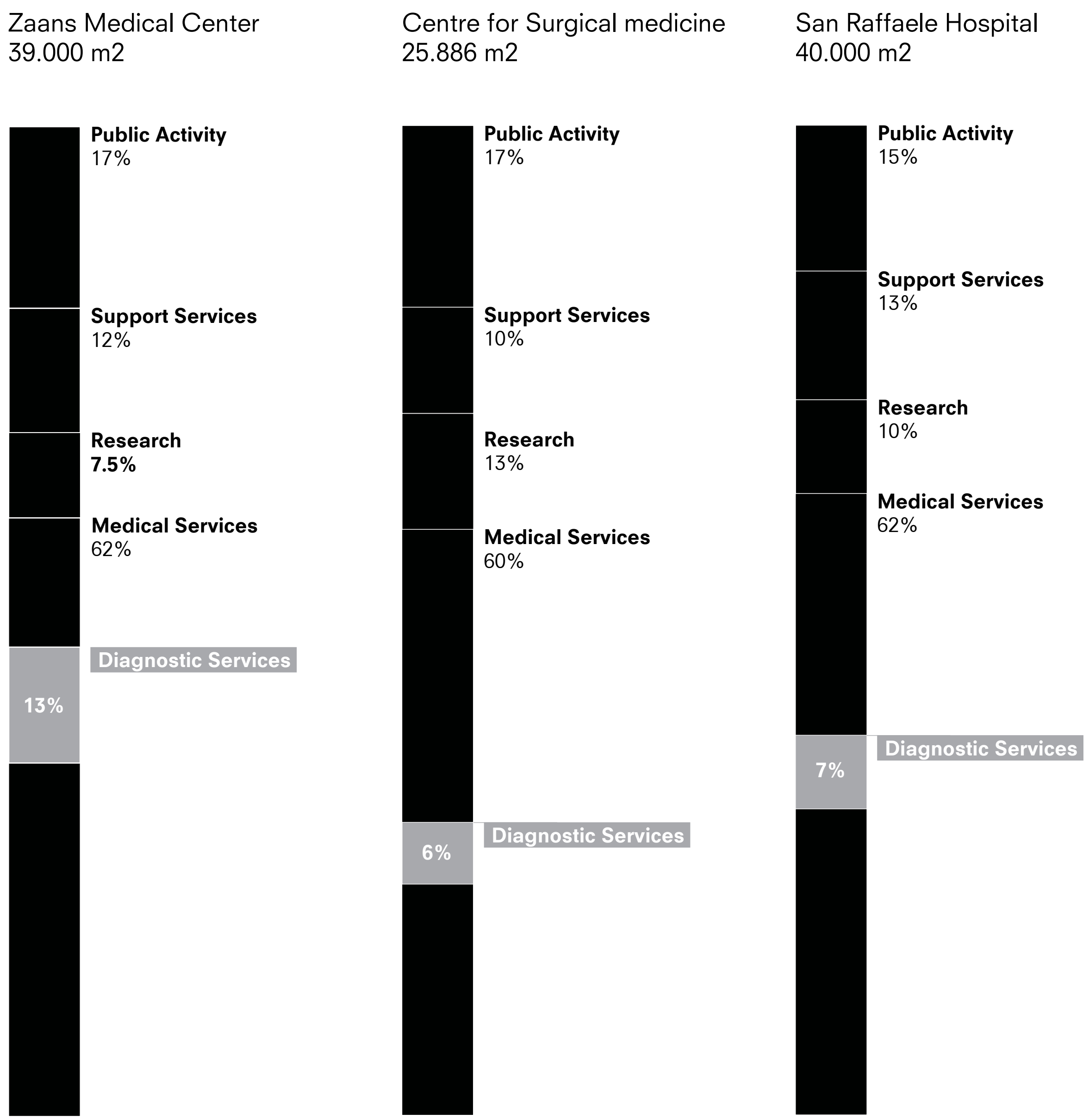
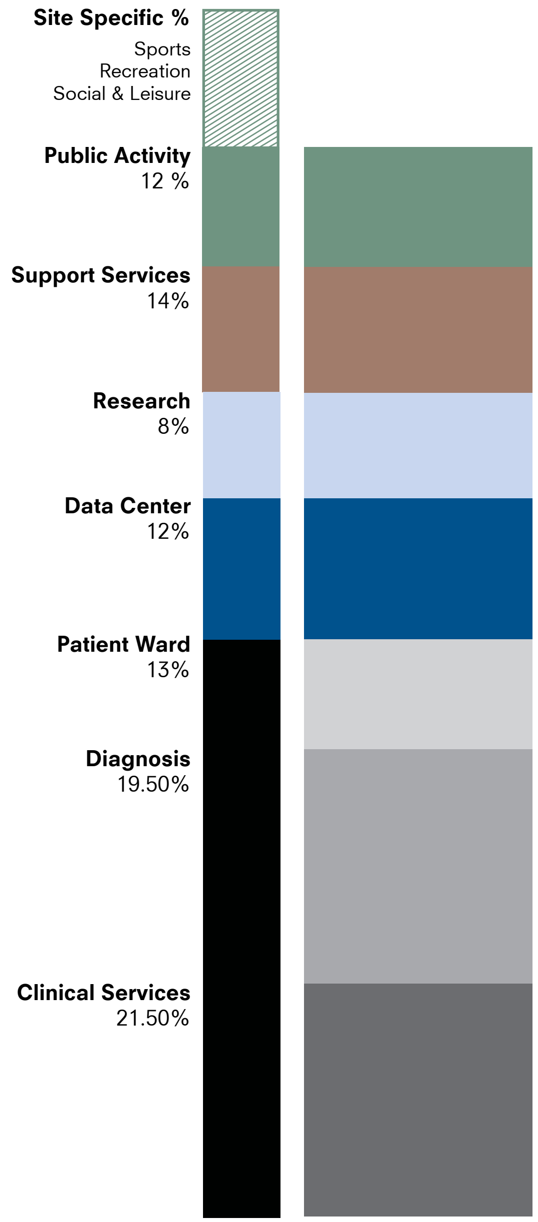
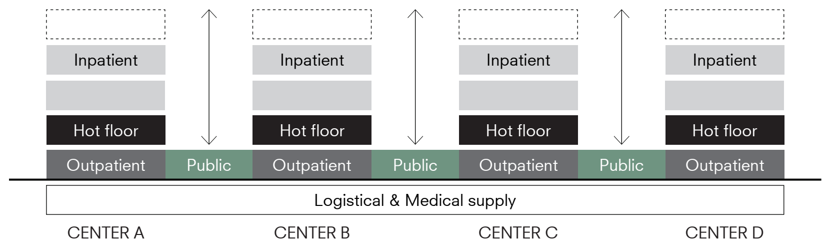


Figure 13: Diagnositc services as small part of program; *graphic by author*

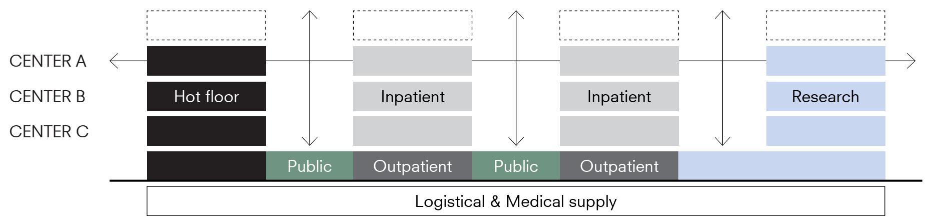
Proposed Program



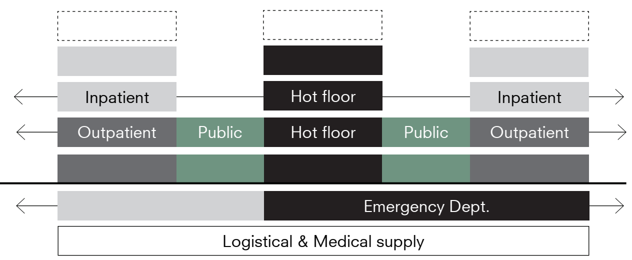
Public Activity	**4450 m2**
Public plaza (Library; Pharmacy)	1500 m2
Cafe; Restaurant	600 m2
Vertical Circulation	2350 m2
Support Services	**5400 m2**
Reception; Administrative office	600 m2
Kitchen; Logistic; Storage; Back of house	1550 m2
CSSD, 3D Printing Lab	1500 m2
Parking	1750 m2
Research	**3150 m2**
Discovery Analytics Labs	1250 m2
Doctors offices and workplace	1250 m2
Auditorium	650 m2
Data Center	**5000 m2**
Data storage racks; Server rooms;	4000 m2
Security & Access control; Regulatory office	500 m2
Break out rooms	500 m2
Patient Ward (100 Beds)	**4750 m2**
Inpatient Rooms	3000 m2
Nursing Station	750 m2
Diagnosis	**7400 m2**
EEG & EMG Labs	1050 m2
Radiology Lab; DNA Lab; Nuclear medicine	1050 m2
Real-time diagnosis department	1250 m2
3D modelling; Brain-Device department	1250 m2
Data collection & processing lab	1400 m2
Data visualisation & analysis lab	1400 m2
Clinical Services	**8350 m2**
Emergency	900 m2
Operational room; Recovery & Holding	1500 m2
Intensive care unit	750 m2
Outpatient clinics	2750 m2
Neurosurgical department	1600 m2
Gross Floor Area	**38.500 m2**



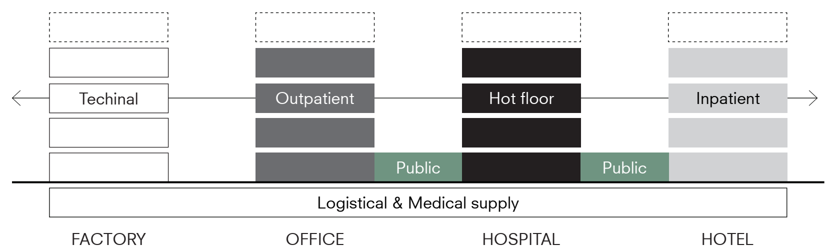
THEME MODEL
FLOW: Vertical
FOCUS: Patient needs



CENTER MODEL
FLOW: Vertical & Hortizontal
FOCUS: Medical processes



THREE FLOW MODEL
FLOW: Horizontal
FOCUS: Patient Traffic



TYPOLOGY MODEL
FLOW: Vertical & Hortizontal
FOCUS: Hospital as a generic building

Figure 14: Zoning and traffic flow theories; *ref. Wagenaar, C. e. (2018). Hospitals : A Design Manual*

Zoning & Traffic Flow

All hospital buildings are compositions of distinctive functional zones connected by their internal traffic structure and logistical layouts, making their organization a crucial aspect of hospital planning.

Several theories regarding zoning and traffic flows have been explored to better understand and implement effective spatial configurations within healthcare facilities *(figure 14)*.

Theme Model:

The Theme Model advocates for the subdivision of the hospital complex based on specific medical conditions or patient groups. The vertical flow is orchestrated to align with patient requirements, ensuring a tailored approach to medical care within distinct thematic zones. This model reflects a patient-centric design philosophy, acknowledging the diverse needs of individuals seeking healthcare services.

Center Model:

In the Center Model, hospital design involves both vertical and horizontal flows, emphasizing multidisciplinary medical processes. The layout is organized around the efficient execution of medical procedures, necessitating a separation of patient and staff traffic flows. This model seeks to streamline medical processes and enhance the overall operational efficiency of the healthcare facility.

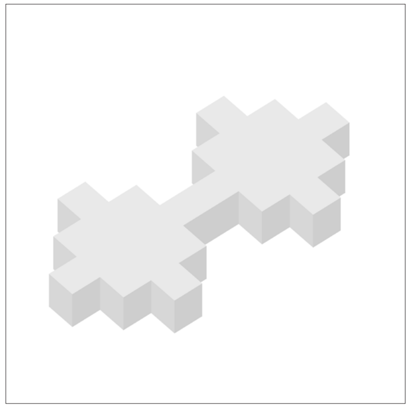
Three Flow Model:

The Three Flow Model strategically differentiates between various patient traffic, emphasizing horizontal flow. It delineates distinct pathways for acute patients, inpatients, and outpatients. This approach optimizes the movement of individuals through the hospital, recognizing the unique requirements and trajectories of different patient groups.

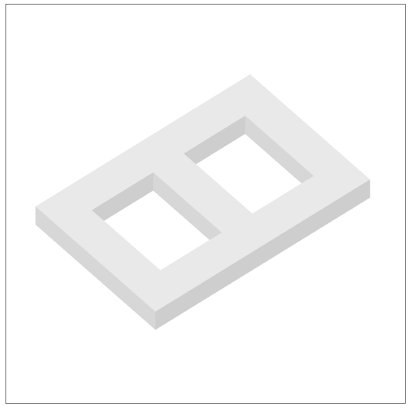
Typology Model:

The Typology Model takes a holistic view, categorizing the hospital into four distinct types of spaces: Factory (technical), Office (outpatient), Hotel (inpatient), and Hospital (hot floor). This model acknowledges the multifaceted nature of a hospital, viewing it as a generic building with diverse functions. Both vertical and horizontal flows are considered to create a harmonious and functional healthcare environment.

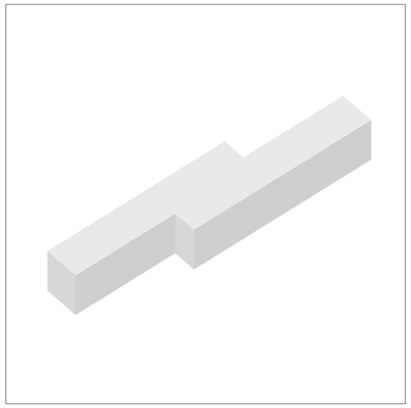
Each of these models brings a unique perspective to the planning and design of hospital spaces, showcasing the complexity of considerations involved in creating a healthcare facility that caters to the needs of patients, medical processes, and the overarching functionality of the hospital as a dynamic institution. The exploration of these theories serves as a foundation for conscious and thoughtful hospital design, ensuring an environment that fosters effective medical care and supports the diverse needs of both patients and healthcare professionals.



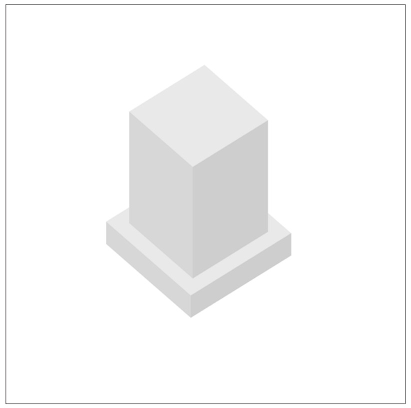
The Cross
open plan - crucriform design



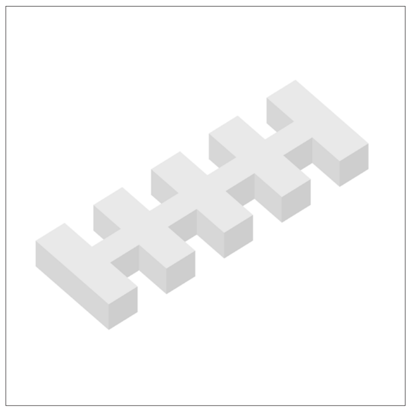
The Square
cell structure - ring arrangement



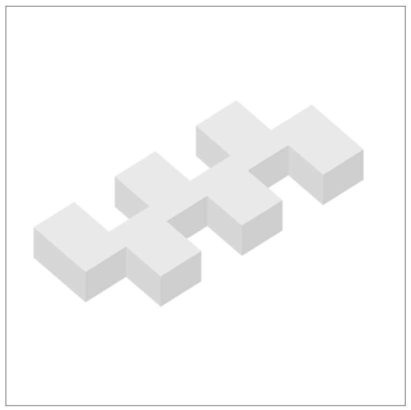
Linear rows
cell structure - rows aligned in a specific orientation



High-rise & Compact
Cell structure - radial arrangement round a central vertical access core



The Comb
cell structure - othrogonally arranged along a magistrate



The Pavillion
open plan - detached

Figure 15: Typology form studies of Hospital Architecture; *graphic by author*

Typology Form

To fully comprehend the architectural form and function of modern hospital buildings, it is essential to examine their typological evolution. Over time, hospitals have adopted various designs, each reflecting changes in medical practices, patient care philosophies, and technological advancements. Here, we explore six primary typologies that have influenced hospital architecture: The Cross, The Square, Linear, High Rise and Compact, The Comb, and The Pavilion.

The Cross:
The Cross typology, characterized by its open plan and cruciform design, represents one of the earliest hospital layouts. This design features a central intersection from which four wings extend, forming a cross shape. The open plan promotes efficient circulation and easy access to different hospital departments, facilitating quick response times and streamlined patient care.

The Square:
In the Square typology, the hospital is organized around a central courtyard, creating a cell-like structure. This design includes a ring peripheral arrangement, where departments and rooms are placed around the outer edges of the square. The central courtyard serves as a tranquil, green space that enhances the healing environment, providing patients and staff with a peaceful retreat within the hospital's confines.

Linear Rows:
The Linear typology features a straightforward, cell structure arranged in rows. This spatial arrangement places departments and rooms in a single line or series of lines, optimizing space usage and allowing for straightforward expansion. This layout is particularly effective for long, narrow sites and facilitates clear, direct pathways for movement within the hospital.

High Rise and Compact:
In urban areas where space is limited, the High Rise and Compact typology becomes essential. This design features a radial arrangement around a central vertical core, with a flat, large base housing essential hospital functions such as operating rooms, emergency services, and diagnostic facilities. Patient wards and other less space-intensive departments are located in the tower that sits atop the base, optimizing vertical space usage and allowing for a compact footprint.

The Comb:
Orthogonally Arranged Around Axis
The Comb typology is defined by its linear circulation axis, known as the magistrale. This central spine acts as the main artery of movement within the hospital, with spaces orthogonally arranged around it. This layout ensures efficient circulation and easy navigation, as all departments and rooms are accessible from this main axis. The orthogonal arrangement also supports modular design, allowing for flexible use of space.

The Pavilion:
The Pavilion typology emphasizes a central axis from which spaces branch out. This design creates a series of interconnected pavilions or wings, each dedicated to specific functions or patient groups. This layout offers flexibility and can be easily adapted to changing medical needs or expansions. The pavilion design also allows for natural light and ventilation in each wing, contributing to a more pleasant and healing environment.

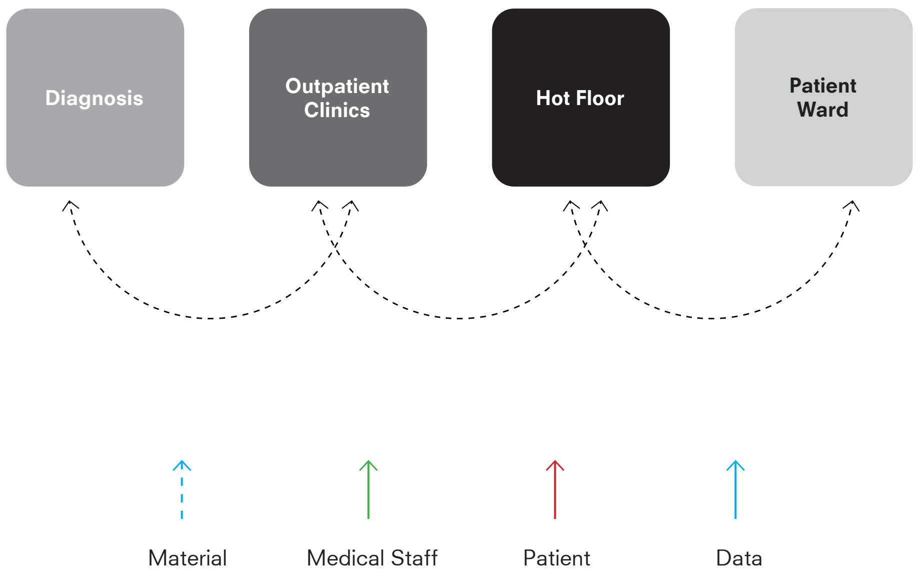


Figure 16: Key space and different flows; *graphic by author*

Types of Flows

From the patient's perspective, four main key spaces in a hospital are Diagnosis, Outpatient Department, Hot Floor, and Patient Ward. Ideally, patients navigate through these spaces within the building as part of the treatment process.

Each of these key spaces is complex, particularly the Hot Floor (see Figure 14), which involves multiple coinciding flows. The study of each space and its interrelation is essential, considering different flows and functions. The various flows in the building include:

Medical Staff: The movement of doctors and nurses is crucial for the smooth operation of medical processes. Hospitals are often designed with separate corridors to ensure their flow is unhindered, and their activity spaces are distinct from other users.

Patients: The patient experience is paramount in hospitals. The movement of patients between key spaces, without overlapping with other users, must be carefully considered. Privacy is crucial for patients in these places of recovery.

Logistics and Material: For efficient hospital functioning, the flow of materials must be smooth. Various finishing and raw materials enter and exit the hospital, and waste materials need to be managed while maintaining hygiene standards.

Data: In the era of the information society and the proposal of the Human Data Twin (HDT) in hospital buildings, the flow of data becomes crucial in each of the key spaces.

This comprehensive understanding of different flows and functionalities ensures effective hospital planning, addressing the needs of various users and optimizing operational efficiency. These flows will be assesed for the key spaces in Hospital.

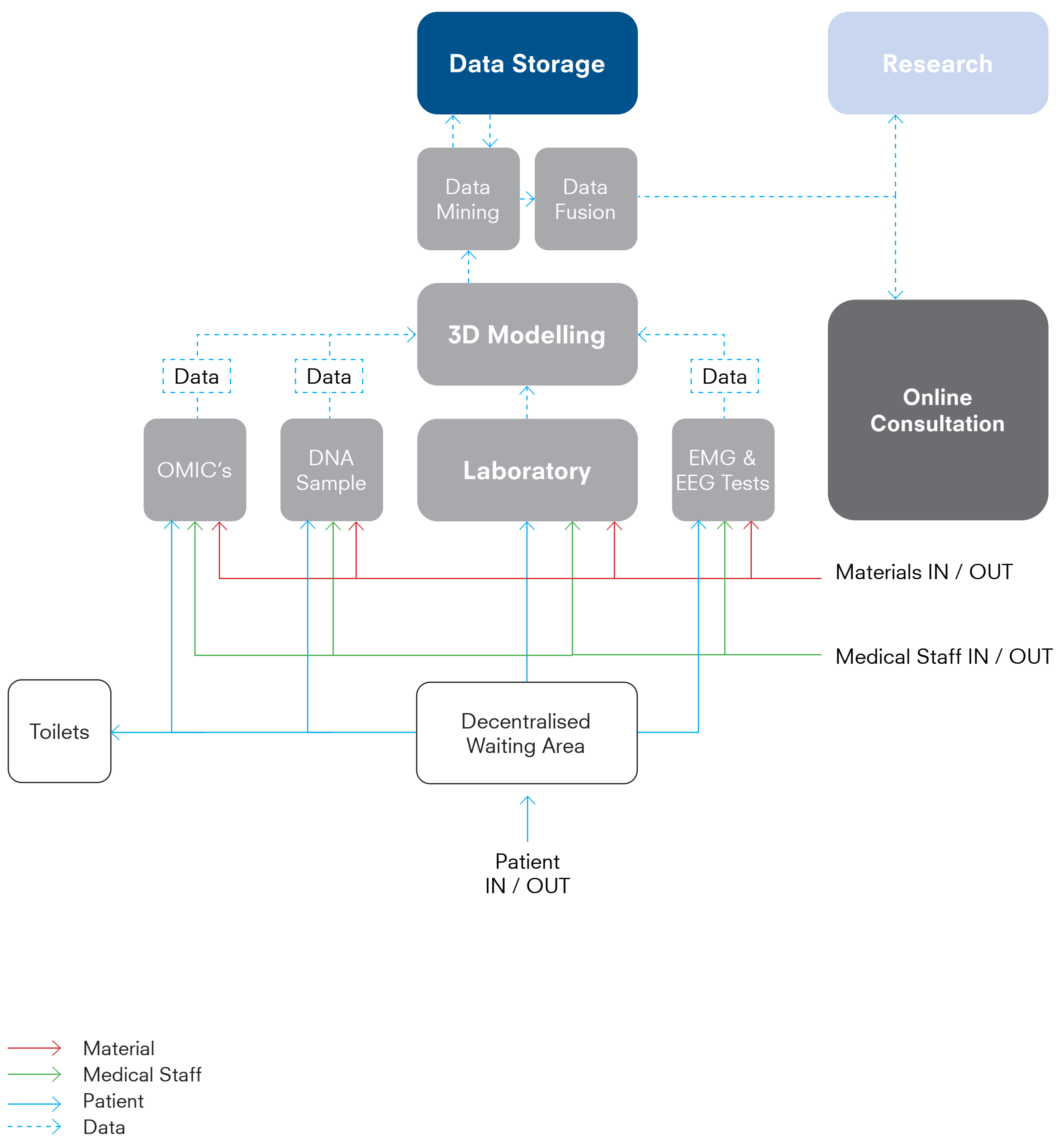


Figure 17: Flows for Diagnosis; *graphic by author*

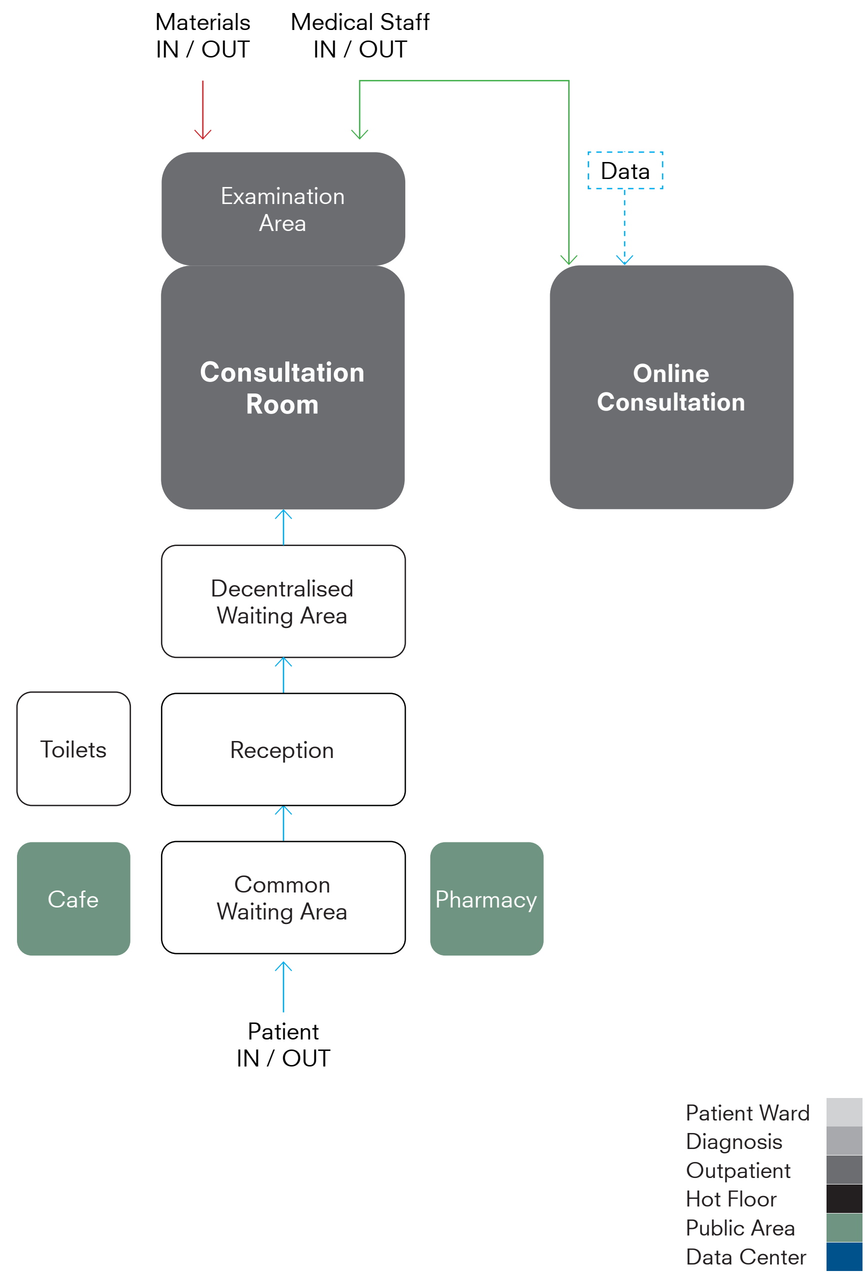


Figure 18: Flows for Outptient department; *graphic by author*

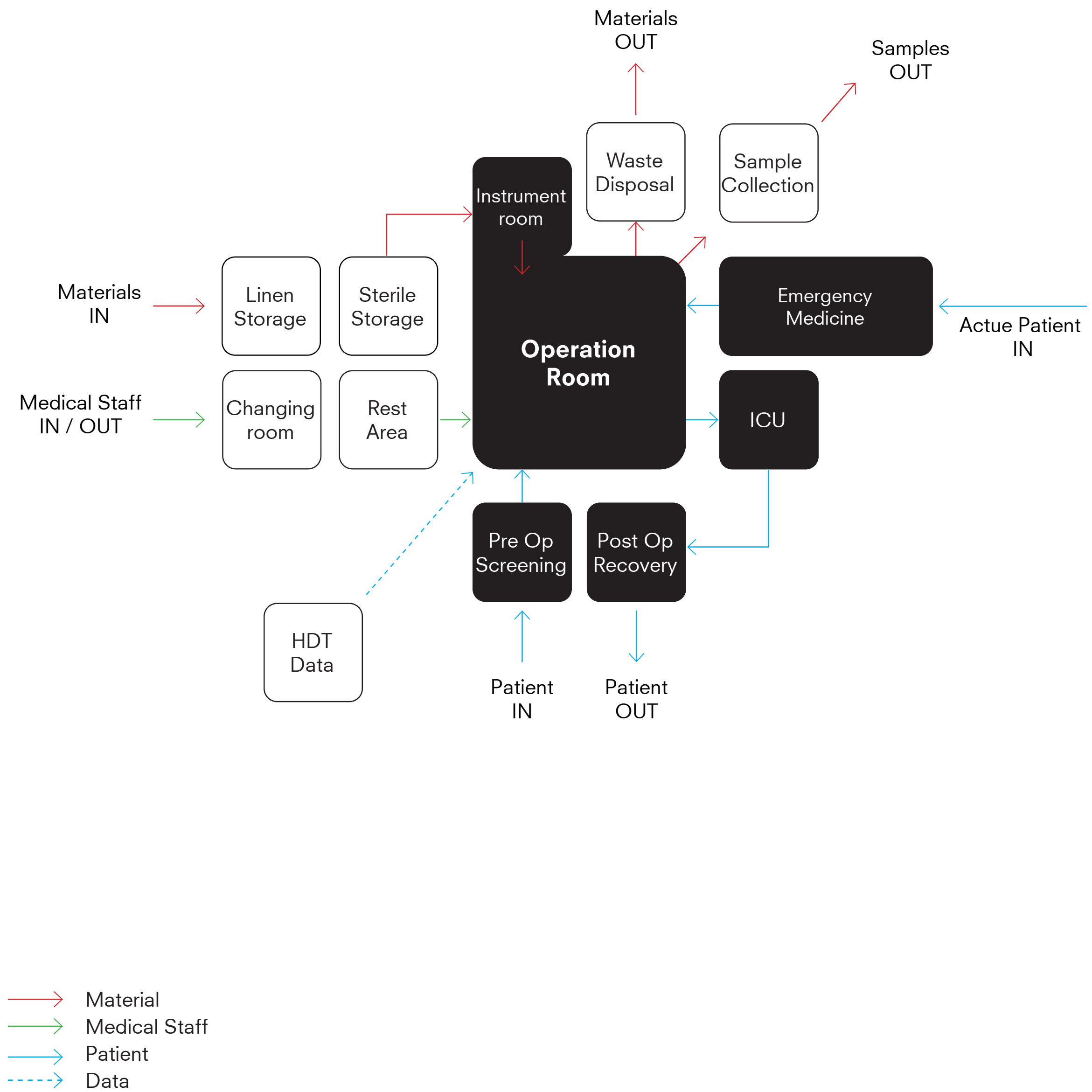


Figure 19: Flows for Diagnosis; *graphic by author*

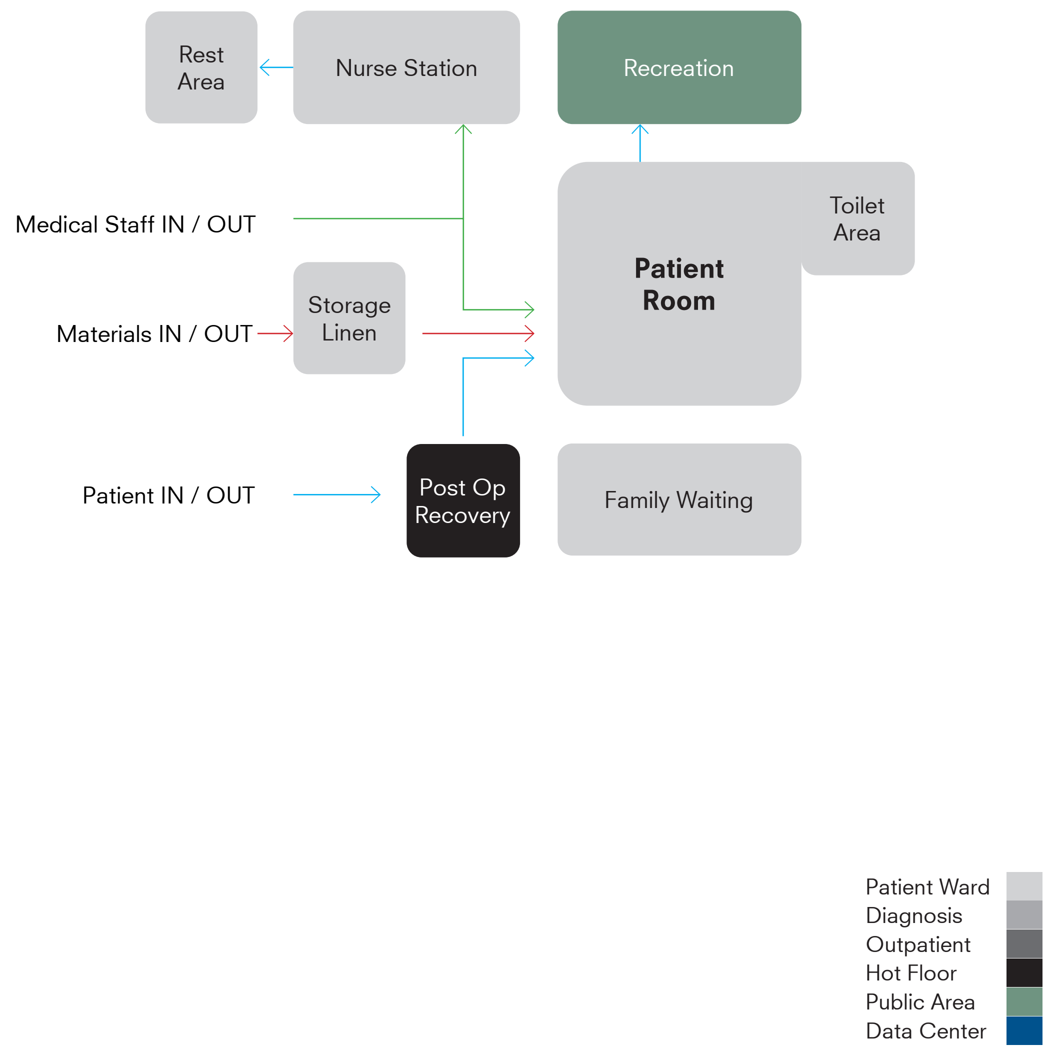
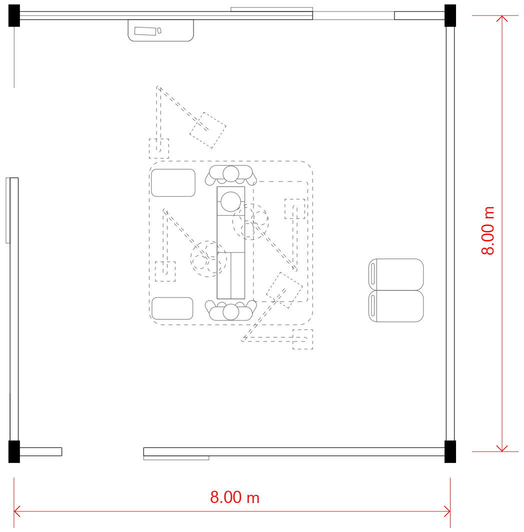
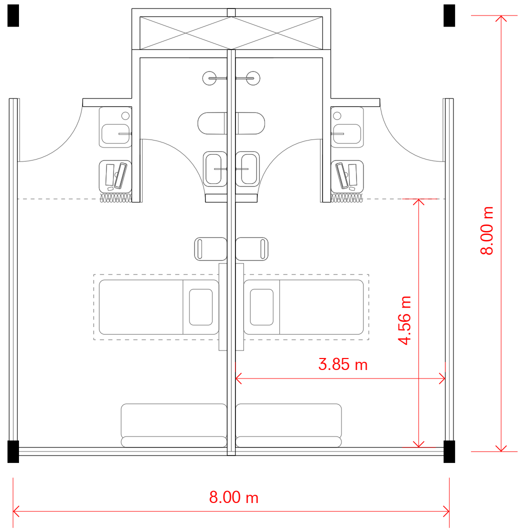


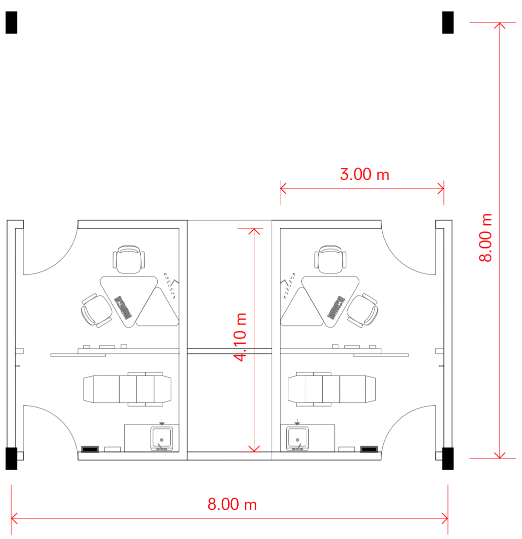
Figure 20: Flows for Outptient department; *graphic by author*



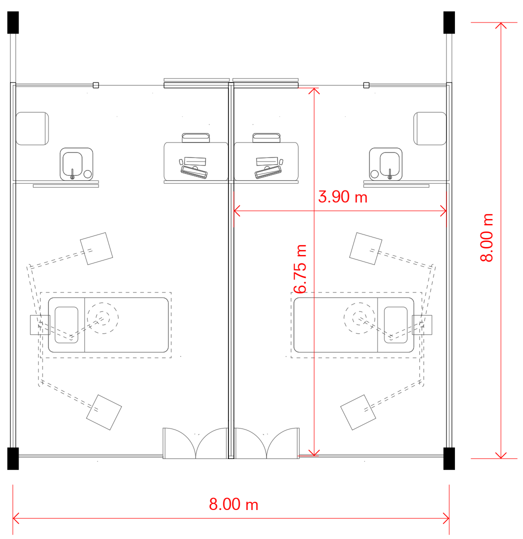
Operation Room



Patient Room



Consultation Room



ICU

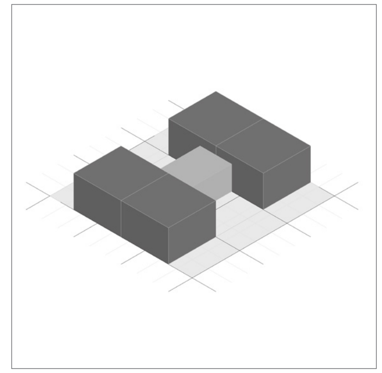
Figure 21: Key sapces spatial analysis in a hospital grid of 8m x 8m; *graphic by author*

Standards

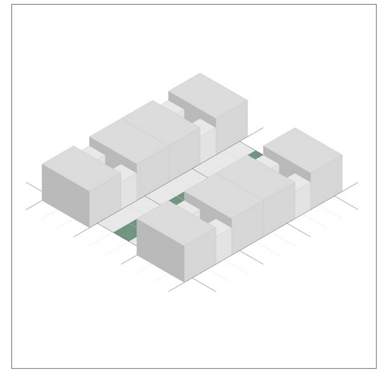
Ensuring optimal standards for key spaces in hospitals is paramount for efficient healthcare facilities. In particular, the dimensions of critical areas such as the operation room, patient room, and examination room play a crucial role in providing quality medical care.

For instance, a large operation room dedicated to neurology is recommended to be 56 m2. Similarly, a spacious patient room accommodating a single bed and two family members should have a size of 37 m2. Additionally, a large consultation room with an attached examination space is advised to be 12 m2.

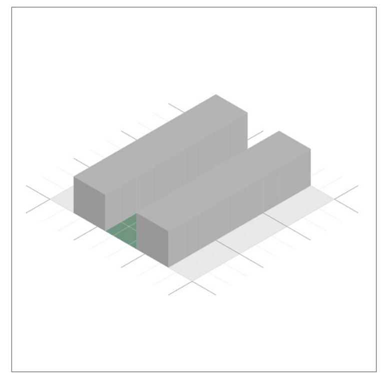
To maintain a cohesive and adaptable hospital design, a study suggests adopting an ideal modular grid of 8m x 8m. This grid aligns seamlessly with the recommended sizes for key spaces *(figure 21)*. Conducting individual studies for each of these critical areas allows for multiple configurations within this grid, aiding in determining the minimum width of the hospital building, which should be in multiples of 8m, ensuring a versatile and efficient healthcare environment. The study concludes that the minimum width of the hospital building should be 24m, adhering to these grid dimensions for optimal functionality and adaptability.



Module:
Operation Room



Module:
Patient Ward



Module:
Exam Room

Figure 22: Configurations within a grid ; *graphic by author*

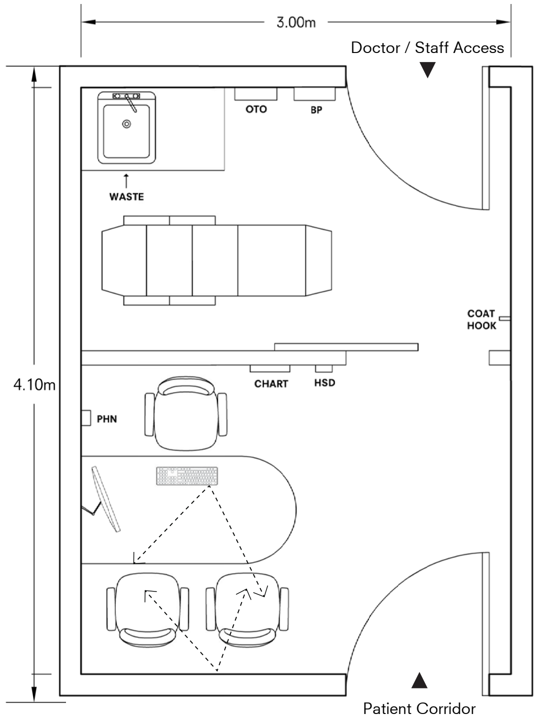


Figure 23: Typical consultation room

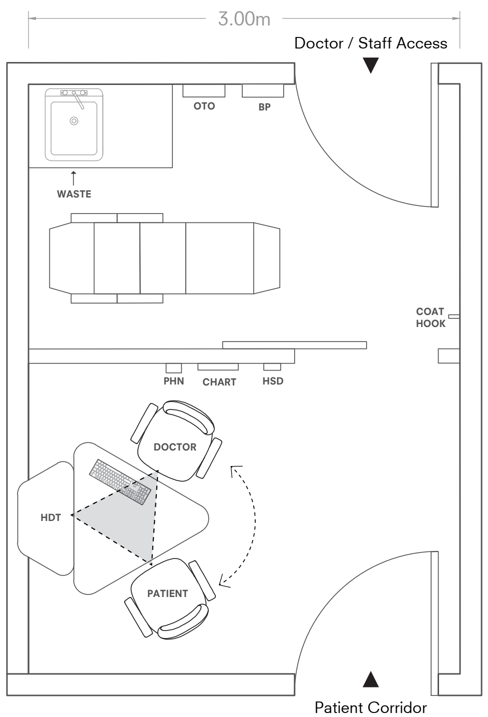


Figure 24: Consultation room with the HDT as key participant

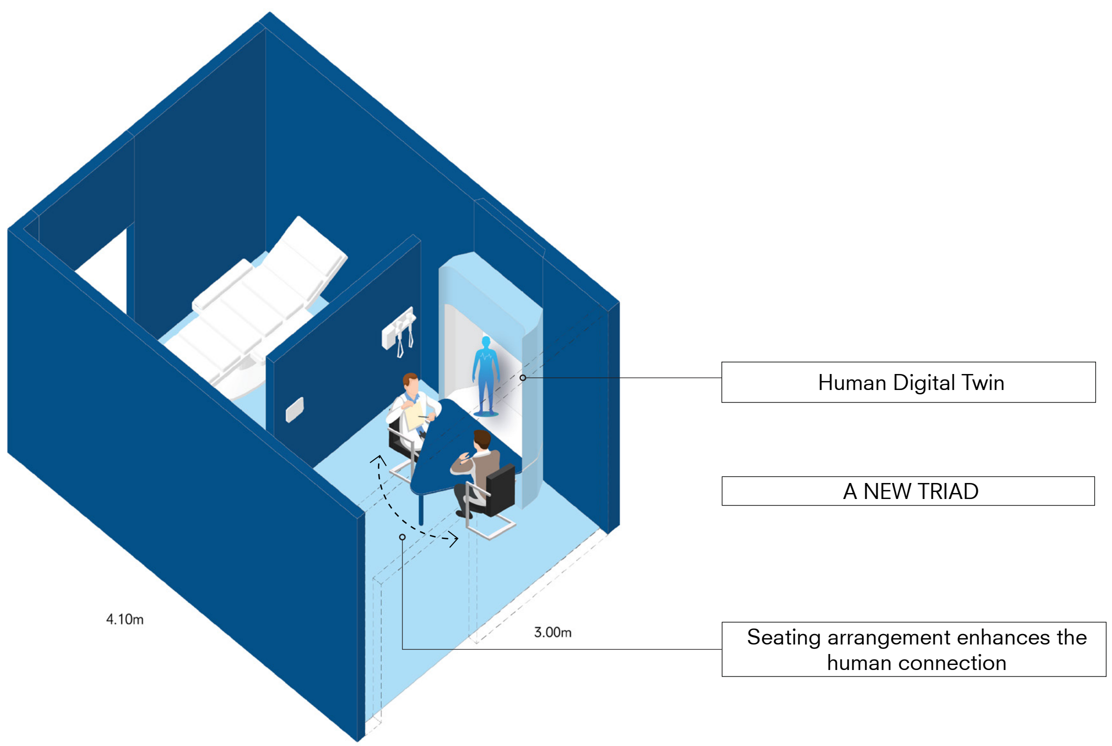


Figure 25: Consultation room with HDT the as key participant

Key Space: Consultation Room

In the chronology of designing a consultation room for effective doctor-patient discourse, key considerations involve the fundamental aspects of privacy, layout, and functionality.

Privacy Considerations:
Curtains and doors play a crucial role in safeguarding the privacy of patients during sensitive moments. Privacy curtains not only shield patients from the corridor but also enable doctors to efficiently manage charts while patients change. Backdoor access from the work core enhances staff privacy.

Examination Table Placement:
The positioning of an examination table significantly impacts a patient's visual privacy. Specialties like ENT and Orthopedics require a 360-degree clearance around exam tables to ensure patients feel comfortable and secure.

Consultation Area Design:
With an average interaction time of around 11 minutes, consultation areas need careful design. Separate examination areas accommodate multiple care providers or patient guests, emphasizing the need for insulated walls to ensure privacy.

Sanitation Facilities:
Given the importance of hand sanitation in healthcare, sinks are strategically placed near consultation tables and examination areas to facilitate easy access for care providers, aiming to prevent infections and cross-contamination.

Seating Arrangement for Effective Communication:
Seating arrangements are crucial for promoting effective discourse. Proximity between doctors and patients fosters a sense of authority, facilitating meaningful communication. Pediatric clinics often incorporate benches for parents to sit beside their children, providing comfort and reducing anxiety.

Integration of AI in Healthcare:
Considering the AI revolution, questions arise about how AI-programmed Human Digital Twins influence spatial configurations. In a consultation room scenario, AI can play a role in analytical accuracy, efficiency, and risk reduction, allowing doctors to focus more on the human aspects of care, such as empathy and critical thinking.

Research suggests that AI can alleviate the burden on doctors, reducing burnout and the risk of medical malpractice. With Large Language Models (LLMs) like ChatGPT and Med-PaLM, which demonstrate success in medical case-solving, physicians can manage patient loads more effectively.

Proposed New Triad:
AI's role in the consultation area suggests a reevaluation of seating arrangements. The new triad incorporates doctor, patient, and AI, enhancing the efficiency of medical care while maintaining a focus on the human aspects of the doctor-patient relationship. This integration aims to bring about a transformative and harmonious experience in the healthcare setting. *(figure 24 & 25)*

Legend:

HSD:	Hand Sanitizer dispenser
BP:	Blood Pressure monitor
OTO:	Otoscope
PHN:	Phone
HDT:	Human Digital Twin

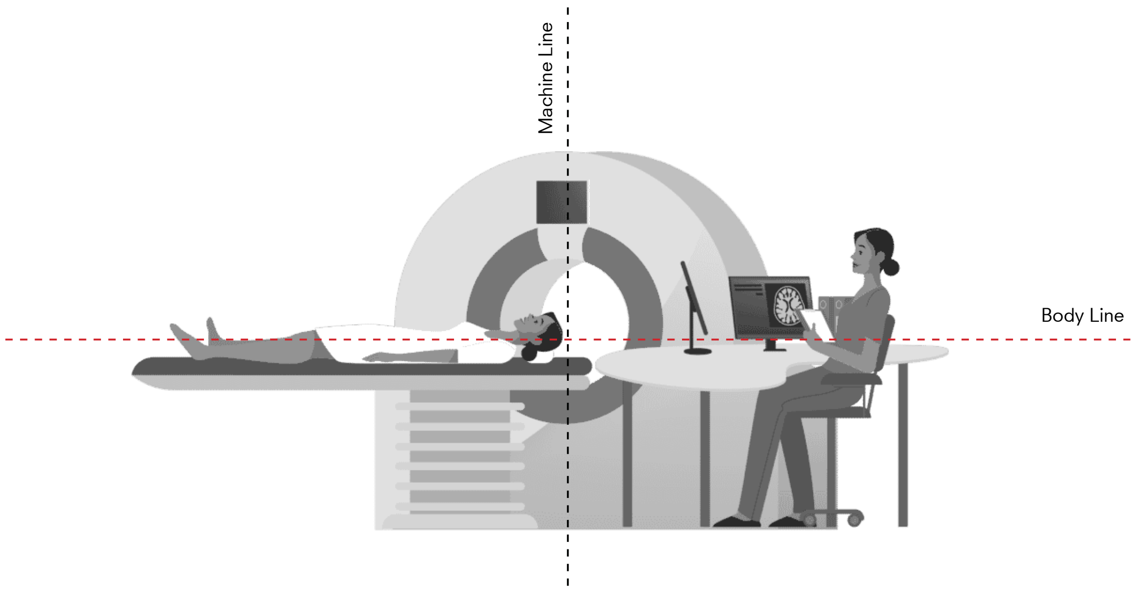


Figure 26: Traditional flow of a CT Scan

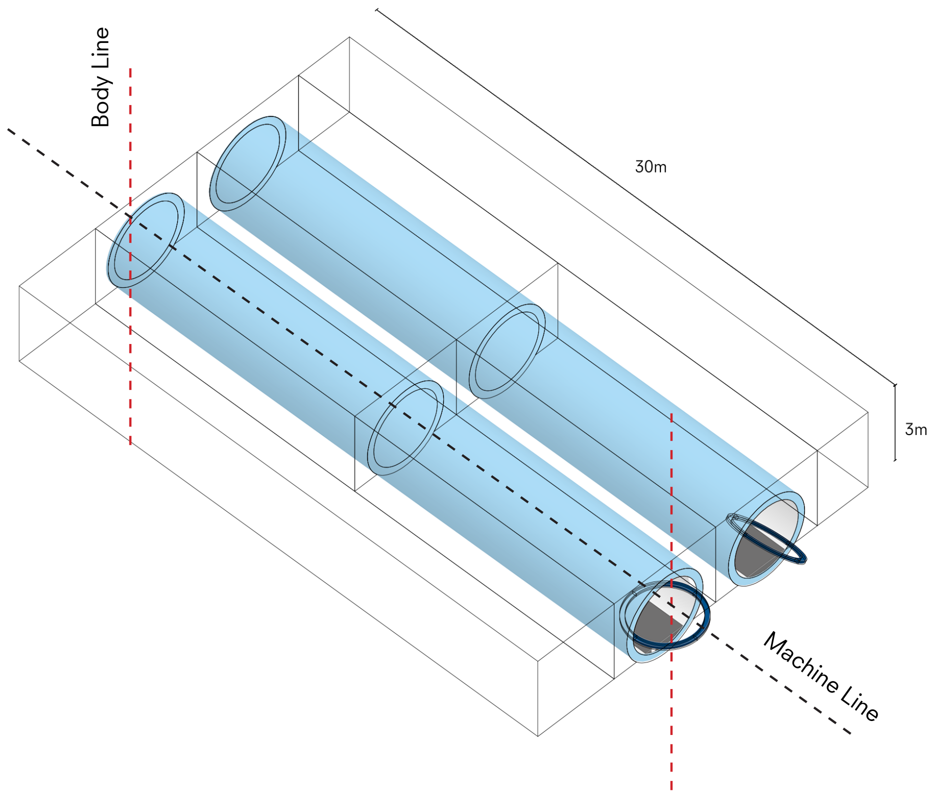


Figure 27: Reimaging the design of CT Scan when put into the public domain; *graphic by author*

Key Space: Imaging Walkways

In an effort to make advanced imaging techniques like CT scans more accessible to the public, an existing technique using CT scans was studied and reimagined. Traditionally, CT scans serve a vital purpose in medical diagnostics, providing detailed images of internal organs, bones, soft tissues, and blood vessels, aiding in the diagnosis and monitoring of various health conditions.

Traditional CT Scan Setup:

In a conventional CT scan setup, the body lies at rest on a bed, positioned along the x-axis, which is perpendicular to the machine line, the z-axis. This stationary positioning ensures accurate imaging as the machine rotates around the body, capturing cross-sectional images.

Reimagining the CT Scan:

To make CT scanning more accessible, a novel approach was conceived by altering the traditional setup. By reorienting the body line to the z-axis and the machine line to the x-axis, the body is no longer at rest but can move during the scanning process. This innovative reconfiguration led to the development of "Imaging Walkways." (*figure 27)*

Design of Imaging Walkways:

Imaging Walkways are designed as tunnels equipped with travelators, approximately 30 meters long, with a travel time of one minute. As individuals walk through or stand on the moving walkway, the CT scan machine scans their body in a 360-degree manner. This dynamic scanning approach not only facilitates continuous movement but also integrates seamlessly into daily activities.

While traversing the Imaging Walkway, individuals can enjoy various amenities such as ordering an espresso at one end and picking it up at the other, listening to a one-minute podcast, or viewing an exhibition within the tunnel. This integration of everyday activities makes the scanning process less intrusive and more engaging.

Accessibility and Security:

To balance accessibility with privacy, these Imaging Walkways can be accessed through security gates similar to those found at train stations. This design ensures that while the facility remains secure and private, it is also easily accessible to the public. Moreover, the flow of individuals using these walkways does not necessarily have to be confined within the main hospital building, further enhancing accessibility.

Key Space:
Human Twin Interaction Lab

Figure 28: Human Twin Interaction of the outside; *graphic by author*

The Human Twin Interaction Lab is an essential space where patients can meet and interact with their Data Twins. This interaction space allows patients to engage with their digital replicas, providing valuable insights into their health conditions and understanding their treatment plans in a more interactive and informative manner. Another crucial function of the lab is to establish a connection with the twin in terms of behavioral patterns, such as the length of stride and pace of movement, to generate better dynamics with the data.

Design and Functionality:

The design and form of this space evolved with the intention of creating a space that facilitates movement inside while ensuring privacy for interactions on the outside. The interior space is designed to allow for walking, which will be monitored by sensors. Screens on the curved walls will simulate the twin's movement, providing real-time feedback and comparison. Additionally, there is a designated space for technicians to monitor and manage the interactions.

On the exterior, there will be screens for interacting with the twin, where patients can receive information about their overall health. Since health data is private, it is essential to provide privacy during these interactions. The circular form of the lab, which is concave on the inside, was chosen after testing many forms and shapes. This design creates a loop for movement on the inside, while the convex shape on the outside ensures the necessary privacy.

The Human Twin Interaction Lab represents a thoughtful integration of technology and architecture, designed to enhance patient engagement and improve healthcare outcomes through interactive and private interactions with Data Twins.

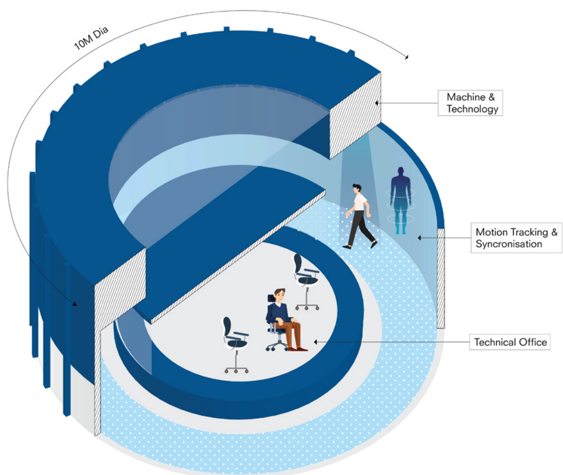


Figure 29: Human Twin Interaction of the inside; *graphic by author*

Key Space: Diffusion Dome

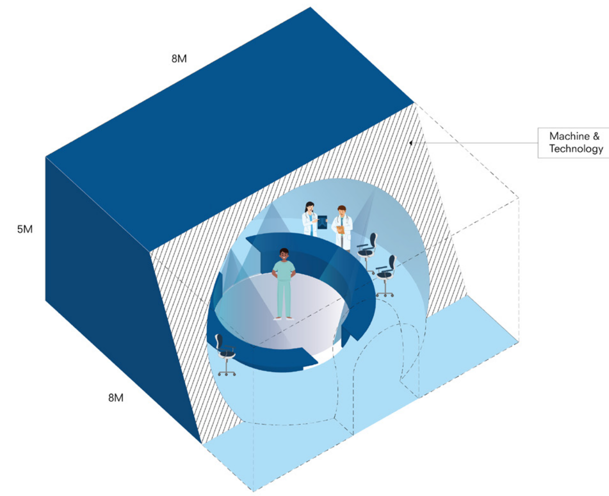


Figure 30: Diffusion Dome; *graphic by author*

The Diffusion Dome is an innovative facility designed to capture high-quality 3D photos of patients' bodies, enabling the creation of exact replica twins in cyberspace, known as Data Twins. This precise and detailed imaging is crucial for providing a personalized healthcare experience.

The technology behind the Diffusion Dome is adapted from the gaming industry, where games like FIFA use similar methods to create pictorial replicas of real-life football players, enhancing the user's experience. By leveraging these advanced imaging techniques, the Diffusion Dome ensures the highest level of accuracy in generating digital twins.

In terms of design and functionality, the dome-shaped interior space is ideal for scanning a body from all angles. The user remains stationary in the center, acting as the main subject, while technicians operate around the periphery. This setup differs from the Human Twin Interaction Lab, where movement is involved. The Diffusion Dome's configuration ensures comprehensive and precise scanning, making it an essential component of the personalized healthcare process.

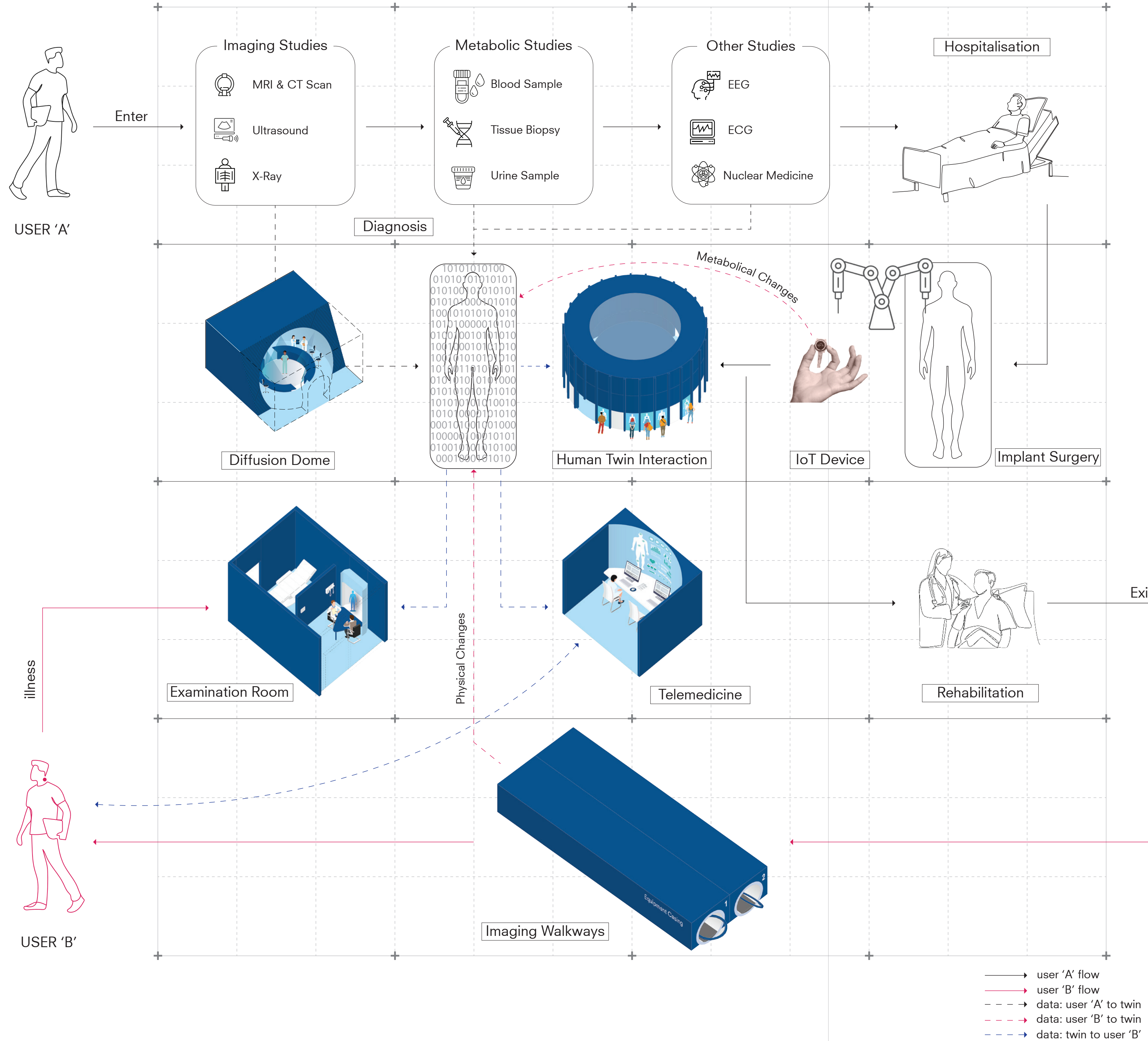


Figure 31: Elements of Digitalisation for the process of Twin Anatomy; *graphic by author*

Elements of Digitalisation

The evolution of healthcare technology has highlighted the need to create specific spaces within hospitals that support and enhance these advancements. These dedicated areas are essential for facilitating the processes and functions of cutting-edge technologies, ensuring they are seamlessly integrated into patient care.

Telemedicine Rooms:
Telemedicine has become an increasingly vital component of modern healthcare, and dedicated telemedicine spaces within hospitals make these services more efficient. These spaces are equipped with advanced communication technologies that allow doctors to consult with patients remotely, providing timely medical advice and treatment options without the need for physical visits.

The integration of these digitally advanced spaces within hospitals is essential for facilitating the processes and functions of modern healthcare technologies. They play critical roles in supporting a more efficient, accurate, and patient-centered healthcare system. The process flow diagram on the left, explains the interaction of these elements of digitalisation with users, processes and the way data is dealt for diagnosis.

Figure 32: Possible areas of intervention based of group criteria; *graphic by group*

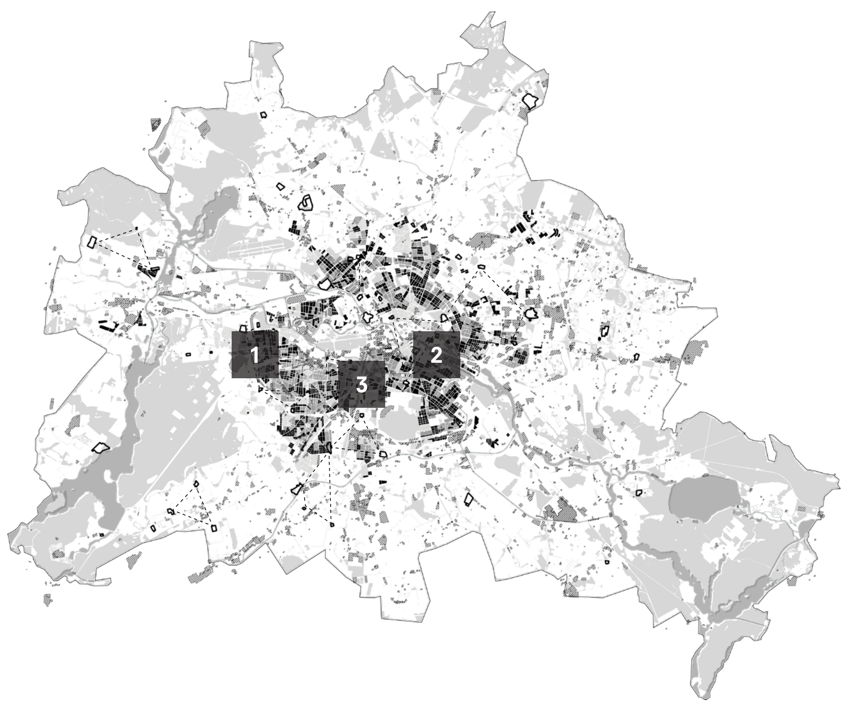


Figure 33: Possible areas of intervention based of building criteria; *graphic by author*

Site

Group criteria

To formulate a digitalization strategy for the city of Berlin, we've established three site criteria for the group. These criteria help us narrow down the interventions points that are influence the staregy on a city scale.

1. Data Decrabonisation:
According to the strategy, each of the group's public buildings will incorporate an edge data center. Edge data centers require cooling services, and this can be achieved by considering the placement of the building closer to flowing water or areas with maximum cool winds.

2. Data Display:
The strategy aims to reconsider areas with low urban growth, defined by having fewer than 15,000 jobs per square kilometer. The goal is to envision the proposed buildings as urban activators, thereby enhancing the local digital infrastructure of the urban area.

3. Data Decentralisation:
The strategy is based on the hypothesis that in the future, there will be an increased use of public transport. Therefore, the proposed buildings need to be situated within a walking radius of a train node.

Builing type criteria

In addition to the group criteria, each public building has its own set of complexities that contribute to its efficient functioning. In the case of a hospital intended to cater to a large population, the following are its three criteria.

1. Hospital nexus:
Berlin hosts a large number of specialized and general medical facilities. The new hospital, based on the data system, will play a crucial role in sharing information and functioning in cohesion within the hospital network.

2. High density area:
The planned hospital will serve as an edge data center and must be situated in close proximity to the Internet of Things (IoT). As per this criterion, it is designated for a neighborhood with a population density ranging from 30,000 to 13,100 people per square kilometer.

3. Healing gardens:
Hospitals serve as spaces for recovery and rehabilitation. It becomes crucial to contemplate the hospital's location in close proximity to nature to enhance the healing process and create a more relaxing environment.

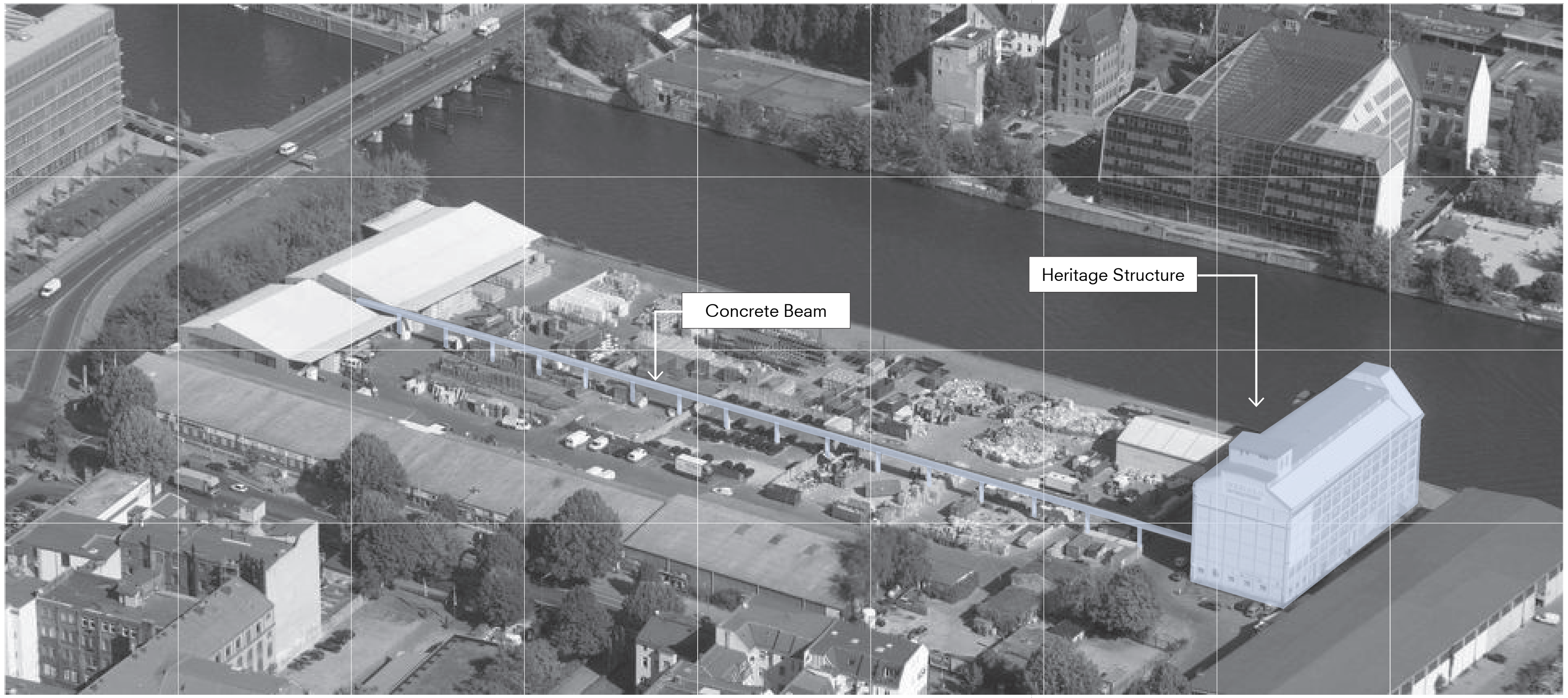


Figure 34: Existing site conditions

Figure 35: Point of reference from the history; **Source and author credit: ©** ddrbildarchiv.de/Manfred Uhlenhut

Site Conditions

The site is located in an industrial area along the Spree River. Historically, due to its proximity to the river, the site was used for shipping goods out of the city. This strategic location facilitated the movement of goods and resources, leveraging the river as a transportation route

Current Land Use and Features:

Currently, the site's land use is industrial. It hosts a heritage building that was historically used as silos for grain storage. A distinctive feature of the site is a concrete beam that extends from this heritage building along the length of the site, effectively dividing it into two halves. This beam was originally developed to move a heavy steel girder, which facilitated the transportation of goods and grains across the site. *(figure 35)*

Site Ambition:

The site's redevelopment ambition includes restoring and repurposing the heritage building and the long concrete beam, recognizing their historical and architectural significance. The heritage building and the concrete beam are interesting elements that add unique character to the site and offer opportunities for creative reuse in the new development.

Temporary Industrial Sheds:

The site also contains several temporary industrial sheds. These structures will be dismantled and relocated to an industrial zone. The materials from these sheds will be repurposed either within this project or for assembly in their new location, promoting sustainability and resource efficiency.

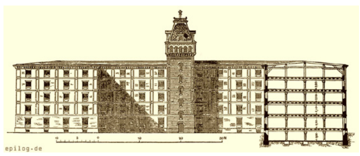
By restoring the heritage building and repurposing the concrete beam, the redevelopment plan aims to preserve the site's historical elements while transforming it into a functional and modern space that respects its industrial past.

Storage Facility

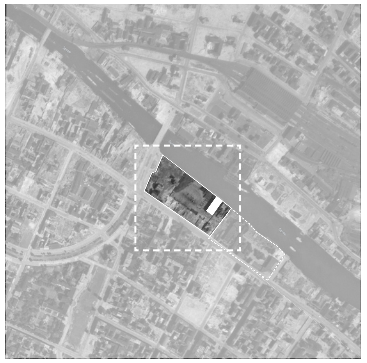
1880

The Victoria storage facility was created due to the increasing need for storage space for grain, spirits and oil from year to year.

Ideal location for storage with road, water and water infrastructure. and railway connections.



Bus Depot



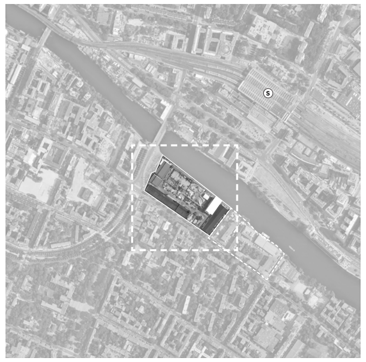
1905

ABOAG, moved its bus depot onto the site. But just two years later, a fire almost completely destroyed the buildings.

1910
Storage Reconstruction

The catastrophe shaped the reconstruction of the architect Franz Ahrens, to store loose grain and legumes

Coal Wholesale



1960-1999

The coal wholesale business was relocated from Urbanhafen to Viktoria Speicher.

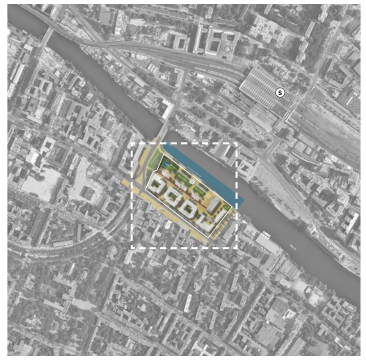
1938
Degenerate Art Depot

The Victoria-Speicher-Block 1 was once used as a storage for 17000 pieces of what the nazi's called 'degenarated art'.

1928
Ownership Change

A state owned port company BEHALA took over of the ownership.

Public Referendum



2000

The referendum under "Spreeufer Fur alle"aims to "Sink Mediaspree development" characterized by dense office space and limited free space.

- Space for riverfront
- Less densly built

Figure 36: Timeline of the site history and uses; *graphic by author*

Site analysis

The site analysis is conducted with an intention to understand the site conditions, site history and the context. The site is located at the convergence point of two districts, Berlin Mitte and Kruezberg-Friedschain. The site had various land uses over the years as seen in the timeline diagram.

The site is a potential site for development and already has some visions proposed under the 'Mediaspree' development. But a campaign called 'Spree fur alls' lead to the issue of public referendum that called for riverfornt accessibility and not so taller buildings.

Drawing sets have prepared for the site analysis that lead to a culmination of following site ambitions:

Heritage:
Building not higher than heritage structure.

Spree for ALL:
Building with an offset of 30 m from the river front

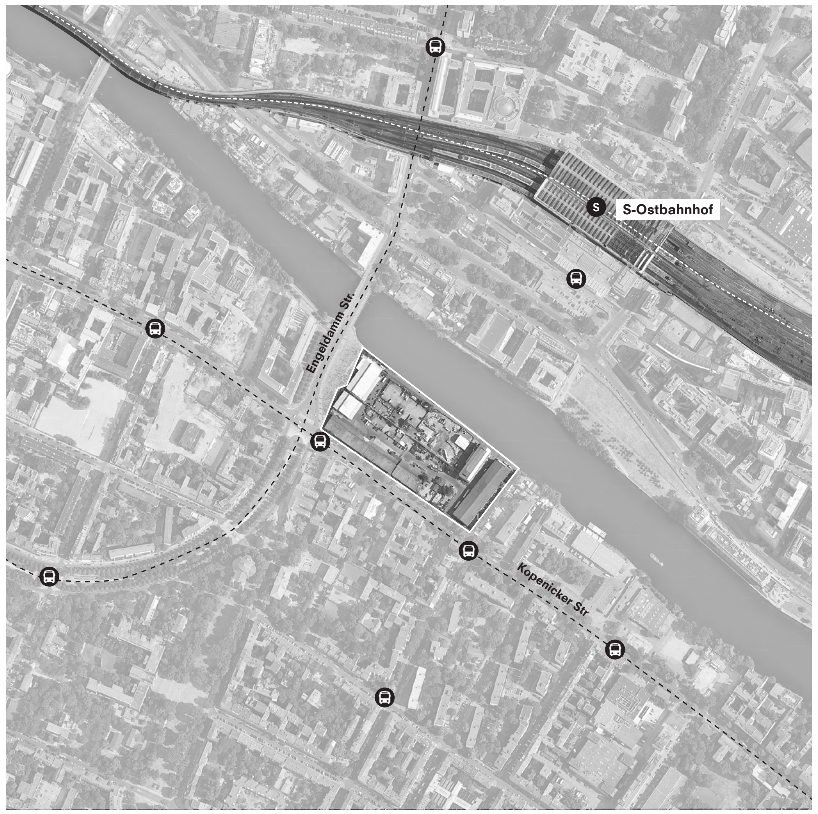
Urban Connections:
Respond to contextual activities

Natural Cooling:
Use of river water to cool data center

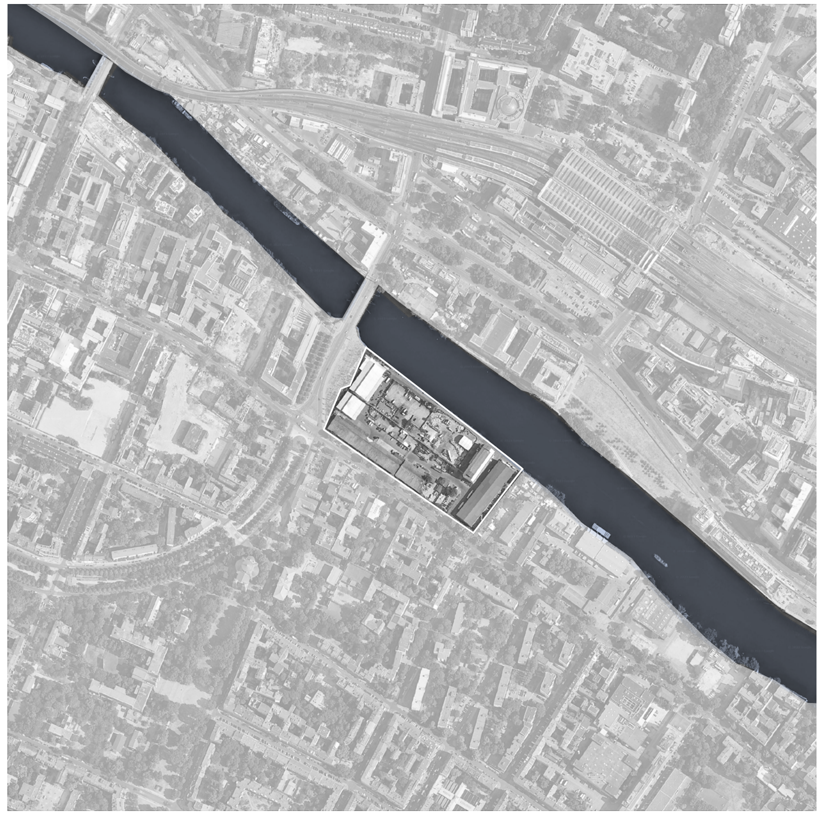
Data Decentralisation
There is no other data center withing a site radius of 1.5km, adding to the city wide data collection network.

Varied Datasets
The site is at a convergence point of three different neighbour hoods and is surrounded by diverse land uses. Its proximity to a train station enhances the potential for collecting diverse datasets.

- Housing area
- Mixed area
- Core area
- Commercial and industrial area
- Public / special area
- Utility area
- Traffic area (without roads)
- Construction site

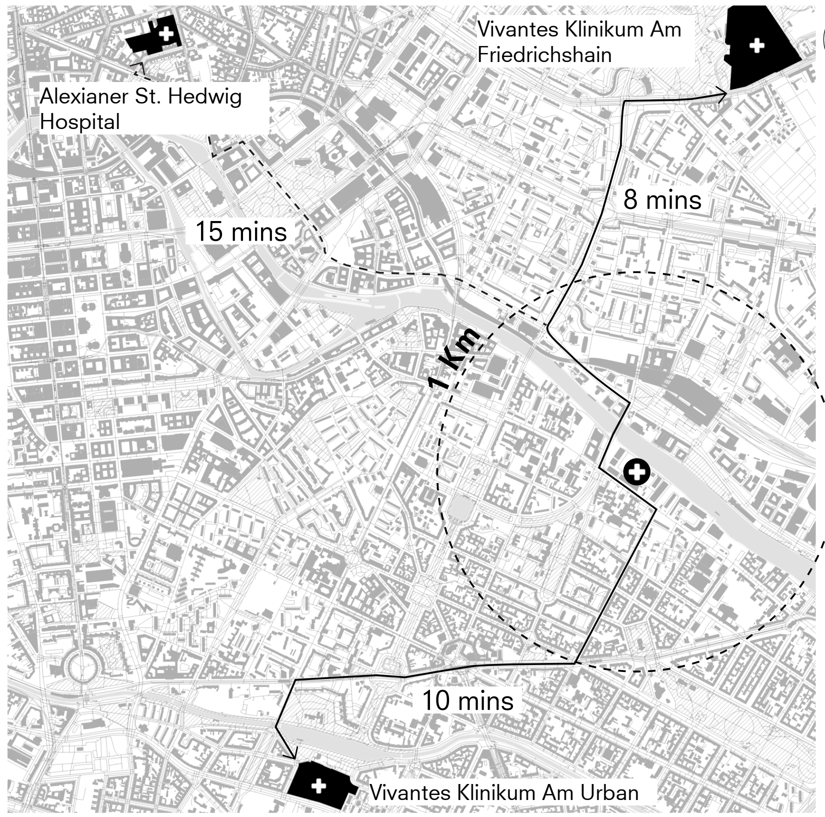


Data Display
Located in a prominient area, withing walking raidus to S-Ostbahnhof, to be able to create data awarness.



Data Decarbonisation
Close to river to be able to use natural conditions for data center cooling

Healing Landscapes
Location is close to the river to adopt privacy and enhance healing



Hospital Nexus
Travel time of 10 mins to nearby hospitals by an Ambulance

Building Form

To develop an innovative and effective design, a series of form studies were conducted within a structured framework. These studies were organized into a 3x3 matrix, allowing for the exploration of different uses across three key categories: site, program, and client. Each category was carefully considered to create a cohesive and functional design.

Categories and Explorations

Site:
Free Ground Space (Floating Form): This approach explores a design that appears to float above the ground, creating an airy and open environment. It maximizes the use of space and allows for flexible ground-level activities.

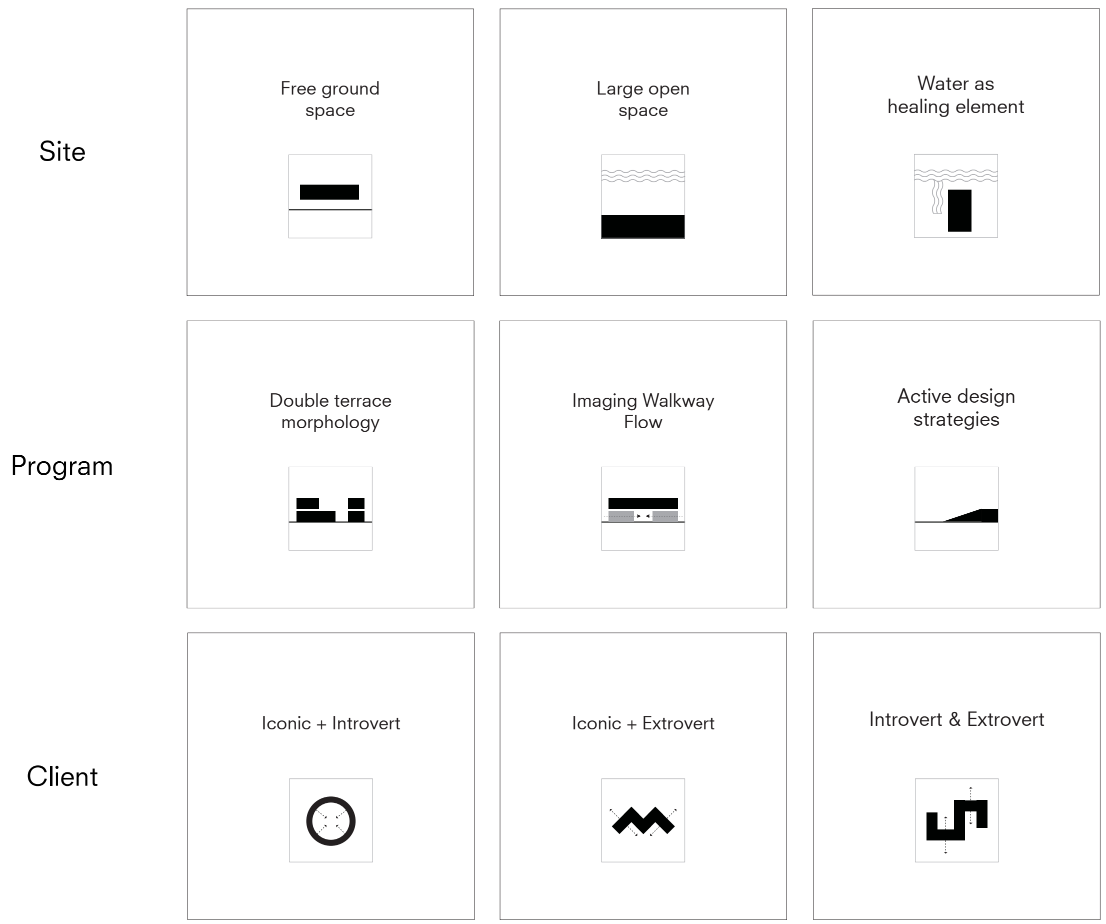
Large Open Space Toward River: By orienting large, open spaces towards the river, the design harnesses the calming and healing properties of water. This approach integrates natural elements into the site, enhancing the overall ambiance and therapeutic potential. Water as a Healing Element: This concept involves bringing adjacent river water into the site, creating water features and landscapes that promote tranquility and healing. Incorporating water into the design provides a serene environment for users.

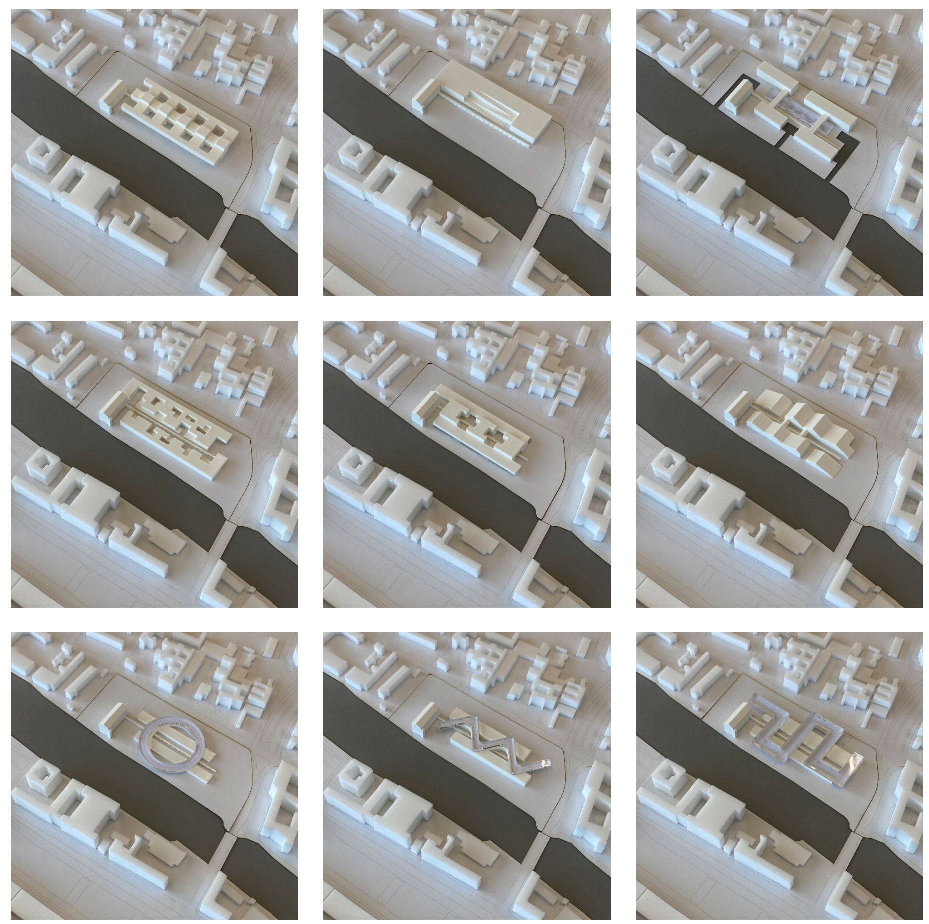
Program:
Double Terrace Typology: This design creates two levels of courtyards and interactive spaces. It emphasizes the flow of imaging walkways and fosters interaction among different areas, enhancing connectivity and user experience.

Active Design Strategies: This approach integrates green spaces, green roofs, and running tracks into the design. These elements encourage physical activity and well-being, promoting a healthy lifestyle for users. Emphasis on Imaging Walkways: Prioritizing the flow and functionality of imaging walkways ensures that these spaces are not only efficient but also pleasant and engaging. This approach makes advanced medical imaging more accessible and user-friendly.

Client:
Iconic Building: The design aims to create an iconic building that stands out and becomes a landmark. This approach focuses on aesthetic appeal and symbolic significance. Iconic Form: Emphasizing unique and memorable forms ensures that the building leaves a lasting impression. The design seeks to be both functional and visually striking.

To explore these concepts in detail, study models were created for each combination within the 3x3 matrix. These models allowed for the visualization and refinement of ideas, ensuring that each aspect of the design was thoroughly examined and optimized.





Form Proposal

After conducting the massing exercise, a concept of twin massing was proposed. This twin idea resonates with the building's concept of twin anatomy, reflecting a harmonious duality in both form and function. The evolution of this form emerged not only from the massing studies but also from the existing site conditions.

Influence of Site Conditions:

The linear concrete beam that divides the site into two became a leading factor in creating the twin massing along its length. This division naturally lent itself to the concept of twin structures, providing a clear and coherent design direction.

Urban Connection and Historical Context:

The staggering of these twin masses was designed to create an urban connection with Engelbecken Park. This park, which used to be a canal connecting the Spree River to a second river running parallel in the south, was closed down and transformed into a green space cherished by Berlin residents. This transformation echoes other changes in Berlin, such as Tempelhofer Feld, a former airport during the Nazi regime that is now an open park. During our visit to the city, we observed how these green pockets are highly valued by the community.

Strategic Positioning and Accessibility:

The site, as shown in the map below, acts as a threshold to access the Spree River in the neighborhood. It is crucial to create a publicly accessible area on the site that encourages physical activity, social health, and recreation. This aligns with the project's intention to promote physical activities through its architecture. By doing so, the site twins with the green space across the river, enhancing the urban fabric and providing valuable recreational space for the community.

The concept of twin massing not only aligns with the architectural vision of twin anatomy but also thoughtfully integrates with the historical and urban context of Berlin. By leveraging the existing site conditions and creating meaningful connections with surrounding green spaces, the design promotes physical activity, social health, and community engagement, ensuring the project contributes positively to the city's landscape.

Figure 37: Proposed form in the Urban Morphology; *graphic by author*

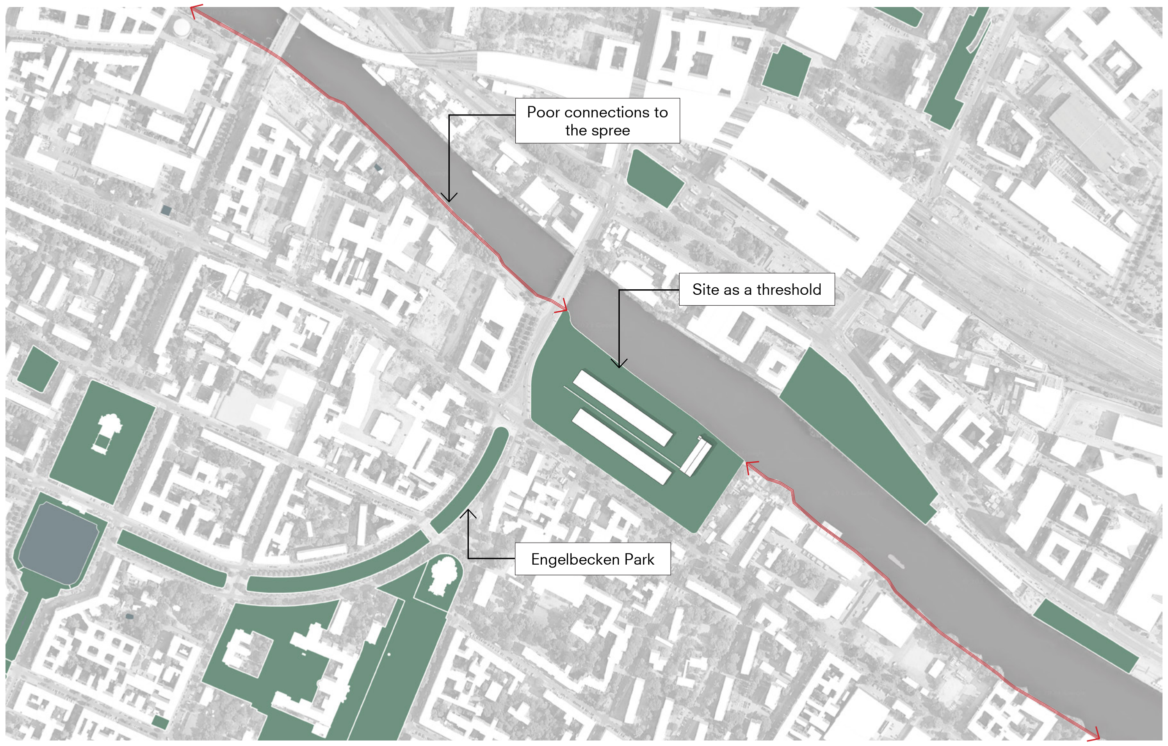
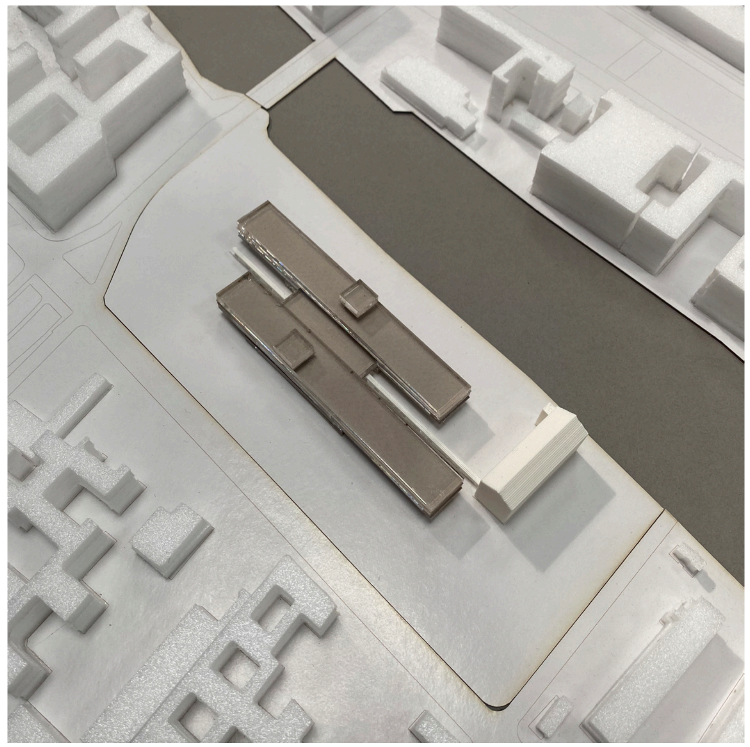
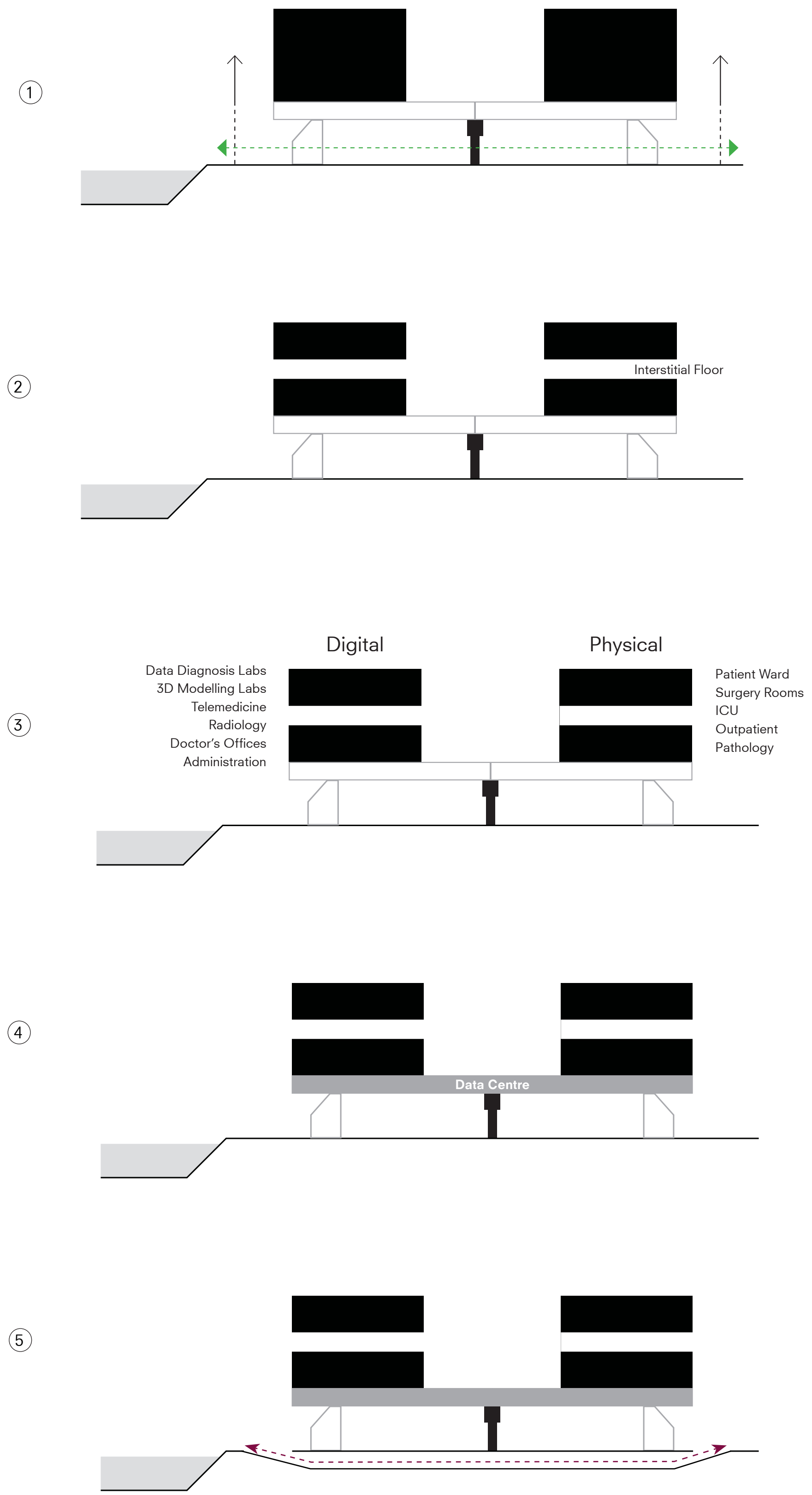


Figure 38: Proposed building form in a study model





Concept

The idea was to create a twin massing that could resonate with the concept and intention of the building, integrating both digital and physical healthcare elements in a harmonious and functional design. This twin massing approach not only addresses the practical needs of the hospital but also embodies the dual nature of modern healthcare, where data and physical care are intertwined.

01 Utilizing Existing Concrete Girders:

The existing concrete girders on the site presented an opportunity to elevate the twin massing, thereby creating a clear ground space. This elevation allows for an unobstructed ground level, enhancing accessibility and providing an open, welcoming environment for patients and visitors.

02 Interstitial Spaces:

Interstitial spaces between the floors are crucial elements of a hospital. These spaces accommodate essential services such as mechanical, electrical, and plumbing systems, ensuring that the hospital operates smoothly and efficiently. By carefully designing these interstitial spaces, the hospital can maintain a high standard of care and functionality.

03 Digital and Physical Program:

The twin massing is arranged with a program that categorizes spaces under 'digital' and 'physical' activities. Everything related to the generation and management of data, such as imaging and diagnostics, is housed within the 'digital' spaces. Conversely, areas where physical presence and activities are required, such as treatment rooms, physical therapy spaces, and patient wards, are situated in the 'physical' spaces. This clear delineation ensures that each function of the hospital is optimally located for efficiency and ease of use.

04 Data Center:

The data center, a critical component of the hospital's digital infrastructure, is strategically placed just under the floating building. This location allows for easy access and maintenance while keeping it close to the digital functions of the hospital, ensuring seamless data management and security.

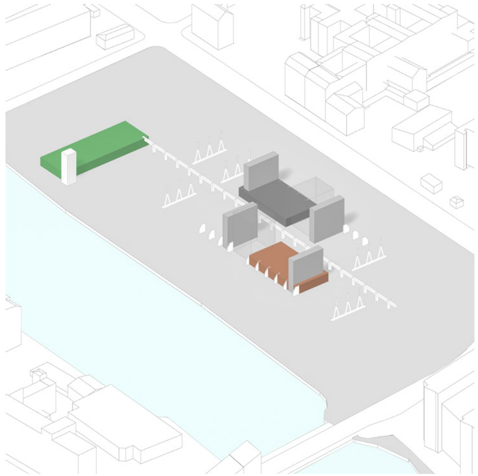
05 Imaging Walkways Flow:

Users of the imaging walkways, whose flow does not need to interact directly with the main hospital functions, can move under the building from the urban side to the riverside and vice versa. This design feature allows for smooth and uninterrupted movement, enhancing the efficiency of data collection and reducing congestion within the hospital.

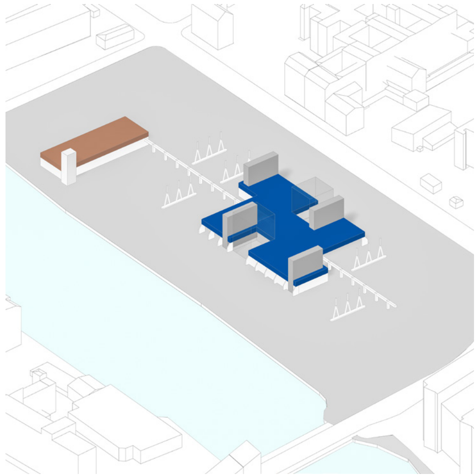
DESIGN

05

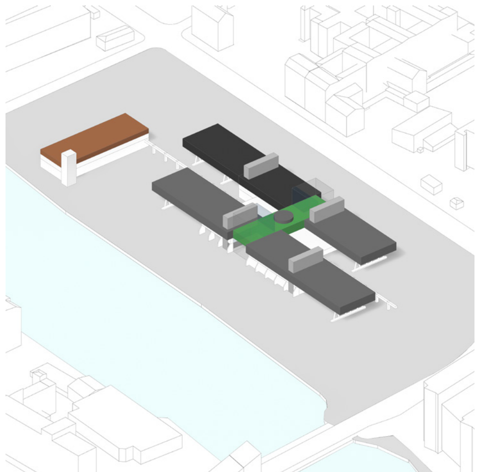
Project Impression



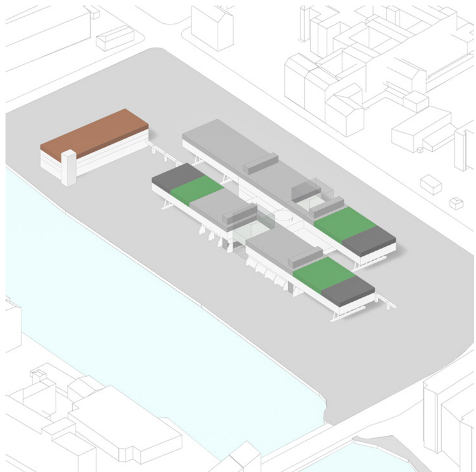
1



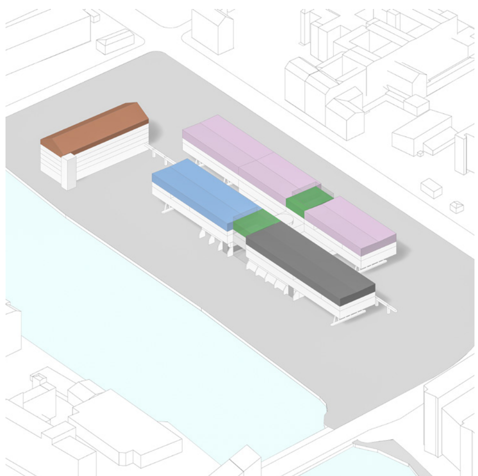
2



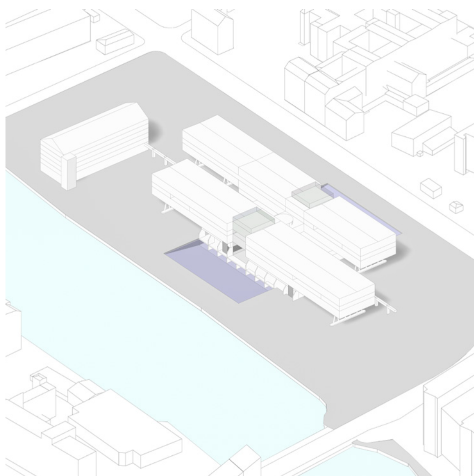
3



4



5



6

Program Arrangement

The research findings culminated in the intention for the project "Twin Anatomy," which seeks to explore how architecture, form, and spaces can promote health. With this idea in mind, the hospital is envisioned as a building floating above the ground, creating more useful and public spaces at street level. Parts of the structure cantilever out to create urban shelters, providing refuge from the city's pace. The diagrams on the left explain how public functions and hospital functions are arranged within this facility.

01. Ground Floor:

Public Spaces: The ground floor features a café and exhibition spaces along the concrete beam. The old heritage building is refurbished with public spaces, including a restaurant that opens out to the Spree River.

Outpatient Rooms: These rooms are easily accessible on the ground floor for the convenience of users.

02. Interstitial Floor:

Data Center: This floor, developed with a truss structure, houses the brain of the building—the data center. The cores are planned to flow movement to the top floor and also act as fire escape routes.

03. First Floor:

Hospital Functions: This floor hosts the majority of the hospital functions, including radiology, pathology, 3D modeling labs, and laboratories.

Operation Area: A secured and controlled area designated for operations.
Human Twin Interaction Lab: Centrally located within the twin massing.

04. Mechanical Floor:

Equipment and Breakout Areas: This floor hosts the machinery and mechanical equipment for the hospital. It also features breakout or recreational areas, indicated in green, for use by the facility's users.

05. Second Floor:

Patient Rooms: Positioned above the operation areas to facilitate easy flow between these spaces.
Doctor's Offices and Data Diagnosis Lab: Located on the side facing the river, providing a serene environment for focused work.

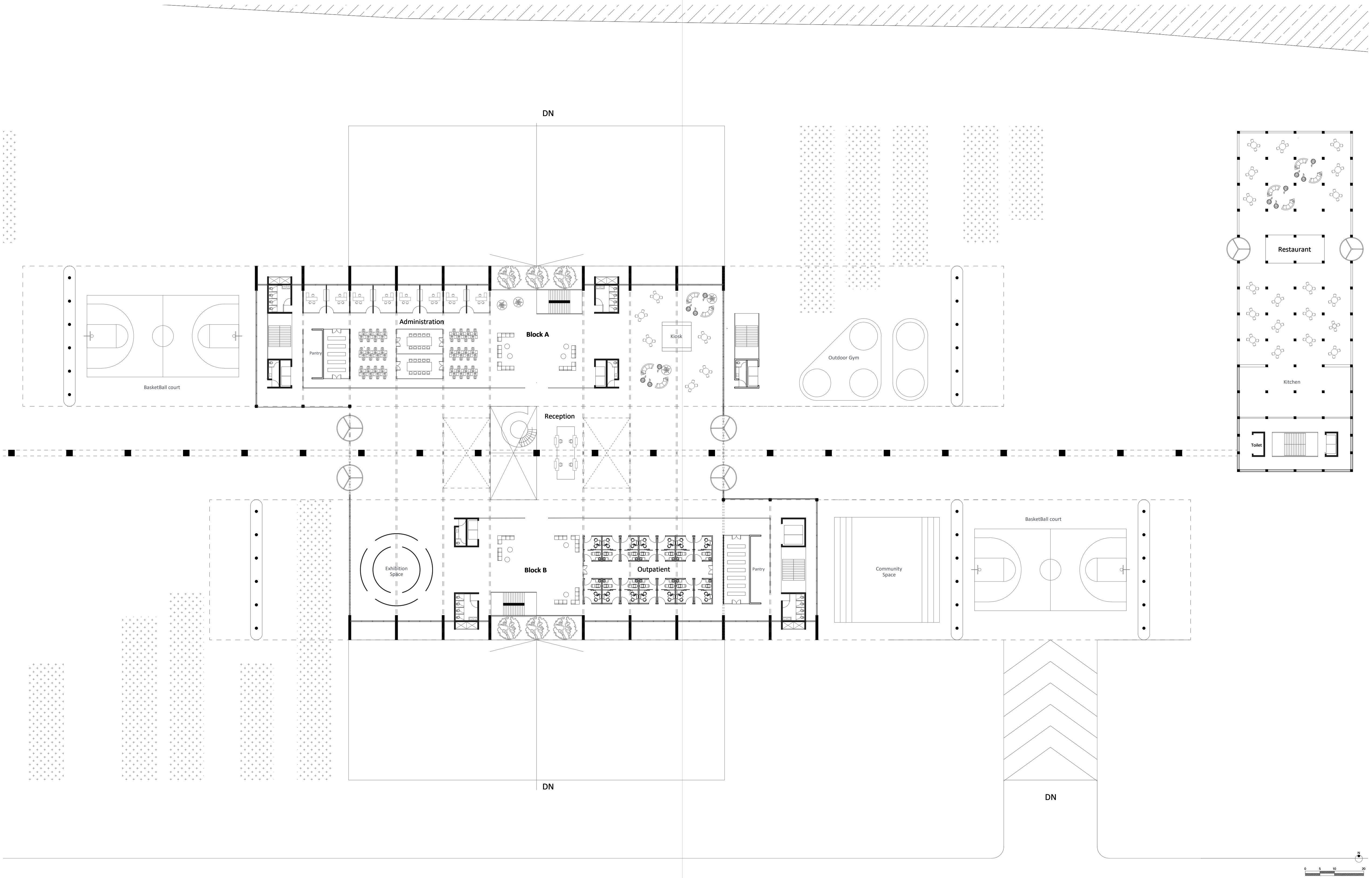
06. Imaging Walkways:

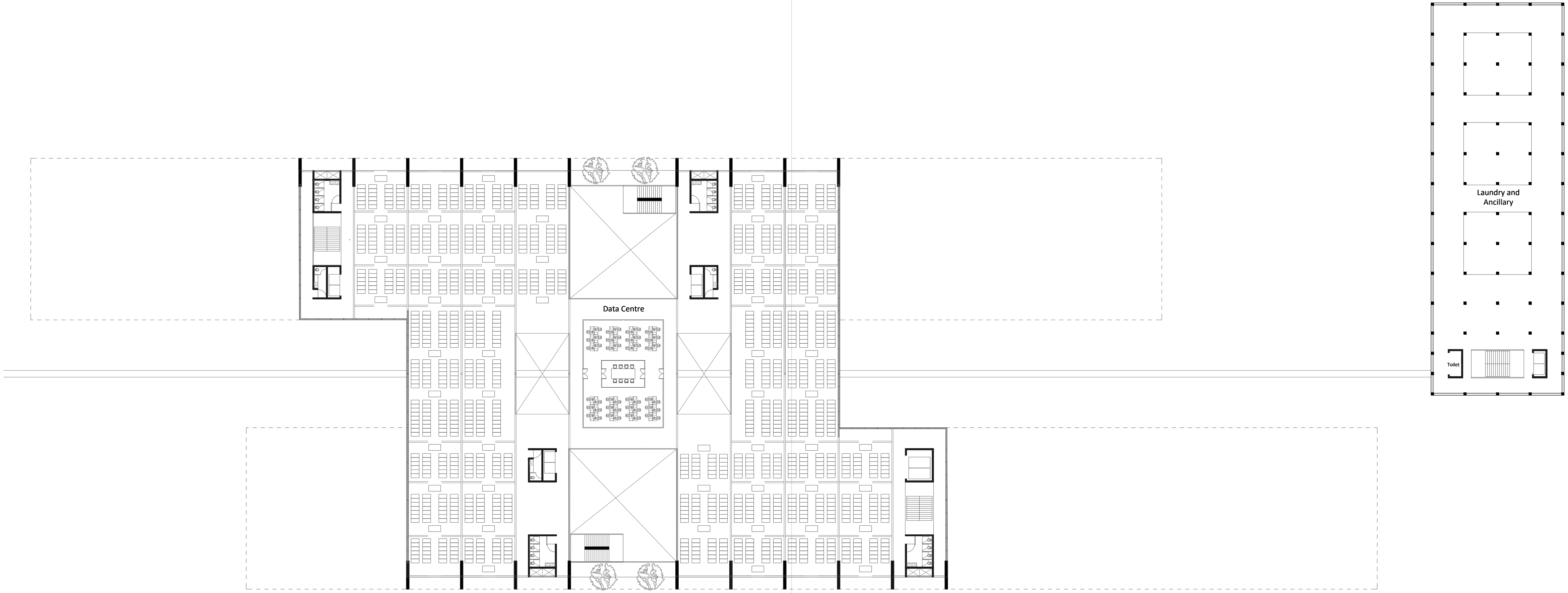
Separate Movement Flow: Users who possess a Data Twin and need to update their physical changes use these imaging walkways. Their movement is independent of the hospital functions, and therefore, the walkways are placed below the building. These pathways facilitate movement from the urban side to the riverside and vice versa.

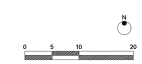
The Twin Anatomy project integrates advanced healthcare functions with thoughtful architectural design, promoting health through its form and spaces. The floating structure, public spaces, and careful program arrangement ensure that the hospital not only meets medical needs but also enriches the urban environment and enhances the well-being of its users.

Diagnosis
Research
Data Center
Patient Area
Services
Clinical Area
Public Area
Imaging Walk

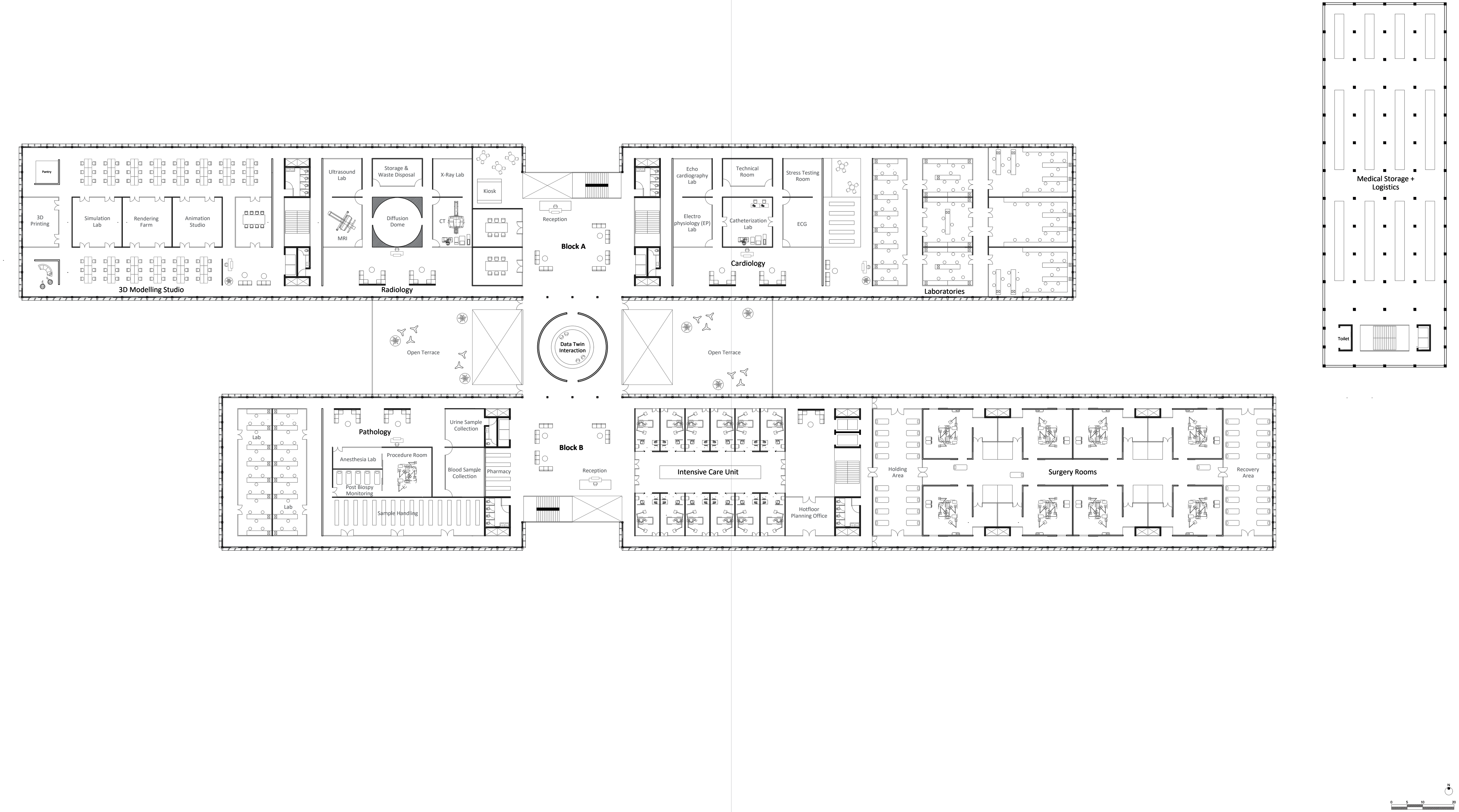

Urban Vision Plan


DN
Administration
Pantry
Block A
Kiosk
Outdoor Gym
Restaurant
Kitchen
Toilet
BasketBall court
Reception
Exhibition Space
Block B
Outpatient
Pantry
Community Space
BasketBall court
DN
DN

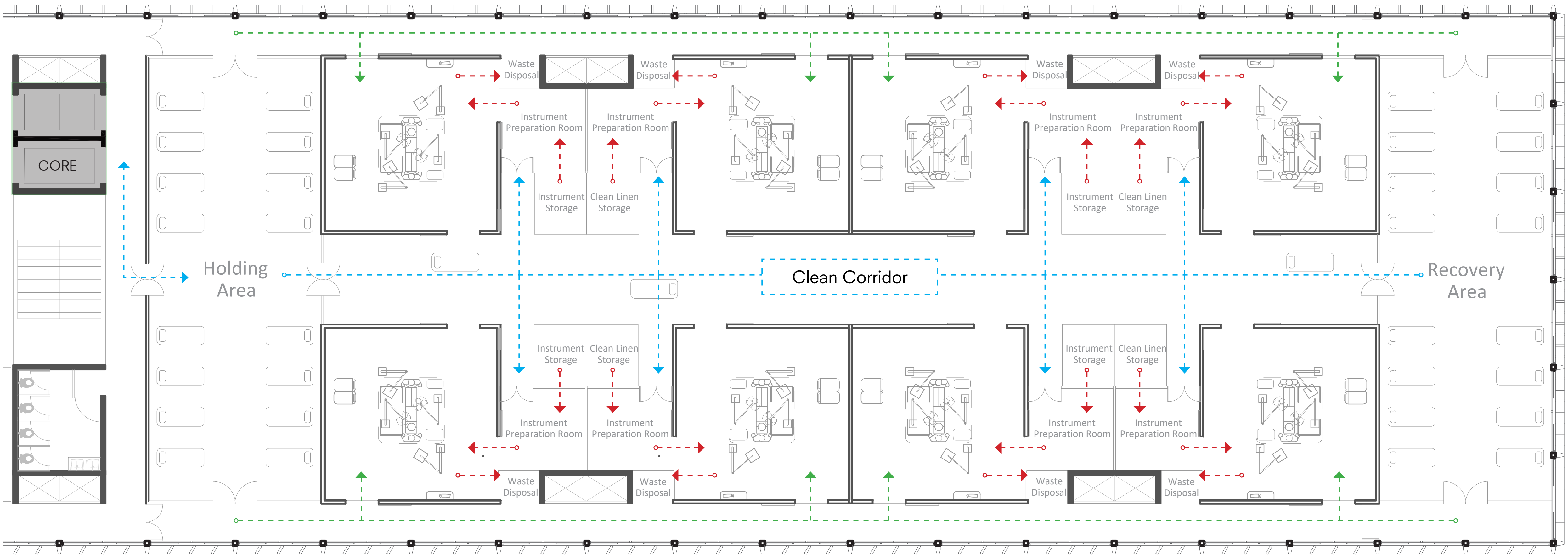




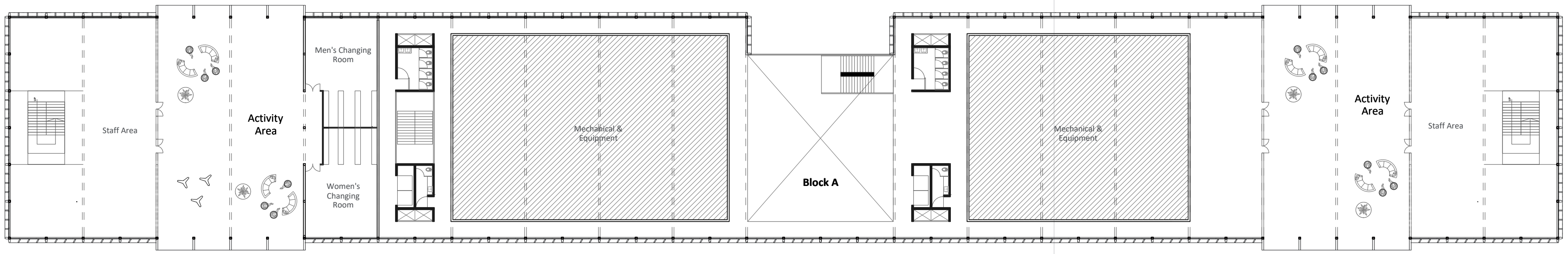
Twin Anatomy | Data Floor Plan

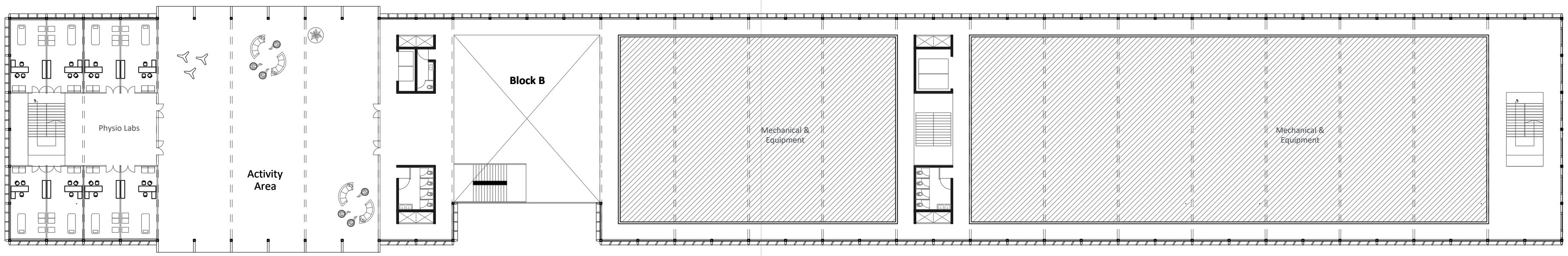


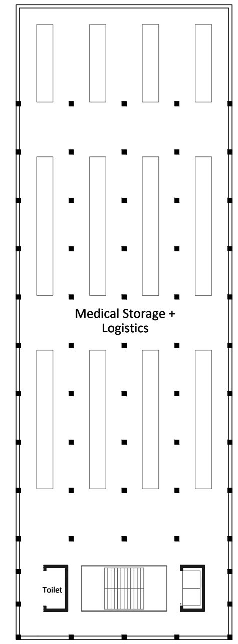
Pantry
3D Printing
Simulation Lab
Rendering Farm
Animation Studio
3D Modelling Studio
Ultrasound Lab
Storage & Waste Disposal
X-Ray Lab
Diffusion Dome
MRI
CT
Radiology
Kiosk
Reception
Block A
Echo cardiography Lab
Technical Room
Stress Testing Room
Electro physiology (EP) Lab
Catheterization Lab
ECG
Cardiology
Laboratories
Medical Storage + Logistics
Toilet
Open Terrace
Data Twin Interaction
Open Terrace
Lab
Lab
Pathology
Anesthesia Lab
Procedure Room
Post Biospy Monitoring
Sample Handling
Urine Sample Collection
Blood Sample Collection
Pharmacy
Block B
Reception
Intensive Care Unit
Hotfloor Planning Office
Holding Area
Surgery Rooms
Recovery Area

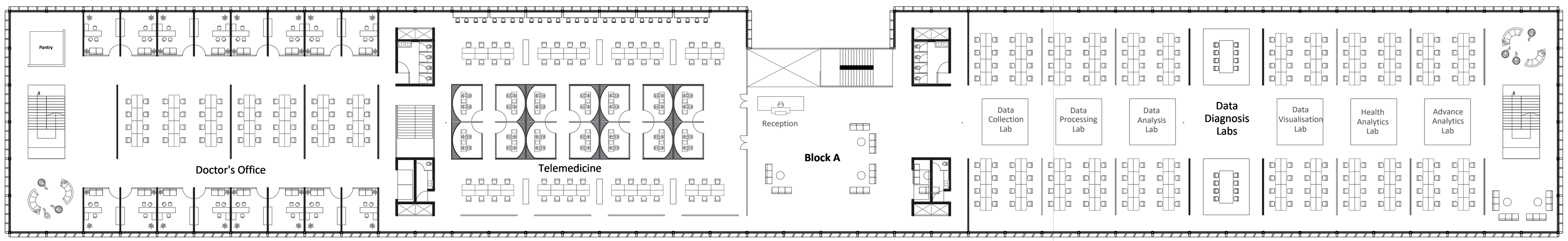


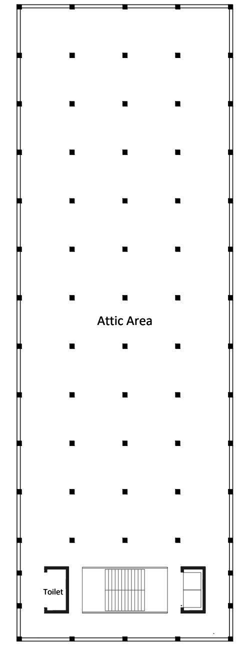
On the operation floor, the movement of doctors, patients, and materials is meticulously organized. Doctors and patients enter the operation area from a peripheral corridor, which is naturally lit before transitioning into the darker operation rooms. A centrally located clean corridor, illuminated with artificial lighting, is designated for moving patients and materials. Materials follow a defined route into the operation area, while waste is disposed of through designated cores, maintaining sterile conditions and ensuring hygiene and safety. This structured flow enhances efficiency and safety within the operation floor.

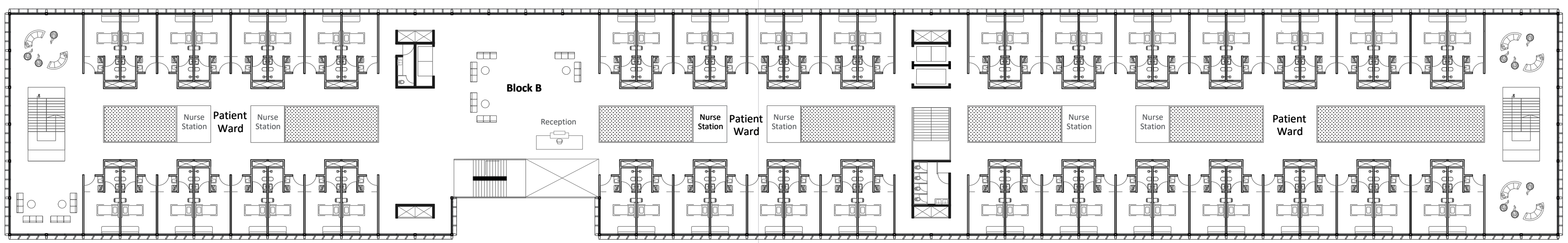

Staff Area
Activity Area
Men's Changing Room
Women's Changing Room
Mechanical & Equipment
Block A
Mechanical & Equipment
Activity Area
Staff Area

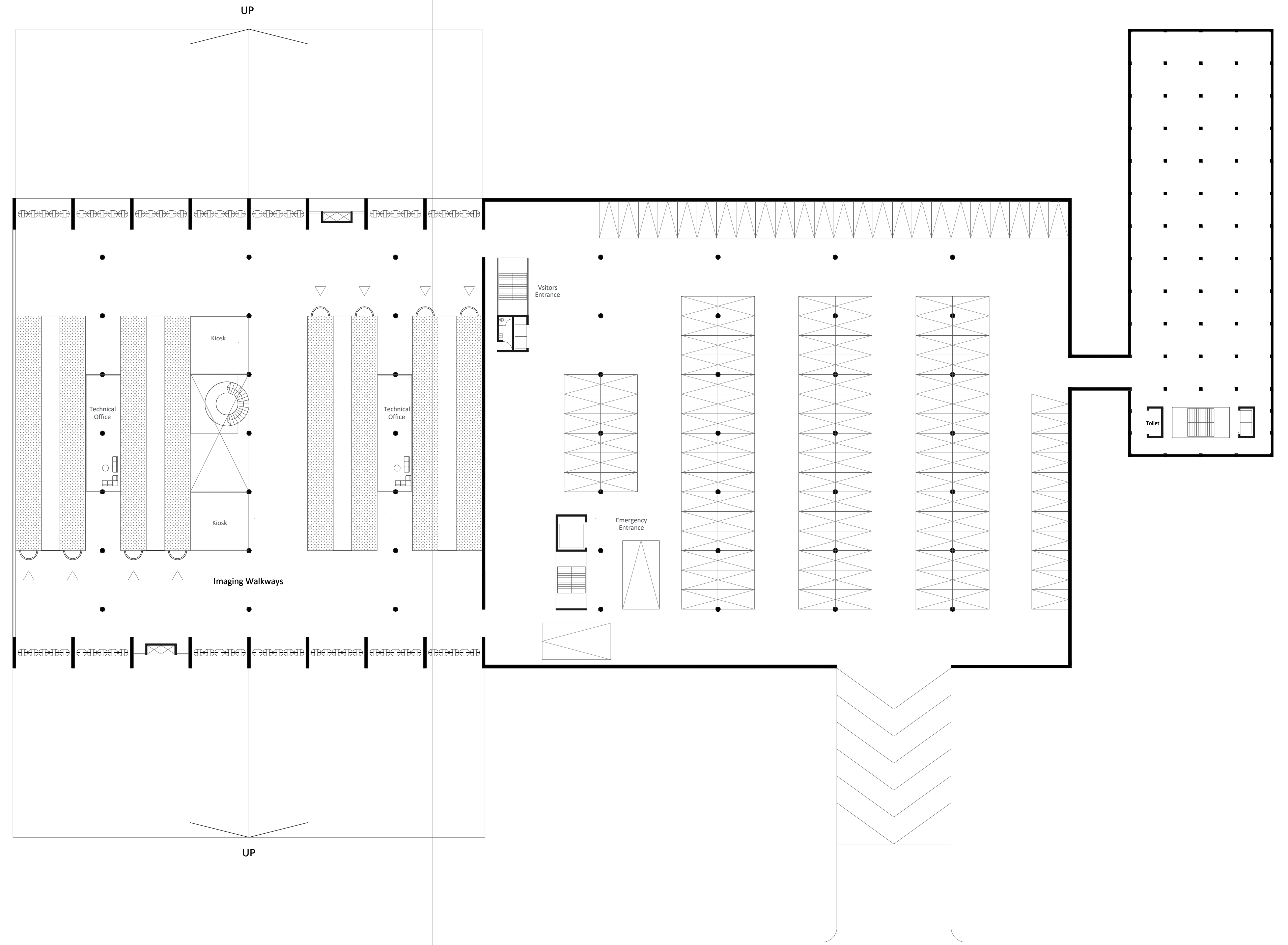

Physio Labs
Activity Area
Block B
Mechanical & Equipment
Mechanical & Equipment


Medical Storage + Logistics
Toilet


Pantry
Doctor's Office
Telemedicine
Reception
Block A
Data Collection Lab
Data Processing Lab
Data Analysis Lab
Data Diagnosis Labs
Data Visualisation Lab
Health Analytics Lab
Advance Analytics Lab

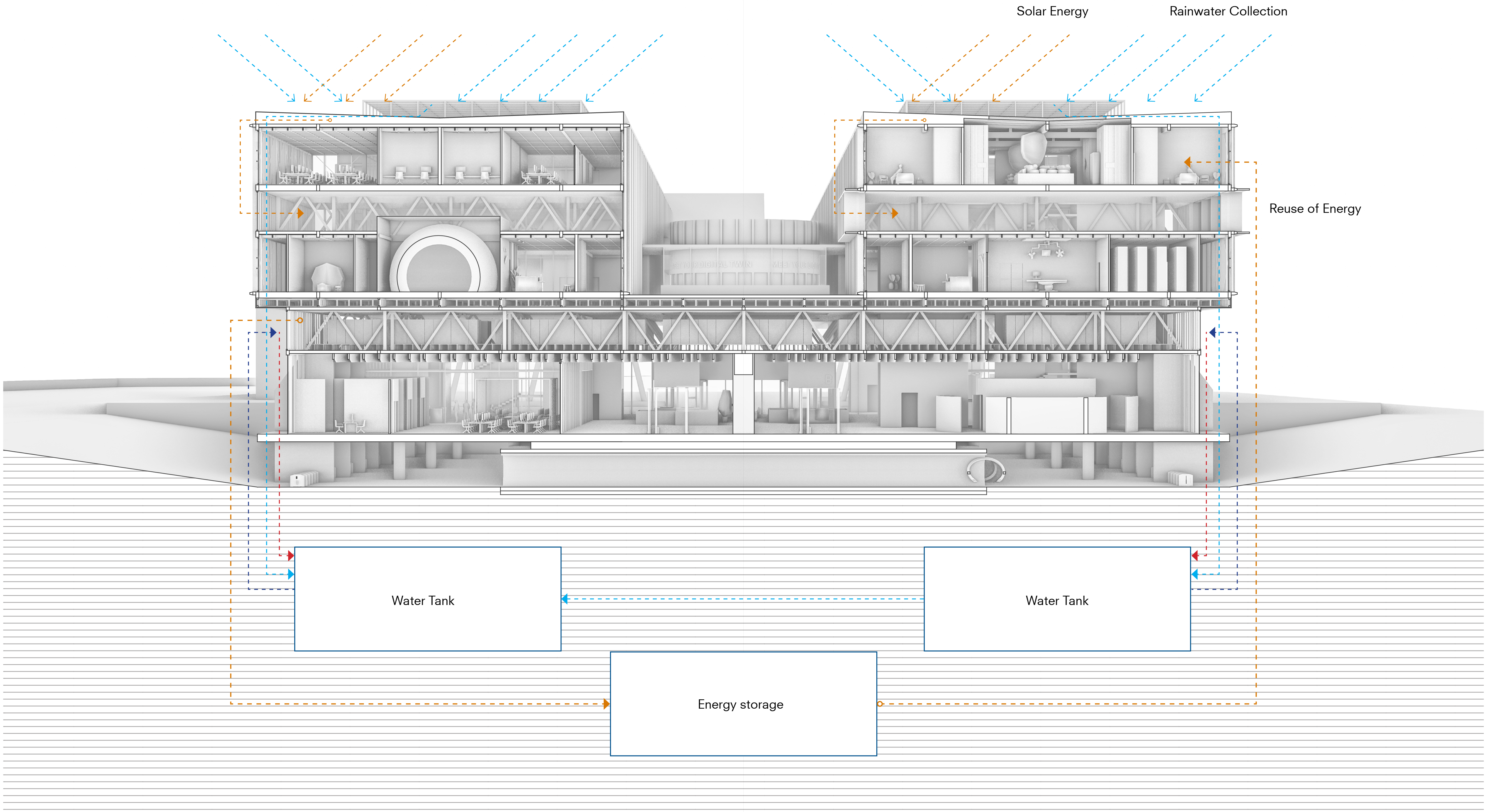

Attic Area
Toilet

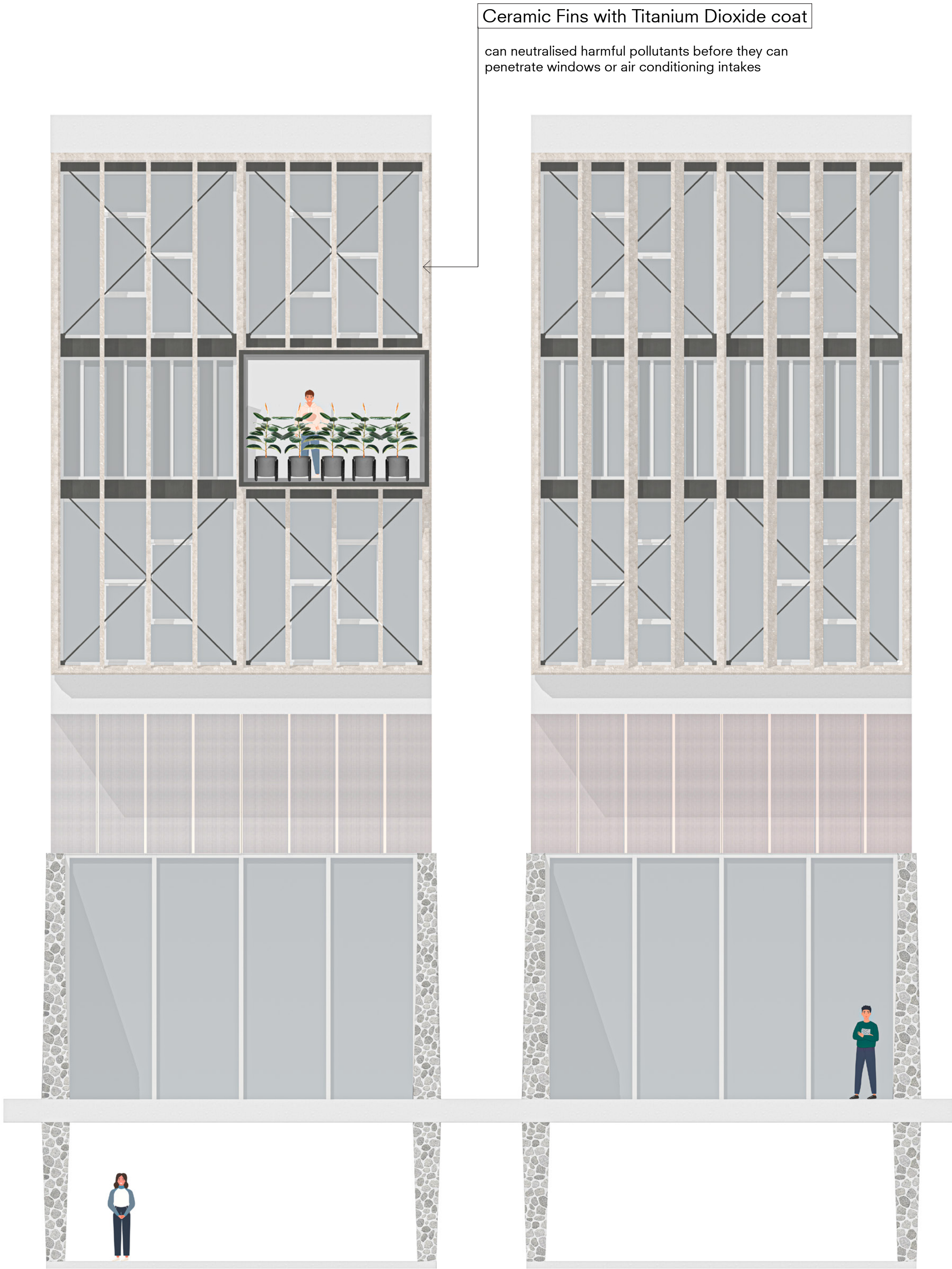

Block B
Reception
Nurse Station
Patient Ward
Nurse Station
Nurse Station
Patient Ward
Nurse Station
Nurse Station
Nurse Station
Patient Ward

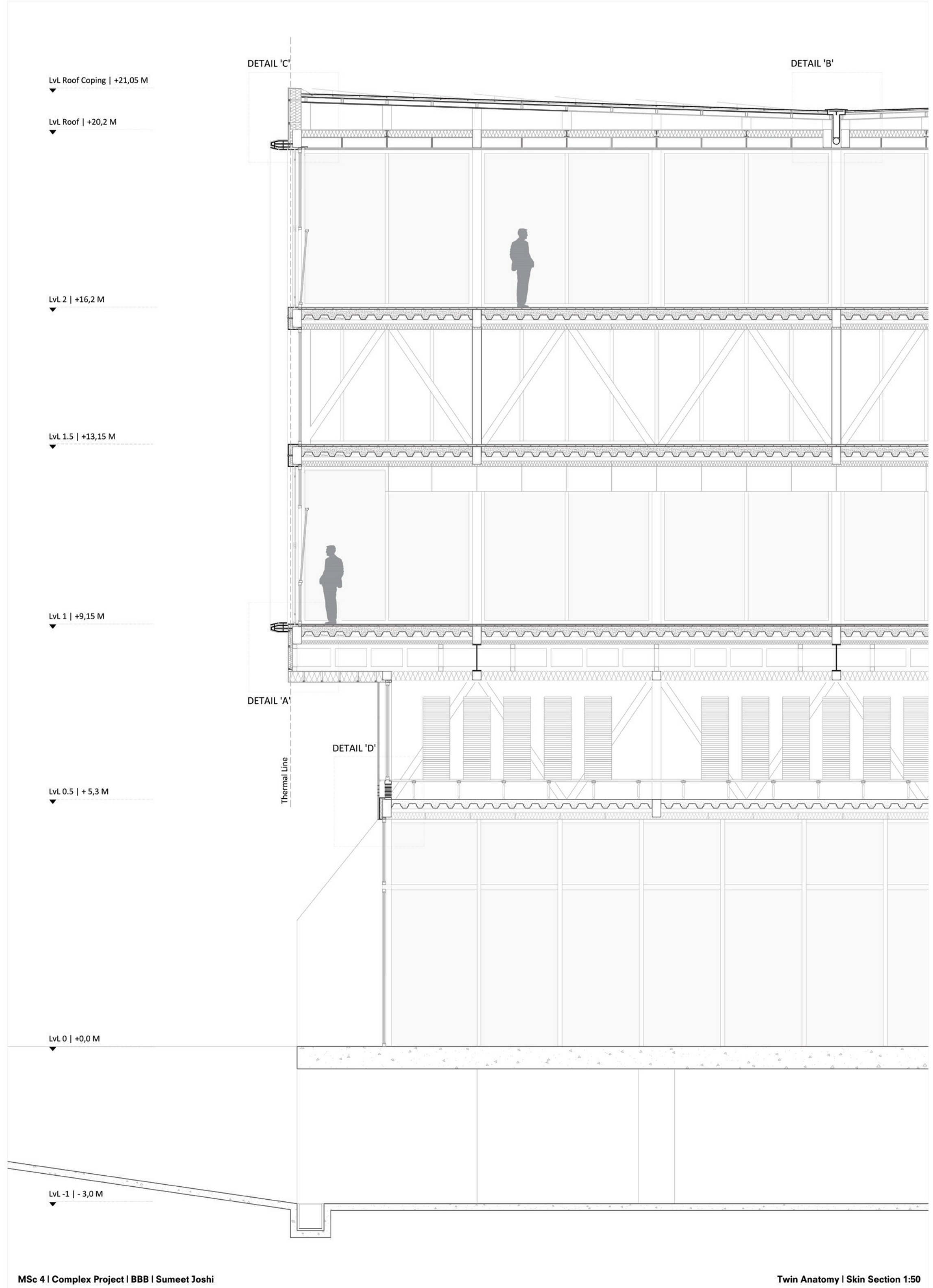

UP
Vsitors Entrance
Kiosk
Technical Office
Technical Office
Kiosk
Emergency Entrance
Toilet
Imaging Walkways
UP

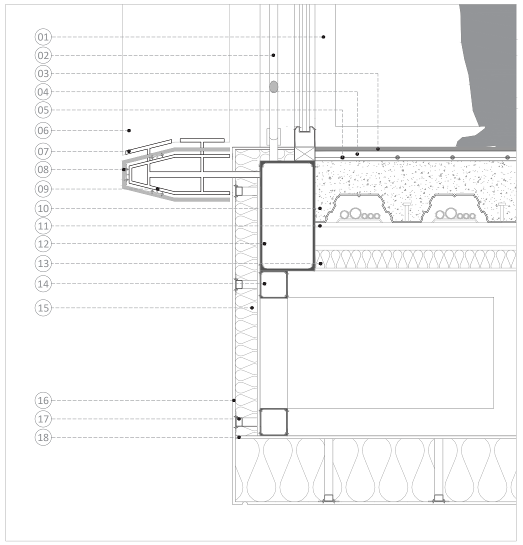
This cross-section explains the concept of twin anatomy. Just as human twins look similar on the outside but differ on the inside, this building creates distinct aesthetics for the digital and physical wings. The digital wing features bright colors that define its character, while the physical wing, where users' bodies are treated, has a warmer aesthetic with the use of timber. Additionally, the below-ground imaging walkways connect the urban edge of the city with the river edge, illustrating the seamless integration of movement and function within the building.

The most interesting part of this building is the roof. It features an inverted pitch, functioning as a large rain gutter to collect water and store it in underground tanks, which is useful for cooling the data centers. Data centers tend to overheat, so the excess heat produced during summer is stored underground and reused to heat the facility during winter. Additionally, the inverted angle of the roof allows for solar panels to be placed on the south-facing side, generating solar energy for use within the building.



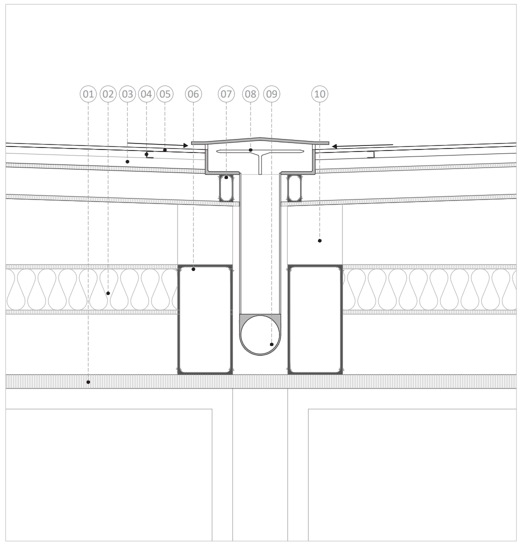

Ceramic Fins with Titanium Dioxide coat
can neutralised harmful pollutants before they can penetrate windows or air conditioning intakes


DETAIL 'C'
DETAIL 'B'
LvL Roof Coping | +21,05 M
LvL Roof | +20,2 M
LvL 2 | +16,2 M
LvL 1.5 | +13,15 M
LvL 1 | +9,15 M
DETAIL 'A'
DETAIL 'D'
Thermal Line
LvL 0.5 | + 5,3 M
LvL 0 | +0,0 M
LvL -1 | - 3,0 M
MSc 4 | Complex Project | BBB | Sumeet Joshi
Twin Anatomy | Skin Section 1:50



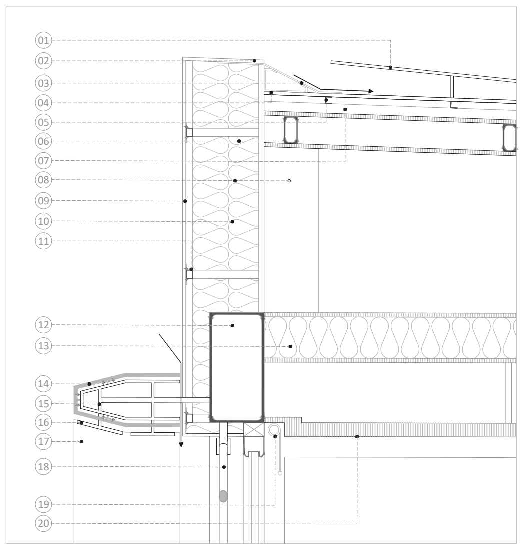
DETAIL 'A' (1:10)

01 TILT & TURN 12MM DOUBLE GLAZING WINDOW
02 60MM DIA STEEL CABLES, CROSS BRACING
03 14MM THICK LINOLEUM FLOORING
04 36MM SANDWICH THERMAL BOARDS
05 RADIENT FLOOR HEATING PIPES
06 30CM WIDE CERAMIC SUN SCREENS (FINS)
07 METAL CLAMPS FOR FINS
08 12MM CERAMIC PANELS
09 12MM STEEL PROFILE
10 125MM THICK COMPOSITE CONCRETE SLAB
11 100mm MS FLOOR BEAM (I SECTION)
12 200*400MM MS BOX SECTION
13 64MM THICK EPS INSULATION WITH 10MM FIBER BOARD
14 100*100 MM MS BOX SECTION (SPACE FRAME)
15 80MM THICK EPS INSULATION WITH 10MM FIBER BOARD
16 10MM THICK EXTERIOR CERAMIC WALL PANELING
17 METAL CLAMPS FOR EXTERIOR CLADDING
18 10MM FIBER BOARD



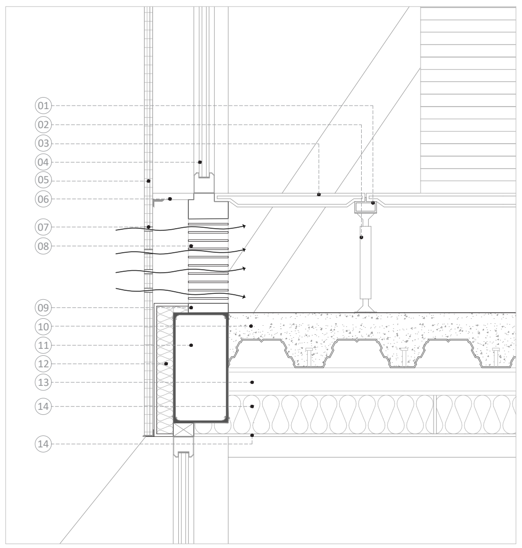
DETAIL 'B' (1:10)

01 50MM GYPSUM FALSE CEILING
02 160MM THICK EPS INSULATION WITH 10MM FIBER BOARD
03 60*35MM MS BOX SECTION PURLINS
04 METAL ROOFING CLAMPS
05 ROOFING WITH WATERPROOFING MEMBRANE
06 200*400MM MS BOX SECTION
07 50*100MM MS BOX SECTION RAFTERS
08 GEBERIT PLUVIA RAINWATER DRAINAGE
09 RAINWATER GUTTER
10 100*100 MM MS BOX SECTION (SPACE FRAME)



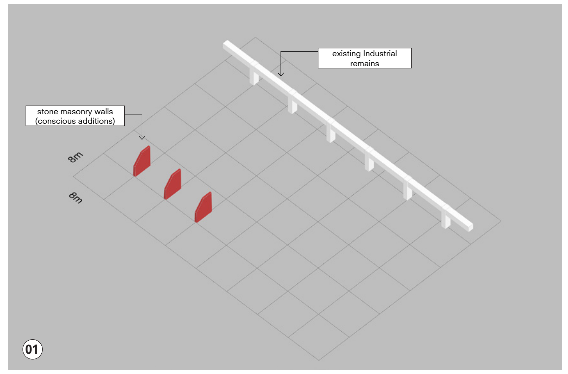
DETAIL 'C' (1:10)

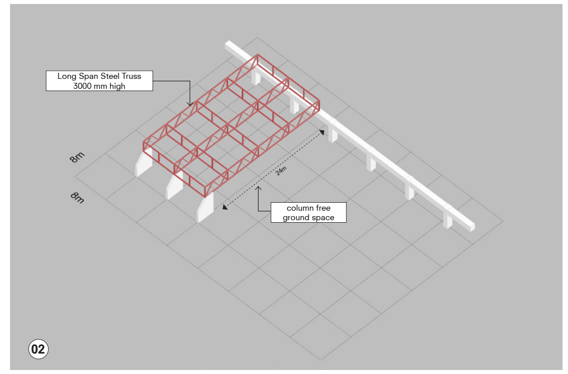
01 SOLAR PANEL
02 10MM CERAMIC EXTERIOR CLADDING
03 ALLUMINIUM LEDGE PROFILE
04 ROOFING WITH WATERPROOFING MEMBRANE
05 METAL ROOFING CLAMPS
06 50*100MM MS BOX SECTION RAFTERS
07 60*35MM MS BOX SECTION PURLINS
08 100*100 MM MS BOX SECTION (SPACE FRAME)
09 12MM CERAMIC PANELS
10 260MM THICK EPS INSULATION
11 METAL CLAMPS FOR EXTERIOR CLADDING
12 200*400MM MS BOX SECTION
13 160MM THICK EPS INSULATION WITH 10MM FIBER BOARD
14 12MM CERAMIC PANELS
15 12MM STEEL PROFILE
16 METAL CLAMPS FOR FINS
17 30CM WIDE CERAMIC SUN SCREENS (FINS)
18 60MM DIA STEEL CABLES, CROSS BRACING
19 ROLLER BLINDS
20 50MM GYPSUM FALSE CEILING

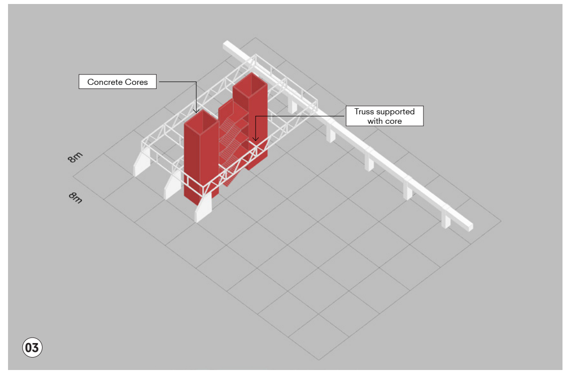


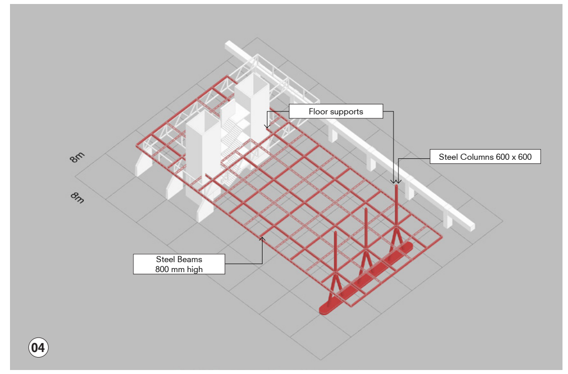
DETAIL 'D' (1:10)

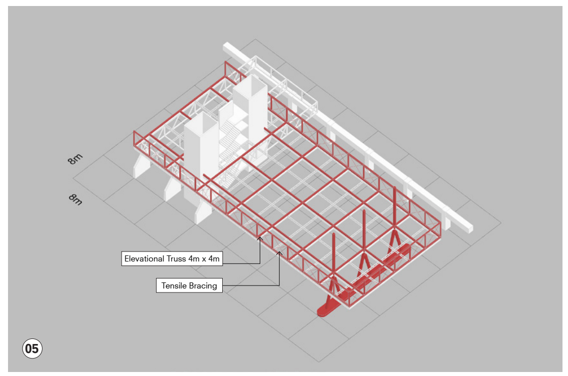
01 80*40MM MS STRINGER
02 350MM HIGH STEEL PEDESTAL
03 50MM THICK DECK FLOORING
04 DOUBLE GLAZING 12MM REINFORCED GLASS
05 30MM THICK THREE LAYER POLY-CARBONATE
06 30MM THICK BOARD AS AIR LOCK
07 20MM WIDE VENTILATION HOLES
08 ALUMINIUM AIR VENTS (FIXED LOUVERS)
09 145MM ALUMINIUM PROFILE FOR AIR VENTS
10 125MM THICK COMPOSITE CONCRETE SLAB
11 200*400MM MS BOX SECTION
12 80MM THICK EPS INSULATION WITH 10MM FIBER BOARD
13 100mm MS FLOOR BEAM (I SECTION)
14 150MM UNDER-DECK EPS INSULATION
15 10MM GYPSUM FALSE CEILING

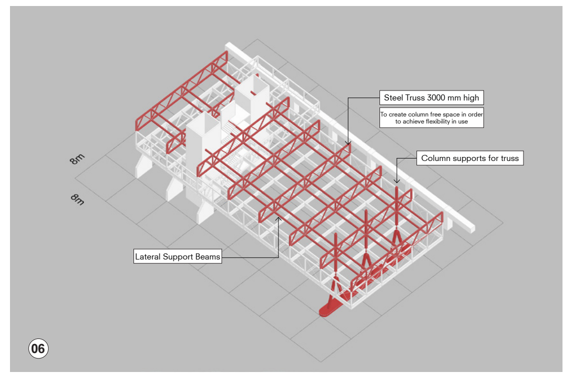


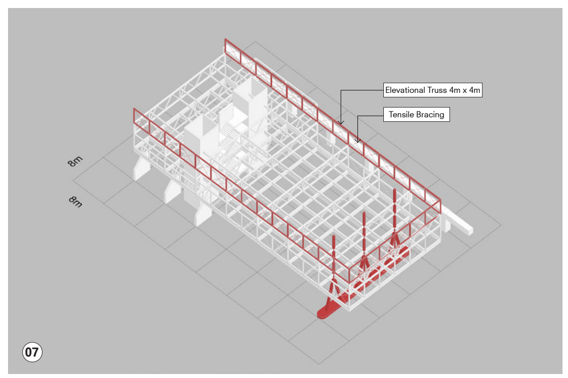


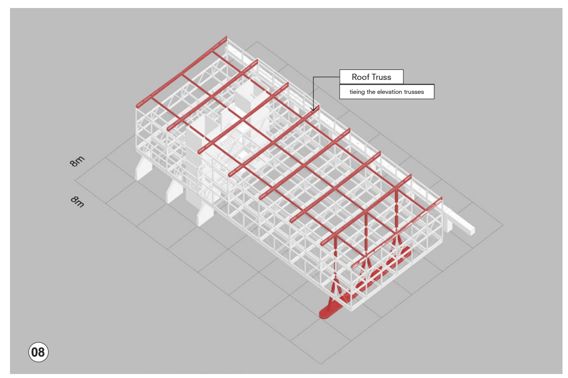






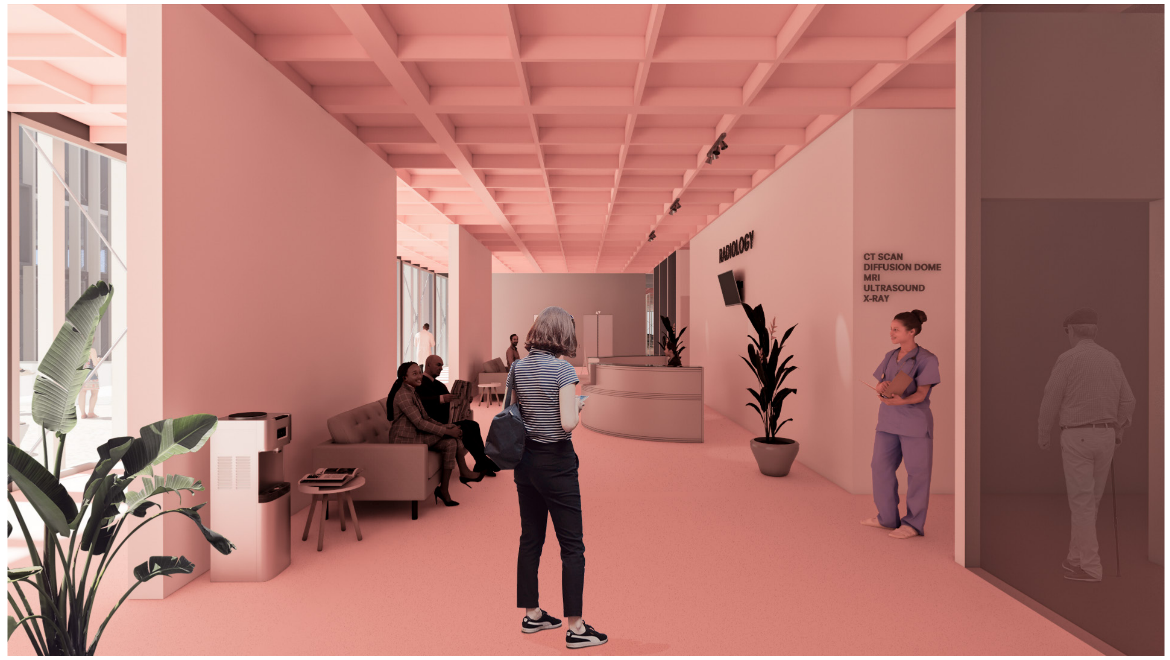






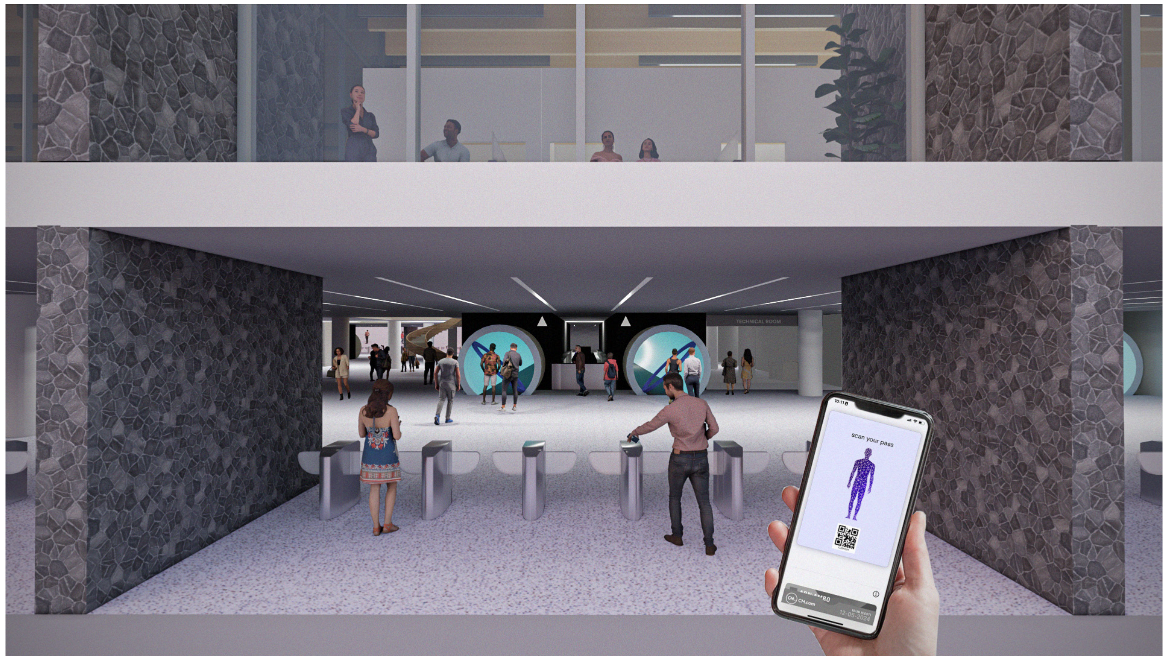
Approach view

Entrance Lobby



Radiology with Bright Colours (Digital Wing)

A view of an operation room

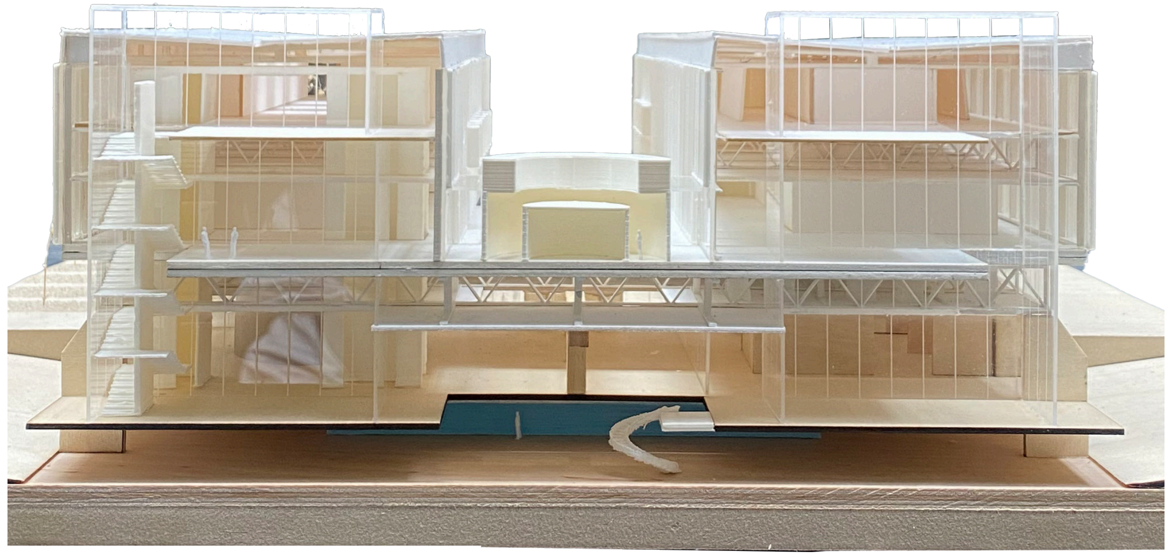


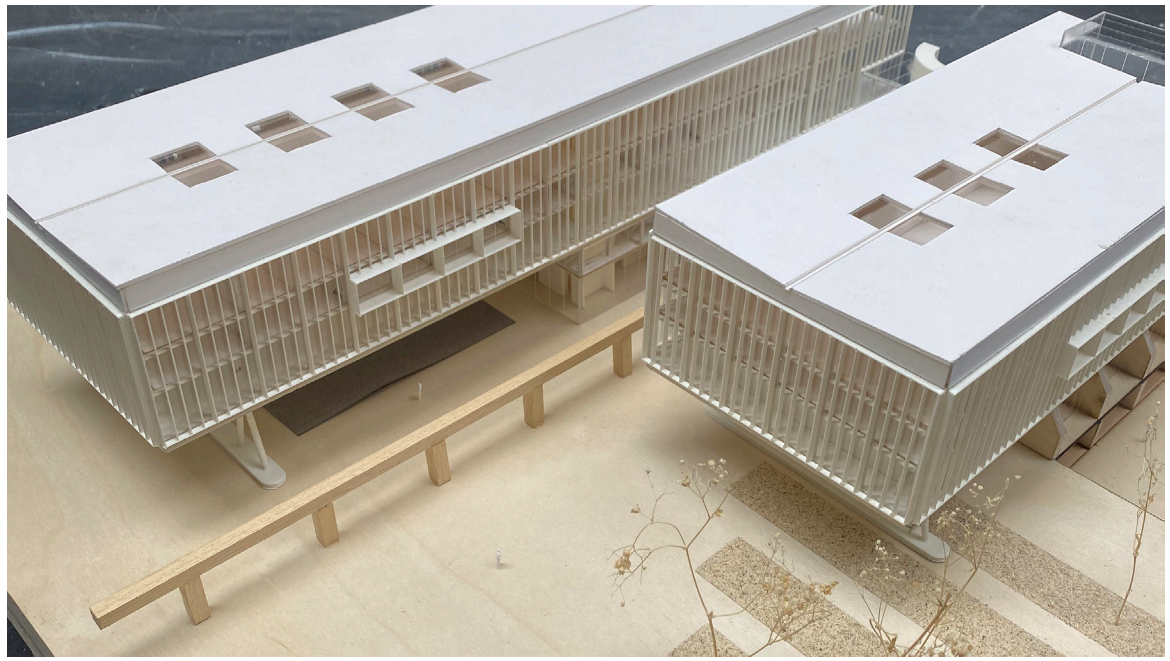
A view from the imaging walkways

Patient Room with warm and wooden aesthtics (Physical Wing)

Human - Twin Interaction Space

Data Diagnosis Offices





REFLECTION

06

ASPECT 01
relationship between graduation topic and studio topic

Our understanding of urban experiences emphasises the dynamic interplay between inhabitants and the built environment. Buildings serve as essential conduits for various activities, shaped by the specific needs and movements of users. Today, buildings are continously growing in size and scale. There is a constant pressure on buildings to be flexible, hybrid, circular and energy effcient. On the other hand, we live in a information-centric society, where data plays a pivotal role, bodies are increasingly perceived as data producers, influencing the demand for more efficient and functional buildings. This paradigm shift contributes to the heightened complexity in designing public buildings, a central focus of our master track.

The Complex Project Graduation Studio provides a platform for integrated research and specialization, offering an opportunity to critically reevaluate public buildings amidst evolving societal dynamics. Specifically, the studio methodology assigns students with a unique lens through which to examine these buildings, with a defined context in Berlin. The graduation project, centered on the reimaging of hospitals with a lens of digitalization, specualtes on a digital healthcare system and its influences on individuals and the society.

The project delves into the concept of the "Human Data Twin (HDT)," exploring the intersection of digitalization, healthcare, and architectural design. It seeks to understand how digitization of the human body in the information society influences the spatial and functional design of hospitals. This concept holds strong potential by revolutionizing the diagnosis process, which is the preliminary step in medical treatment. By envisioning hospitals as integral components of society that play a significant role in care, rather than isolated developments for rehabilitation, the project aims to bring a new perspective to hospital design, fostering dialogue within the urban context.

At its core, the project embodies the forward-looking ethos of our master program, drawing inspiration from near-future predictions of technological advancements in healthcare. The envisioned transformation of healthcare from generalized to personalized and percision medication, facilitated by data science and technology, forms the crux of the project.

By doing so, the project is poised to spark discussions around the imperative nature collaborating with technologies like Artificial Intelligence that will reflect change in the hospital functions, processes and design.

This discourse will also shed light on ethical challenges and considerations inherent in such advancements. In a broader sense, the project aspires to establish guidelines for designing hospitals of the digital future.

ASPECT 02
relationship between research and design

The research significantly influenced the design process, shaping recommendations that address crucial aspects of healthcare architecture and delivery. Conversely, the design considerations also influenced the research direction, guiding inquiries and deepening understanding in key areas.

The research started with understanding the role of the hopsitals by looking at its meaning stated in the oxford dictionary: A 'Hospital' is defined as an institution that provides medical and surgical treatment along with nursing care for sick or injured individuals.

This initial reference point, navigated the research into comprehending the evolution of hospitals and various typlogical and fucntional changes it underwent, resulting into its current model of 'cure and care', where individuals seek medical attention only when afflicted by illness, injury, or diseases.

Research questioned the healthcare infrastrucure and its preparedness, espicially during the onset of the COVID-19 pandemic, which underscored the limitations of the 'cure and care' model, leading to significant loss of lives—both due to the acute illness of the virus and delays in detection, reporting and diagnosis.

Moreover, the research spotlighted the disproportionate emphasis on diagnosis within the hospital program, underscoring the necessity of making diagnostic services more accessible and transparent to the public. This revelation prompted inquiries into transforming hospitals from perceived 'highly secured institutions' into engaging and informative spaces creating informed patients.

The lens of digitalization served as a guiding force in the group research. It brought in different perspectives about looking at the digital infrastrucures in the cities, mainly the architecture of Data Centres. A thorough analysis of 'Datatecture' guided the research into reassesing its position in today 's urban context. The group research helped formulate the graduation project by opening up possibilites to reimagine the healthcare delivery by leveraging on vast health datasets that can be securely stored in the data centre located within the campus, as a part of the group strategy.

The contextual study of Berlin played a pivotal role in understanding local healthcare dynamics and identifying suitable project parameters. This informed the development of a comprehensive design brief, delineating clear goals and objectives before embarking on the design phase.

Throughout the design process, research findings iteratively shaped design decisions. Preservation of existing heritage structures and incorporation of existing heavy concrete girders influenced site massing and program arrangements. Similarly, the imperative need to enhance diagnostic accessibility necessitated a detailed exploration of imaging technologies, culminating in the design of specialized medical equipment like 'imaging walkways'.

Additionally, the design recommendations were informed by specific research on Human Data Twin (HDT) technology, which influenced user flow considerations. This research distinguished between individuals seeking to upgrade to a human data twin and those already possessing one. Consequently, distinct pathways were created: one within the building and one below it, to facilitate seamless intersections.

As the project evolves, the symbiotic relationship between research and design continues to progress and attempts to answer questions raised earlier. Specifically, how can a hospital promote health and well-being in society through its architecture? Further research and explorations during the building's materialization phase are anticipated to yield valuable recommendations.

ASPECT 03

research method and approach in relation to the graduation studio

The design of large, complex buildings requires rigorous research and a structured approach to the design process. The Complex Project Graduation Studio employs a methodical framework for project development. This includes creating a well-defined design brief with problem identification, building typology research, case study comparisons to formulate the building program, urban analysis for potential sites, and studying the profiles of possible project clients. I decided to adopt the methodolgy of the studio as closely posisble, which facilitates focused exploration and evolution of the project.

The methodological approach also allowed space and direction for individual research. During the global pandemic, healthcare systems expanded beyond institutional boundaries into public buildings like schools and sports halls. A typology once highly specific became generic in its requirements. This change in typology based on the situation reflects the constant necessity of care delivery in today's society. The studio's focus on digitalisation, strengthen the intention of the individual research to make healthcare accessible. This led to a review of various literature, research papers, articles, and books related to healthcare.

Digitalization in healthcare is a vast topic that ranges from telemedicine to 3D printing of organs, tissues, or prosthetics to the application of artificial intelligence in medical processes. It needed a unique perspective to explore. This is when the concept of creating a Human Data Twin composed of large datasets, proposed by Siemens was discovered, and it became the core of the project

The parallel conduct of group research alongside individual research fostered a comprehensive understanding of the project's context and broader themes, such as creating a digital infrastructure for the city of Berlin. This collaborative approach enriched project's depth and allowed for the synthesis of findings into a cohesive project strategy.

To understand the current healthcare system in professional practice, myselfy with the group of students designing hospitals, approached GAF Architects, based in Rotterdam, who primarily work in the healthcare sector. Their valuable recommendations and experiences aided the research for the project at various stages.

In an interview with L'architecture D'aujourdhui, Kees Kaan, the chair of Complex Projects, mentioned that today, we are no longer master builders but master storytellers: architects guide and facilitate the dialogue among the many parties involved in a project. This includes users, owners, and investors on the client side, as well as architects, engineers, and specialists on the design side. The Complex Project Studio is based on the same principle of being able to express the project idea to the design mentors (who are also the critics).

Recurring presentations were prepared to explain the project through diagrams, graphical representations, and collages, which brought clarity and effective communication throughout the process.

The incorporation of physical study models and massing models brought tangibility to the representations of design ideas and aided in visualizing the project's potential atmosphere early on. Additionally, employing various process methods, such as drawings and digital modeling, enhanced the project's ambitions.

In conclusion, the approach taken in the graduating studio of complex projects is comprehensive and pragmatic, neverthless it is heavily based on production and learning by doing.

ASPECT 04

wider social, professional and scientific relevance of the project

The graduation project holds significant academic and societal value due to its exploration of the intersection between architecture, healthcare, and the evolving landscape of the information society. Hospitals, as vital public buildings, play a unique role in society, directly impacting individuals' lives and well-being. The architecture of hospitals not only affects their functionality but also influences the broader societal perception of healthcare and its importance.

By focusing on the potential of the information society and conceptualizing the body as a collection of data for health tracking, the project aims to shift the paradigm toward prioritizing life. This emphasis on leveraging data and digital technologies to enhance healthcare delivery underscores the project's academic relevance in addressing contemporary challenges and opportunities in the field.

The scope and implementation of the project extend beyond mere architectural design. It advocates for healthcare institutions to create spaces for dialogue, sharing medical knowledge, and fostering informed individuals.

One important aspect of making healthcare accessible to the community is the development of adaptable architectural solutions, such as the imaging walkways, which can be implemented in diverse settings and requirements. The advancements in healthcare architecture have the potential to be adopted on a larger scale, similar to how vaccines address the same virus in different contexts.

Moreover, the project's findings, although rooted in Berlin's context, offer insights and lessons that are applicable on a broader scale. It acknowledges the global nature of healthcare while recognizing the importance of context, culture, and individual needs. By reconceptualizing hospitals as more than just treatment centers and envisioning them as social spaces that proactively promote physical activities, the project presents a forward-thinking approach to healthcare design.

Lastly, the project demonstrates a conscientious approach to respecting existing site conditions and addressing public concerns raised by contested industrial sites. By incorporating input from local communities into the design process, the project seeks to create inclusive and responsive architectural solutions that enhance rather than impede the urban fabric.

ASPECT 05
ethical issues and dilemmas

The project assumes a growing emphasis on healthcare delivery as life expectancy extends into the future, even as the causes of deaths remain constant in the present It is based on a scenario where medical inventions have been thoroughly developed, such as the implantation of a sync device that can track individuals' health or a walking imaging scan to communicate changes to one's data twin, or the necessary technolgy to create a Human Data Twin. The project's core idea may sound speculative, but my attempt was to develop a realistic vision.

The intention was to create an architecture that promotes health and well-being. Various iterations led me to a design that floats above the ground, creating a canopy space for leisure and play. Initially, my approach was to translate it into a relatively simple structural principle, which consumes less material, and leaves room for expandability. However, the complexity of site conditions and program requirements resulted in a structure with heavy trusses to create column-free spaces on the ground level, intending to make it public.

Given the time factor and the decisions made early on in the design stage, I proceeded with a truss design, with heavy use a of material. Therefore, focus of my presentation is on cataloging building components, spatial experience and building skin section as the principal element of design. In this way, the material and architectural qualities can be explained more consistently with the concept of the building itself.
Ethical considerations loom large in the project's development. The reliance on health data sets of millions of people raises concerns about data security and privacy. Addressing these concerns requires robust measures to safeguard sensitive information, including involving government oversight rather than relying solely on private entities.

Additionally, the integration of artificial intelligence (AI) in healthcare consultation introduces ethical dilemmas regarding its appropriate role and limitations. While AI offers benefits in terms of consistency, analytical capabilities, and efficiency, its deployment must be carefully managed to ensure it complements rather than replaces human expertise and maintains patient autonomy and confidentiality.

As a hypothetical project investigating the future, it is consistently based on conclusions stemming from conventional research methods. The project is thus a structured study into the future evolution of the hospital type and has the potential to instigate questions about making healthcare accessible and ensuring that healthcare institutions play a more significant role in caring for and creating informed individuals.

BIBLIOGRAPHY

07

References

1. Lee, P., Goldberg, C., & Kohane, I. (2023). The AI revolution in medicine: GPT-4 and beyond. Pearson.

2. Mohamed, K. (2018). Health Analytics Types, Functions and Levels: A Review of Literature. Data, Informatics and Technology: An Inspiration for Improved Healthcare, 137-140.

3. Nickl-Weller, C., & Nickl, H. (2020). Architecture for Health. Braun.

4. Li, A., & Shi, P. (2022). Research progress on wearable devices for daily human health management. Wearable Technology, 2 (1), 82 .https://doi.org/10.54517/wt.v2i1.1654

5. Riva , M. A., & Cesana, G. (2013). The charity and the care: the origin and the evolution of hospitals. European Journal of Internal Medicine, 24, 1-4. doi:https://doi.org/10.1016/j.ejim.2012.11.002

6. Shengli, W. (2021). Is human digital twin possible? Computer Methods and Programs in Biomedicine Update, 1, 100014.

7. Wagenaar, C. e. (2018). Hospitals : A Design Manual. Walter de Gruyter GmbH. Retrieved from http://ebookcentral.proquest.com/lib/delft/detail.action?docID=5155807.

8. Ramdurai, Balagopal. (2021). Use of Artificial Intelligence in Patient Experience in OPD. 1-8. 10.5923/j.computer.20211101.01.

9. Meskó, B., & Görög, M. (2020). A short guide for medical professionals in the era of artificial intelligence. NPJ digital medicine, 3, 126. https://doi.org/10.1038/s41746-020-00333-z

10. Puaschunder, Julia & Feierabend, Dieter. (2019). Artificial Intelligence in the Healthcare Sector. SSRN Electronic Journal. 10.2139/ssrn.3469423.

11. Rao, D. J., & Mane, S. (2019). Digital twin approach to clinical dss with explainable ai. arXiv preprint arXiv:1910.13520.

12. Capolongo, S., Gola, M., Brambilla, A., Morganti, A., Mosca, E. I., & Barach, P. (2020). COVID-19 and healthcare facilities: a decalogue of design strategies for resilient hospitals. Acta Bio Medica: Atenei Parmensis, 91(9-S), 50.

13. Heijink, A., van den Heuvel, J., & Schoonhoven, M. (2022). Increasing efficiency in healthcare: a showcase in an orthopedic outpatient clinic. International Journal of Lean Six Sigma, 13(1), 33-45.

14. Babbu, A. H. (2016). Flexibility: a key concept in hospital design. Int J Appl Innov Eng Manag, 5, 24-28.

15. Setola, N., Borgianni, S., Martinez, M., & Tobari, E. (2013, October). The role of spatial layout of hospital public spaces in informal patient-medical staff interface. In the Ninth International Space Syntax Symposium, Seoul: Sejong University.

16. Freihoefer, K., Nyberg, G., & Vickery, C. (2013). Clinic exam room design: present and future. HERD: Health Environments Research & Design Journal, 6(3), 138-156.

17. Lin, S. (2022). A clinician's guide to artificial intelligence (AI): why and how primary care should lead the health care AI revolution. The Journal of the American Board of Family Medicine, 35(1), 175-184.

18. Feenstra F. Reactivating Hospital, Active Patients Through Special Design. HERD: Health Environments Research & Design Journal. 2021;14(1):87-105. doi:10.1177/1937586720966757

19. Lacanna, G., & Wagenaar, C. (2018). Public Spaces in and Around the Hospital: Streets, Squares, Patios, Waiting Areas, Healing Gardens. In Hospitals: A design manual (pp. 61-64). Springer.