# ABSTRACT

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| Title of Thesis: | THE DISTRIBUTION OF CARE: A MODULAR FACILITY FOR THE TREATMENT OF DISEASE-STRICKEN COMMUNITIES IN AFRICA |
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| Thesis Directed By: | Lecturer, Julie Gabrielli, School of Architecture, Planning and Preservation |

Africa experiences a disproportionate amount of the global disease burden, and existing health care centers struggle to meet everyday patient needs. During a disease epidemic, this inability to accommodate communities is exacerbated by a lack of resources to diagnose and treat infectious disease as well as a physical separation from the location of outbreaks. This thesis investigates how patients of disease outbreaks in Africa can be better accommodated through the exploration of a modular health facility capable of treating communities no matter when and where an outbreak occurs. Outbreaks unexpectedly affect vulnerable populations, and immediate action is crucial to contain the disease. The current Ebola outbreak in the Democratic Republic of Congo is utilized as a case study in this thesis, considering its relevance as an ongoing epidemic. Due to the abrupt and destructive nature of disease, a modular and flexible health facility is needed to handle any outbreak in any location.

# THE DISTRIBUTION OF CARE: A MODULAR FACILITY FOR THE TREATMENT OF DISEASE-STRICKEN COMMUNITIES IN AFRICA

by

Kelsey Winters

Thesis submitted to the Faculty of the Graduate School of the
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Lecturer Julie Gabrielli, Chair
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**Chapter 9**

# List of Abbreviations

| | |
|---|---|
| AIA | The American Institute of Architects |
| CCCs | community care centers |
| CDC | Center for Disease Control |
| DALYs | disability-adjusted life-years |
| ELWA | eternal love winning Africa |
| EOC | emergency operations center |
| ETC | Ebola treatment center |
| ETU | Ebola treatment unit |
| EVD | Ebola Virus Disease |
| FMTs | foreign medical teams |
| HZs | health zones |
| MoD | Ministry of Defense |
| MSF | Médecins Sans Frontières |
| IHR | International Health Regulations |
| PHEIC | Public Health Emergency of International Concern |
| PPE | personal protective equipment |
| WHO | World Health Organization |

# Chapter 1: Infectious Disease in Africa

## *Prevalence of Disease Today*

Infectious diseases have always been prevalent in the world, but recent global phenomena, such as climatic changes, ecosystem variations, conflict, changes in human behavior and demographics, as well as social inequality have led to a reemergence of infectious disease. In fact, any progress in the health condition of people in Africa directly correlates with political stability, less conflicts, and changes in demographics or economics within the region. In Africa, two-thirds of the disease burden is caused by communicable, or infectious, diseases.[1] Infectious diseases are spread when bacteria or viruses are transmitted from one person to another, either through contact, air, blood, or vectors (Fig. 1.1).

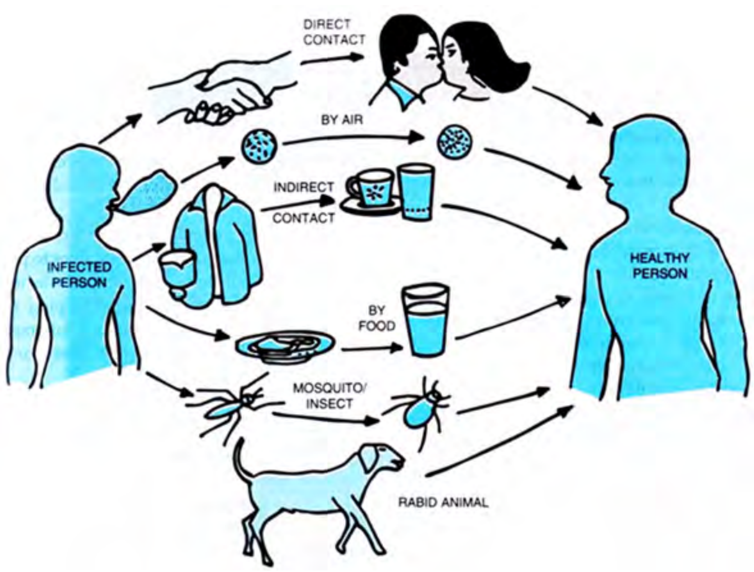


**Figure 1.1: Transmission of Communicable Diseases**
Source: BiologyDiscussion.com

[1] World Health Organization: Africa, *The Health of the People: What Works—The African Regional Health Report 2014* (Geneva: WHO Regional Office for Africa, 2014). Accessed October 16, 2019. https://www.who.int/bulletin/africanhealth/en/

Significant progress towards combatting infectious diseases was made in the 1970’s, through means of vaccines, antibiotics, technology, and other methods of treatment. At that point in time, we began to see a lesser presence of microbes and disease, which researchers thought meant we had won a victory over disease. However, rather than being wiped out of existence, the diseases were just hidden—out of sight. Since then, researchers have discovered 1,500 new types of pathogens, including Ebola and HIV, two extremely deadly viruses. Out of the newly discovered diseases, about 70% originate from animals, and can remain dormant for years before suddenly reappearing again (Fig. 1.2). This experience proves a lesson that will continue to repeat over time: There will always be disease. There will be a new HIV, or Ebola, or flu, no matter how it is transmitted. Whether it’s brand new to us or has laid dormant for 50 years, diseases will continue to affect us, and they will usually do so unexpectedly.[2] Africa itself has experienced many epidemics in the last several years, being affected by diseases both familiar and new.

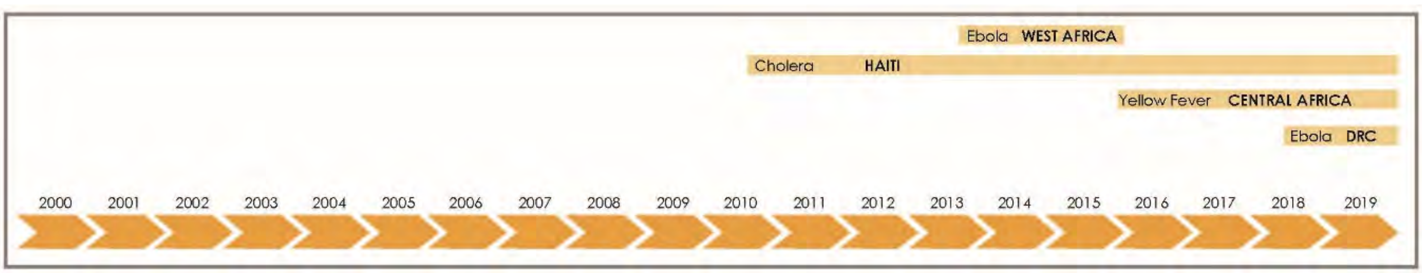


**Figure 1.2: Major Epidemic Threats in Africa**
Source: WHO (Edited by Author)

[2] World Health Organization, *Managing Epidemics: Key Facts About Major Deadly Diseases* (Luxembourg: World Health Organization, 2018): 14. Accessed October 16, 2019. https://www.who.int/emergencies/diseases/managing-epidemics-interactive.pdf

*<u>Disproportion of Disease Burden</u>*

Africa is known as having the worst infectious disease burden in the world (Fig. 1.3), while at the same time having the worst public health infrastructure. Such a concerning disproportion of the disease burden exists in Africa because many of the traits that fosters the emergence and spread of infectious disease, such as low vaccination rates, poor nutrition, overcrowding, poor regional design, lack of hygiene (due to poverty), dirty drinking water, rapid climate changes, and natural disasters, exists in many African countries.[3] Vector-borne diseases, or zoonotic diseases, are transferred between animals and people, and are responsible for over 60% of infectious diseases. Risk of contracting zoonotic infectious diseases is especially prevalent in lower latitude developing counties, such as tropical Africa. Half of the deaths in Africa are by cause of infectious diseases, which is shocking considering in Europe, data states that only 2% of deaths can be attributed to infectious disease.[4]

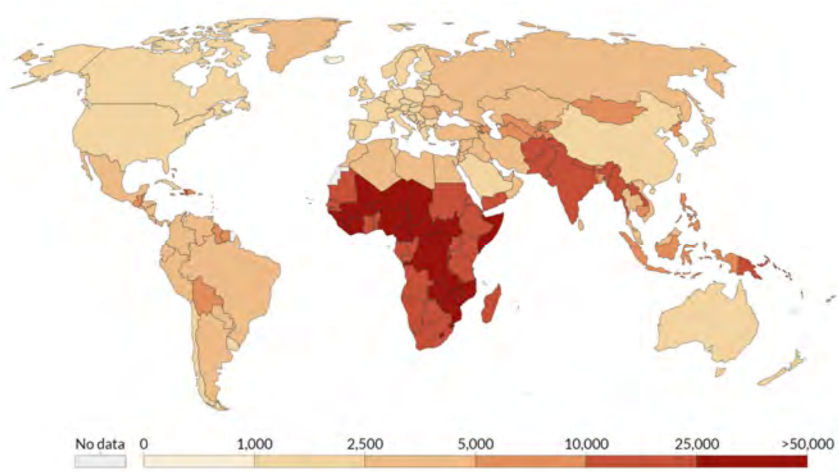


**Figure 1.3: DALY Rates from Communicable Diseases, 2017**
Source: Our World in Data

[3] Jonathan Ameli, "Communicable Diseases and Outbreak Control," *Turkish Journal of Emergency Medicine* 15, no. 1 (October 2015), https://doi.org/10.5505/1304.7361.2015.199702452247316600596
[4] F. Fenollar and O. Mediannikov, "Emerging Infectious Diseases in Africa in the 21st Century," New Microbes New Infect. 26 (Sep 2018), https://doi:10.1016/j.nmni.2018.09.004

Globalization and human mobility are not helping the world disease problem, and global pandemics increase as global interconnectedness increases. Globally, the spread of disease becomes worse as the trend towards urbanization continues. In these scenarios, people become closer together and closer to elements that allow disease vectors to thrive. For example, mosquito-borne virus malaria is more prevalent in poorer areas with standing water in or around the home, and risk of infection becomes higher as populations in these living conditions become physically closer. Already, approximately 90% of the 300-500 million yearly malaria cases affect Africans.[5] Due to globalization, diseases can spread much more rapidly and on a global scale than in previous instances, where these diseases tended to be more localized within a community. On the opposite side of the spectrum, rural communities also greatly suffer from disease outbreaks, especially considering the isolation they live in can make it extremely difficult to access doctors when sick. Alternatively, these communities are also considered too difficult to reach, and so they are often left to suffer the burden of disease on their own.

Another reason for the disproportionate health problems present in Africa is the lack of spending in the healthcare sector and the lack of physicians or health workers. Countries in Africa have the lowest health expenditure per capita while most of those countries have a much higher disease burden than countries on other continents (Fig. 1.4).

[5] World Health Organization: Africa, *The Health of the People: What Works*

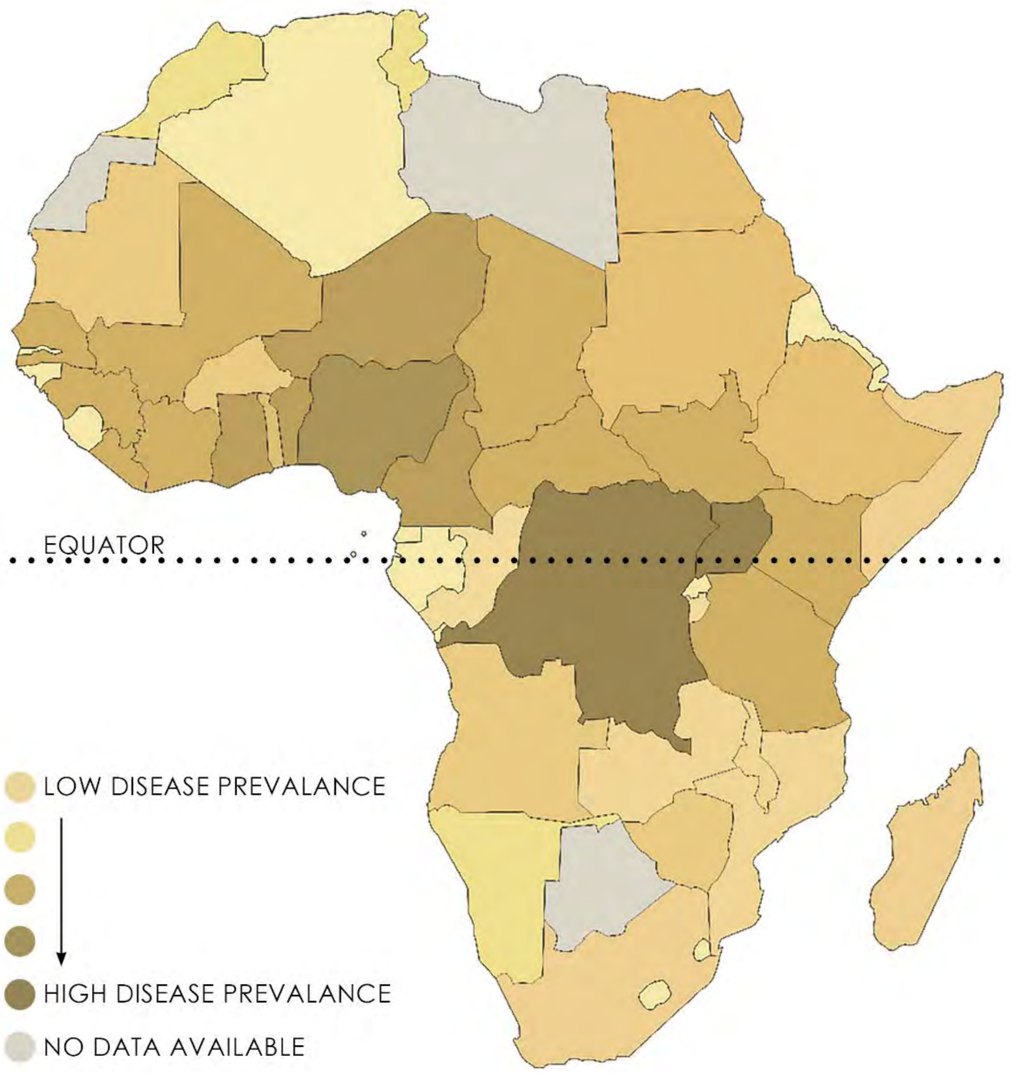


**Figure 1.4: Africa's Disease Burden**
Source: Author

Poverty and poor healthcare leads to the continent's average spending in healthcare to equate to $36 per person in 2001, compared to a much higher $4800 in the United States. Due to its susceptibility to disease and outbreaks and its lack of health care (Fig. 1.5), Africa should be the number one priority in the global fight against the spread of infectious diseases.[6] Infectious disease is considered to be the most common cause of illness and death in Africa, yet health workers continue to fail to identify causative microorganisms in most patients. Due to this, even when medicine capable of curing disease is available, outbreaks are larger and more devastating than they should be because patients do not promptly receive the right medication in time to cure them.[7]

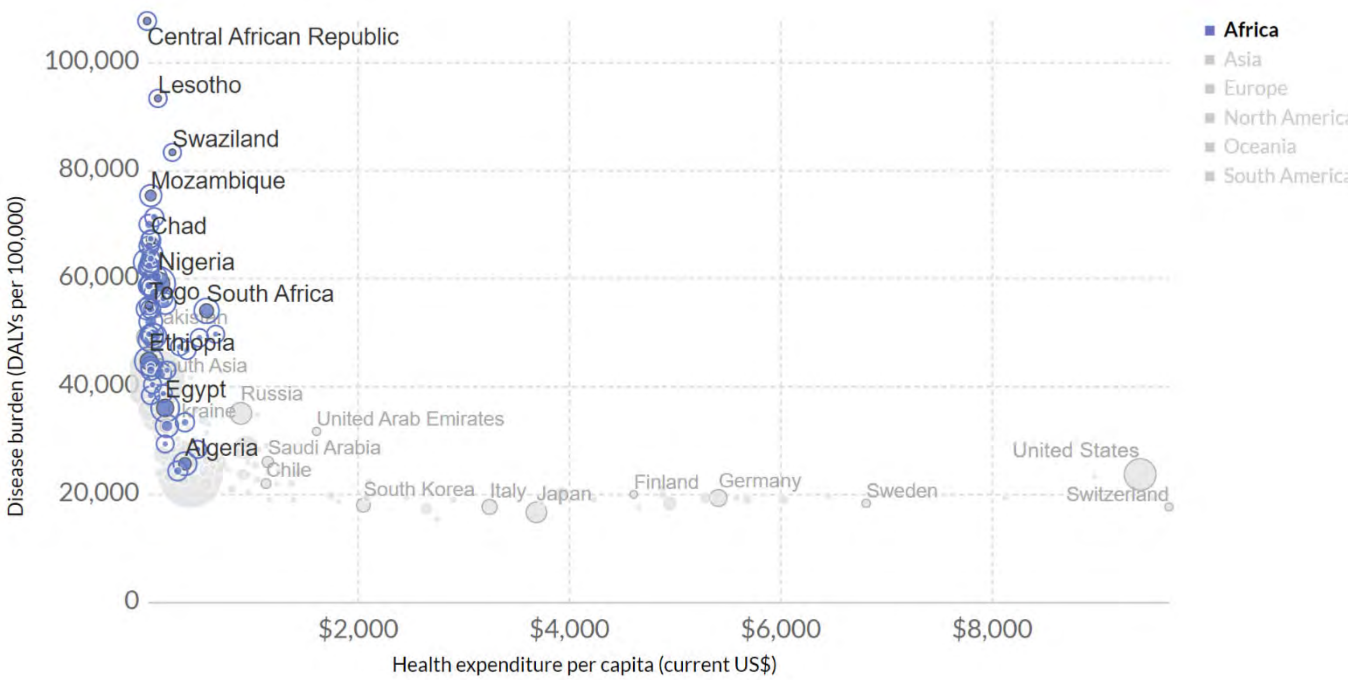


**Figure 1.5: Disease Burden vs. Health Expenditure per Capita, 2014**
Source: Our World in Data

Due to this, Africa is highly dependent upon incoming support from global health organizations during times of outbreak and crisis. External organizations assist in bettering Africa's disproportionately weak health system even when there is no

[6] F. Fenollar and O. Mediannikov, "Emerging Infectious Diseases in Africa in the 21st Century"
[7] Iruka N. Okeke, *Divining Without Seeds: The Case for Strengthening Laboratory Medicine in Africa* (Ithaca : ILR Press, 2011), 3, EBSCO.

ongoing outbreak, but there is still more improvement to be made considering not every country is receiving equal amount of help and service (Fig. 1.6). Even when a disease outbreak occurs, many of these external resources and organizations refrain from immediately assisting in the epidemic unless the country announces it as an emergency. This is a practice that many professionals are trying to change, so that other countries and organizations are more willing to come set up a field camp and respond to the emergency before the affected country must request help.

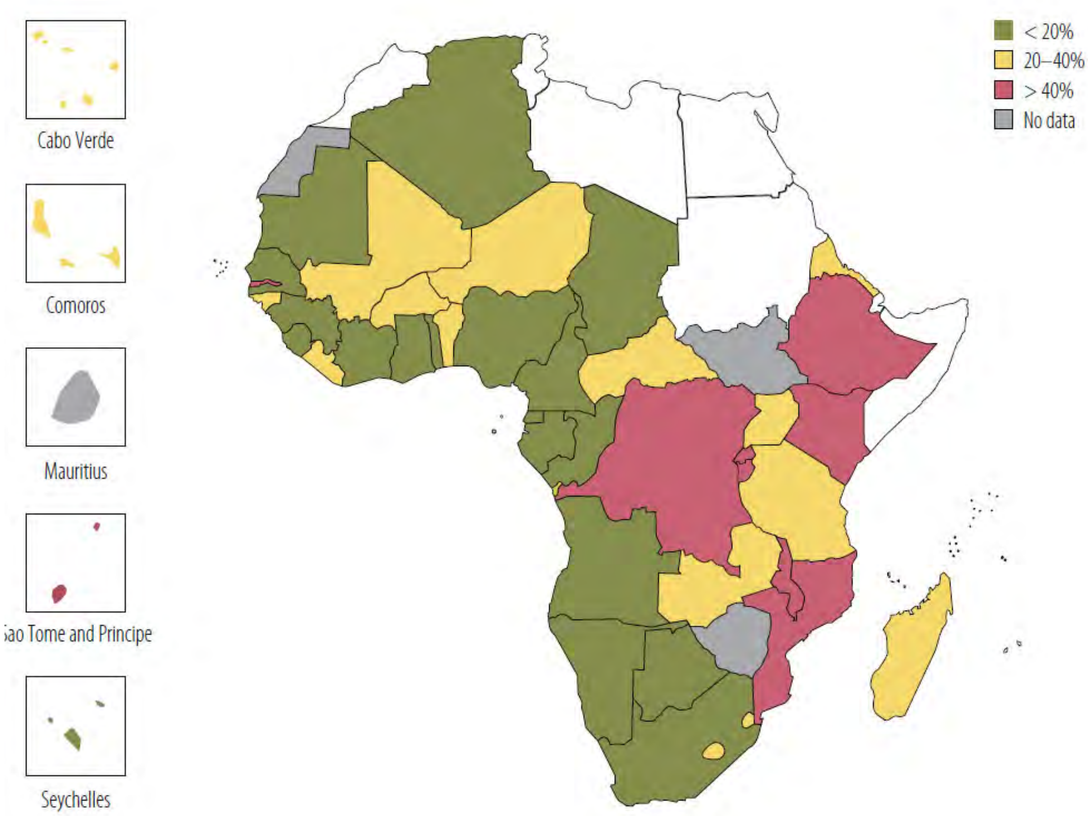


**Figure 1.6: External Resources on Health as a Percentage of Total Health Expenditure in the WHO African Region, 2012**
Source: World Health Organization, *Health of the People: What Works*

Many infectious diseases, such as Cholera, HIV/AIDS, Ebola, etc. disproportionately affect populations in Africa. Cholera is a disease that is reemerging in Africa due to the presence of a variety of risk factors throughout the continent, such as its lack of access to drinking water as well as internal physical conflicts, overpopulation, poverty, lack of hygiene, and poor sanitation. It is unfortunate that Cholera has the capacity to kill humans in Africa, considering its main symptom is diarrhea, which leads to death by dehydration of the individual. However, this disease still has the capacity to ravage communities, considering one-third of the African population lacks access to clean drinking water and decent sanitization.

Diseases like Ebola, which originates from animals such as monkeys, are also prevalent in Africa due to living conditions and humans' proximity to primates, or other animals that have had contact with the infection. However, not every part of Africa has the same susceptibility to disease: For example, countries within Africa have a varying risk for Yellow Fever, which is different from each country's susceptibility to West Nile Virus infection, or Zika Virus, and each infectious disease.

*Efforts to Combat Infectious Disease*

Recent efforts to identify and treat infectious diseases in Africa have increased and have led to the discovery and identification of new infectious agents that can be transferred between humans in ways other than bacterial or viral that medical personnel and community members will need to be aware of. After the 2014-2015 West Africa Ebola outbreak, it became clear that monitoring disease should be a priority. The implementation of programs such as the Integrated Disease Surveillance and Response Strategy over the last decade have significantly enhanced, prioritized, and improved the ability to perform early detection, reporting and response to communicable diseases, especially following the devastation of the 2014 Ebola outbreak.

Early detection of disease can be enhanced through practicing passive surveillance and reporting, which occurs while there is no active threat of disease. Passive reporting helps to identify more cases of diseases, so that the sick can be treated, and data can be collected for research. For example, confirmed cases of cholera skyrocketed in the 1990's after the implementation of improved detecting, diagnosing, and reporting (Fig. 1.7). This doesn't mean that all of a sudden cholera was spreading and affecting larger populations, but rather the number of cases have most likely always been higher, but now we are more aware and are treating more patients due to better detection and reporting of information.

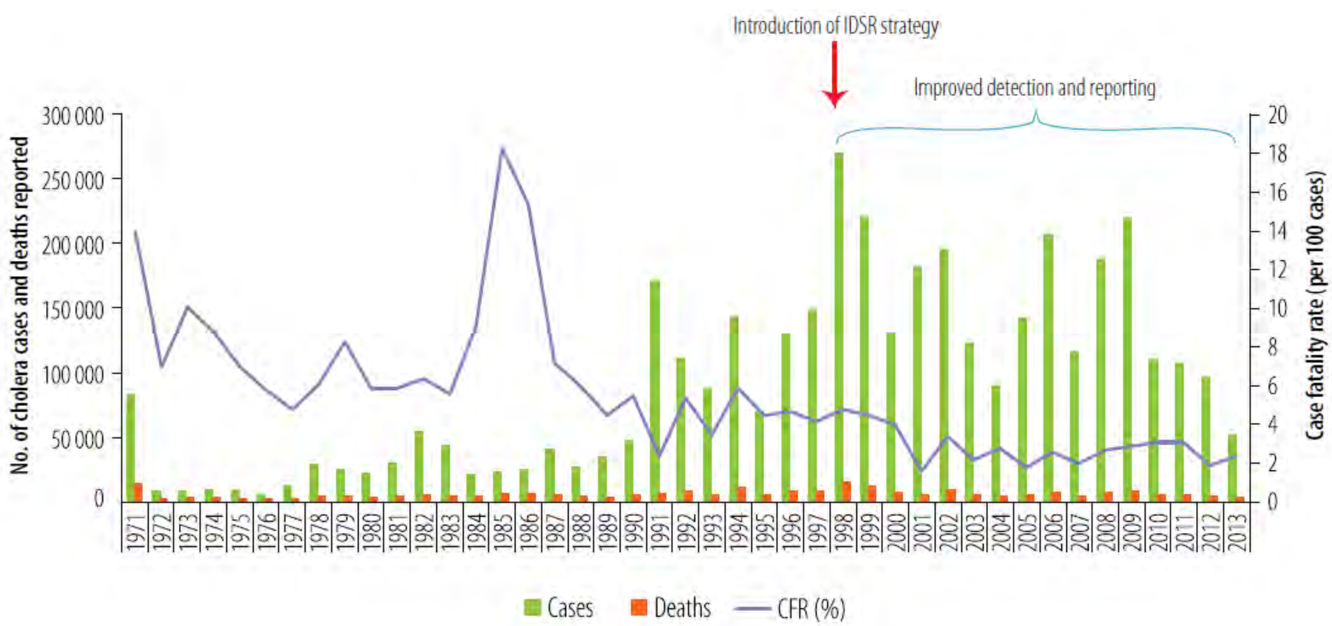


**Figure 1.7: Trend of Cholera Cases and Deaths Reported in the WHO African Region, 1971–2013**

Source: World Health Organization, *Health of the People: What Works*

In passive reporting, health care providers must be capable of recognizing disease through means of identifying the physical characteristics of disease as well as other symptoms as stated in case definitions for the disease.[8] The issue with passive surveillance is that it depends on communities having access to health care facilities, which is not the case in many parts of Africa. For many, health care facilities are too sparse or far away, which causes many sick individuals to refrain from seeking care. When this happens, not only does the likelihood of the infection spreading to friends or family of the individual increase, but then health care professionals are also unaware of these instances, which inhibits reporting, research, and data collection. Even health centers are accessible to the sick, there is still the issue of under-recognition of diseases. This occurs for many reasons, including if a disease is newly emerging and is not widely known, if a disease has non-specific symptoms, or if the symptoms are similar to other more well-known diseases, then misdiagnosis can be common. Also, for the study and surveillance of many diseases, laboratory support is necessary, but unfortunately in many parts of the world, including Africa, this type of support is inadequate and lacking.[9]

*Strategies to Deliver Effective Treatment*

In order to combat the spread of infectious disease, what is needed is a combination of disease surveillance, epidemic preparedness, and response. Constantly

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[8] World Health Organization: Africa, *The Health of the People: What Works*

[9] "WHO Report on Global Surveillance of Epidemic-prone Infectious Diseases – Introduction," Emergency Preparedness Response, World Health Organization, accessed October 16, 2019, https://www.who.int/csr/resources/publications/introduction/en/index4.html

conducting laboratory disease surveillance and research surveys would help to identify sources of disease before it spreads and causes an epidemic to occur. Unfortunately, however, in order to conduct surveillance, research, and treatment, there needs to be a massive increase in the number of doctors and medical personnel available in the African region.[10]

Due to the prevalence of disease, families in Africa mold their lifestyles around disease prevention. In many cases, African organizations expend resources to educate communities on methods to avoid disease and illness, such as practices of personal protection, including wearing clothing covering the whole body, using insect repellant, and sleeping under mosquito nets. Africans may also implement physical barriers in the home such as window screens, keeping doors to the outside closed, and keeping pets or animals outside and away from human sleeping and cooking areas. Another concern is to eliminate vector breeding sites near the home, such as open water containers, standing water, and trash to reduce the number of vectors, infected or otherwise, near frequented locations.

[10] F. Fenollar and O. Mediannikov, "Emerging Infectious Diseases in Africa in the 21st Century."

# Chapter 2: Standard Outbreak Protocol

## *Outbreaks versus Epidemics*

Typically, when an illness mysteriously begins infecting a population, an epidemic is not the first assumption (at least to researchers and medical personnel). In some cases, like a food-borne illness, there may be an outbreak of sickness caused by a food or beverage that can be traced and the mystery is solved. Despite many people claiming to be sick, that doesn't always mean that there is an epidemic or emergency. There are many possibilities as to what is transpiring, and it could be an epidemic, or it could be an outbreak, environmental issue, or more concerningly, an act of bioterrorism.

Whereas an epidemic is a widespread occurrence of an infectious disease in a community at a particular time, an outbreak is a sudden rise in the number of cases of a disease. There are usually outbreaks that are expected, like seasonal flu outbreaks or other diseases that tend to occur annually. A rise in cases of disease may be considered more serious if there are a drastically higher number of sick than usual or if the disease being spread is unexpected. Before a state of emergency is declared, researchers and health officials will determine an approximate cause or source of the issue. Depending on how many people are being affected and how quickly the bacteria or virus is spreading, additional health safety measures may be taken. Hopefully, passive surveillance will help to catch outbreaks early before too many people become infected, but sometimes than isn't the case and communities can become alarmed when there is no large threat. Precautions must be taken to determine if there is a threat of an epidemic, so that resources are not needlessly used.

*Standard Operating Procedures in Africa*

International Health Regulations are a legally binding set of international laws with the purpose of assisting countries in working together to save lives and livelihoods endangered by the international or global spread of disease. Under the IHR, all countries in agreement must report all events of international public health importance. The IHR requires State Parties to have a surveillance and response strategy in place to manage health events that could be harmful to humans.

The requirement is that all countries must Detect, ensure all laboratories and surveillance systems are capable of detecting potential threats; Assess, work with other countries to make decisions in times of health emergencies; Report; all countries must report any diseases or events of public health concern; and Respond, the countries must respond in times of emergency.[11] With these precautions in place, the goal is that threats can be eradicated before they become international public health emergencies. This supports the role of the World Health Organization, which is especially focused on overseeing and minimizing the threat of health events of international concern. WHO helps State Parties to maintain public health emergency systems, networks, partnerships and tools so that health officials may quickly and proactively identify, verify and assess risks to public health.[12]

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[11] "Infographic: International Health Regulations (IHR) Protecting people every day," Global Health, CDC, accessed October 18, 2019, https://www.cdc.gov/globalhealth/infographics/global-health-security/ihr.htm

[12] World Health Organization Regional Office for Africa, *Standard Operating Procedures for Coordinating Public Health Event Preparedness and Response in the WHO African Region*, 2014.

*Outbreak Response*

During the beginning stages of a perceived outbreak, there is an ideal sequence of events that will transpire so that surveillance and response strategies are effective. As represented in Fig. 2.1, early detection, laboratory confirmation, reporting and response causes the epidemic curve to move to the left. This trend represents an overall significant reduction in potential case numbers, morbidity, and mortality when performed within the first two weeks of an outbreak.[13]

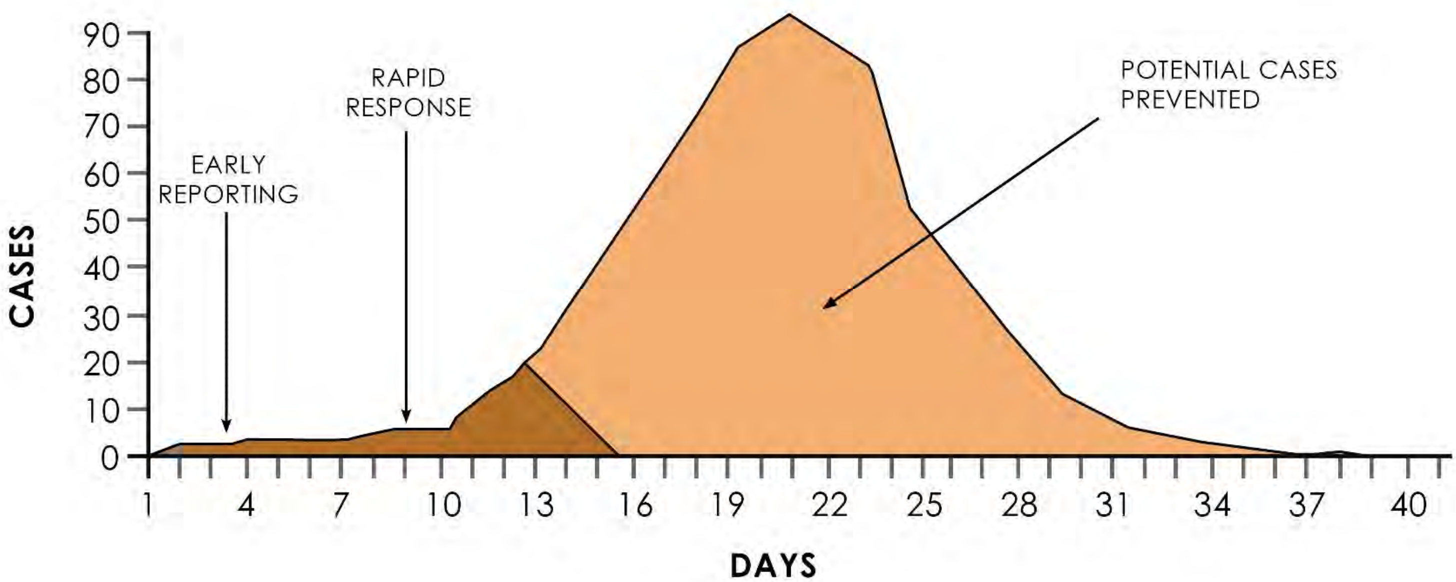


**Figure 2.1: Benefits of Prevention through Early Reporting and Response**
Source: Global Health Risk Framework (Edited by Author)

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[13] The National Academies of Science, Engineering, Medicine, *Global Health Risk Framework: Resilient and Sustainable Health Systems to Respond to Global Infectious Disease Outbreaks – Workshop Summary* (Washington, D.C.: The National Academies Press, 2016), 77, https://www.nap.edu/read/21856/chapter/6#76

At a presentation hosted by the National Academy of Medicine in 2015, two speakers, Nguku and Nasidi, presented that there are certain factors that can help reduce case numbers, morbidity, and mortality. They are:

- Implementing and maintaining a functional and effective surveillance and response system.
- Infrastructure with isolation rooms, a functional and networked laboratory, ventilation control, soap and clean water, and adequate personal protective equipment (PPE).
- A skilled public health workforce.
- Inter-sectoral collaboration and coordination.
- A strengthened public health system, funding, and leadership.[14]

Another speaker, Perl, noted five key elements of outbreak response that is critical to reducing the spread of disease, including: Proper outbreak management; treatment and care of a large number of patients; protection of health care workers and patients; effective communication with health care workers, patients, families, communities, authorities, and organizations; and advanced multidisciplinary planning.[15] When an outbreak is suspected, there must be an investigation to determine the source of the illness or disease agent (if possible), how the infection is being transmitted, and what the incubation period is (the time period between exposure to disease and development of symptoms).

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[14] The National Academies of Science, Engineering, Medicine, *Global Health Risk Framework*, 77.
[15] The National Academies of Science, Engineering, Medicine, *Global Health Risk Framework*, 77-78.

Although there are standard elements of care for all outbreaks or epidemics, there are also disease-specific precautions that may not be necessary in every scenario. For example, with cases of Ebola, it is imperative to isolate patients and practice safe burials, along with the usual practices of case management, epidemiological surveillance, contact tracing, and community sensitization. With diseases like Ebola where isolation of patients is necessary (Fig. 2.2), isolation facilities tend to be set up near affected communities in order to limit the patient's travel to the facility so that the chances of the disease spreading is minimized.[16]

**Figure 2.2: Parents Visiting 15-year-old, Suspected of Ebola Infection, at the Ebola Treatment Center in Beni, DRC (January 2019)**
Source: United Nations

When patients are required to be isolated due to diagnosis of a serious, life-threatening illness, families are briefed on the patient's condition daily and both the patient and the family receives counseling, support, and information. Disinfection and

[16] The National Academies of Science, Engineering, Medicine, *Global Health Risk Framework*, 81.

proper burials are essential to ensure no transfer of disease, especially since some serious diseases are air-borne and can easily spread.

In order to achieve a timely and appropriate response from foreign partnerships during a time of emergency, country governments turn to global health reserve teams. Foreign medical teams, or FMTs, grew out of the response in Haiti and are a part of the Global Health Emergency Workforce that helps countries during times of health emergencies. Since their introduction, FMTs have been broken down, organized, and categorized into types for more efficiency. Type 1 (mobile) are mobile outpatient teams capable of reaching remote areas with a capacity of about 50 patients (per day). Type 1 (fixed) are general outpatient facilities, either set up in a tented structure (Fig. 2.3) or in an abandoned building, capable of treating over 100 patients (per day). Type 2 are inpatient facilities with the capability of conducting surgeries and can serve over 100 outpatients (per day) and 20 inpatients. Type 3 provide referral-level care to over 100 outpatients (per day) and 40 inpatients, also capable of conducting surgeries and other procedures.

According to speaker Norton, FMTs require staff, supplies, space, and systems to coordinate outbreak responses, as well as Ebola treatment unit (ETU) buildings. Incoming clinicians need to be able to quickly assimilate into the field work, starting to immediately work with case finding and community outreach. These clinicians are often key in early detection and response, and thus need the space and resources to begin work immediately upon their arrival into the country in need.[17]

[17] The National Academies of Science, Engineering, Medicine, *Global Health Risk Framework*, 82-83.

**Figure 2.3: Ebola Response Team Tent Camp**
Source: Slate

*Communicable Disease Control*

Outbreak control involves preparation, detection, confirmation, response, and evaluation. Preparation involves setting up a camp with isolation wards and a laboratory, gathering treatment supplies, and collecting healthcare workers. Detection required early recognition of disease as well as confirmation through either clinical or laboratory diagnosis. Disease response means after the diagnosis is confirmed, a hypothesis must be formulated to determine the source, pathogen, and method of transmission, and the outbreak event will then be controlled through means of treatment. Lastly, after every field response to an outbreak event, and evaluation will take place to change public health policies as needed, write an outbreak report, and assess the steps taken to determine successes, appropriateness, and failures.[18]

Considering that overcrowding, poor regional design, lack of hygiene, dirty drinking water, rapid climate changes, and natural disasters all combine to foster conditions that allow for the easy transmission of disease, then the opposite conditions must be created to prevent the spread of disease. To quickly control the spread of communicable diseases, the primary step is to create a camp for health care workers to begin researching, working with patients, and managing the disease.

The overall goals of a field camp are rapid assessment, prevention, surveillance, outbreak control, and disease management.[19] In less than four days, a rapid assessment should be completed to identify the disease being spread and to collect detailed information about the host country. The next step, prevention, involves site planning, creating shelter, maintaining cleanliness, and employing vaccinations, vector control strategies, and education opportunities. Setting up the medical camp involves site planning and creating a shelter, and the best solution is to create a building with plenty of space for all personnel (avoid packing individuals tightly together), and to select an environment/site location by avoiding areas with a high vector transmission, poor water supply, low security, sparse vegetation and soil, and low accessibility. The site would ideally be placed with a little distance from a major center, but not so far as to make travel impossible.[20]

[18] Ameli, "Communicable Diseases and Outbreak Control"
[19] Ameli, "Communicable Diseases and Outbreak Control"
[20] Ameli, "Communicable Diseases and Outbreak Control"

After a camp is properly set up, health workers should immediately begin surveillance and set up early warning systems to watch for disease, find trends, confirm diagnoses, and report outbreaks earlier rather than later. During this phase, researchers will also be collecting data to study the current outbreak as well as supplement other data resources and disease tracking.

To maintain a proper camp, clean water must be available for up to seven liters per person per day (considering the most extreme conditions). If serving inpatients or housing doctors, the necessary water supply could rise to up to 20 liters per person per day to allow for bathing and cooking. Waste disposal is also an important consideration, as it must be maintained in a safe way and kept separate from clean water sources. Pits are typically created to bury or burn solid waste, and water waste will be diverted into existing storm water drains or temporarily kept in an isolated pond for future disposal. Medical waste is either burned near the camp to ensure complete disposal or sealed in a metal container and buried.

Traditional and religious health practices can hurt attempts by outside medical teams to contain infectious disease. In addition to traditional healing practices, traditional burial ceremonies including touching the body of the dead leads to an increased rate of community members becoming infected. Unfortunately, there are also set procedures for burying the dead which conflicts with the traditions of many Africans. Whereas family members of the dead wish to touch the body prior to burial (Fig. 2.4), the deceased must not be in contact with anyone as the body remains infected after death. The clothing must be burned, and the bodies must be disinfected, wrapped in a body bag, and buried one meter below the ground.[21]

**Figure 2.4: A Woman Throws a Handful of Soil Towards the Body of her Sister as Ebola Burial Team Members take her for Cremation on October 10, 2014 in Monrovia, Liberia.**
Source: International Business Times

[21] Ameli, "Communicable Diseases and Outbreak Control"

# Chapter 3: Central Africa and the DRC

This thesis is exploring a modular typology fit for the variety of climates and regions within Africa, but is using the Democratic Republic of Congo as a case study due to its relevance of having an ongoing epidemic and also its unique location in the center of the continent, its urbanism, and the consideration of violent occurrences within the country, especially towards health care workers and Ebola Treatment Centers.

## *Geography and Climate*

The Democratic Republic of Congo is located within Central Africa (Fig. 3.1). Central Africa's landscape consists of savannah, or grasslands, and rainforests and the area is dominated by the Congo River. The equator divides the country, with approximately one-third of the country located north of the equator and the remaining two-thirds lying south of the equator. The region within the river basin is tropical and therefore the weather is typically hot and humid, whereas the weather in the southern highlands is cool and dry, and the weather in the eastern highlands is cool and wet.[22] North of the equator the wet season lasts between April and October and the dry season is December through February, whereas south of the equator the wet season is between November and March and the wet season is between April and October.

In addition to socioeconomic factors mentioned in previous chapters, the prevalence of disease in the Central African region and the DRC specifically can be attributed to the geoclimatic conditions that the area experiences.

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[22] Climatezone.com. Democratic Republic of the Congo. CIA World Fact Book. https://www.climate-zone.com/climate/congo-democratic-republic/

**Figure 3.1: The DRC as a Member of Central Africa**
Source: Author

*Demographics and Land Ownership*

As of 2014 statistics, the Democratic Republic of Congo is home to nearly 71 million people. The country's citizens are very poor, considering that out of the entire population, an estimated 80% percent currently lives on less than one U.S. dollar per day. In addition to a low quality of life, people living in the DRC are also categorized as having a low life expectancy—46 years for men and 51 years for women.[23] Due to the low life expectancy, approximately half of the population in the DRC is under 15 years old (Fig. 3.2).

[23] "Democratic Republic of Congo," Land Links, USAID Land and Urban Office, accessed November 11, 2019, https://www.land-links.org/country-profile/democratic-republic-congo/

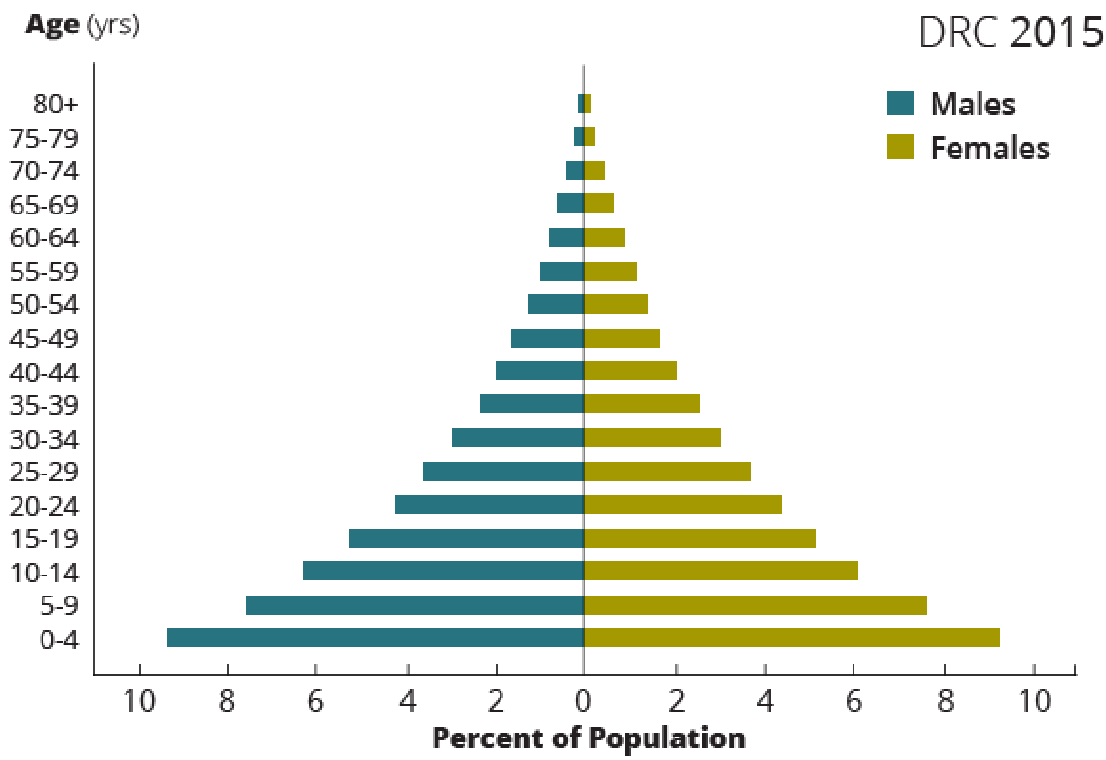


**Figure 3.2: Age Range of Population in the DRC, 2015**
Source: United Nations, Department of Economic and Social Affairs, Population Division

The DRC is considered the third-largest country in Africa behind Sudan and Algeria, comprised of a total land area of 2,267,000 square kilometers. Most of the population lives in rural settlements, with approximately 66% of the population being rural while the remaining 34% lives in more urban areas. According to USAID, exact land tenure information is currently unavailable for most of the country.[24] Land ownership within the DRC is continuously in flux, especially considering the constant state of change the country experiences with civil wars and population migrations due to violence. However, under formal law, the state owns all the land in the DRC. In urban areas, those desiring the right to land use can apply for either concessions in

[24] "Democratic Republic of Congo," Land Links

perpetuity or standard concessions. Concessions in perpetuity are only granted for natives whereas standard concessions are able to be temporarily (25 years with chance of renewal) granted to those foreign to the country. In rural areas, customary law tends to govern, meaning that groups or clans collectively hold land parcels that are allocated to others by traditional leaders. Ownership of this land has traditionally stayed within the community, but this notion has relaxed over the years. [25]

*Violence*

The Democratic Republic of Congo has experienced years of political violence. Since 1997, the wars in the DRC have resulted in numerous shifts in political authorities as well as the deaths of 3.5 million people due to malnutrition and illness.[26] The current government is preoccupied with an agenda to repair a culture of violence, corruption, and mismanagement.

Violence tends to also be a difficult problem to maneuver for external health teams coming in to help control disease outbreaks. During outbreaks of infectious disease, such as the one experienced during West Africa's Ebola outbreak in 2014-2015, health centers tend to experience backlash from community members afraid of the stigmatized disease and the steps needed to control it. During the current Ebola outbreak, in February 2019, attackers harmed health workers and visitors of an ETU, also damaging equipment and burning down parts of the structure (Fig. 3.3). The North Kivu province, where the current Ebola breakout is occurring, experiences a high proportion of violence compared to other regions. In 2013, three MSF staff

[25] "Democratic Republic of Congo," Land Links
[26] "Democratic Republic of Congo," Land Links

members were abducted from this region and are still missing. In the Ituri province, another region currently plagued by Ebola virus, MSF was forced to withdraw their services and staff from a health center and ETU in Biakato after it was stormed by a group of people armed with sticks and machetes. This follows another attack on Ebola health workers in Biakato in November 2019, which unfortunately resulted in the loss of life.

**Figure 3.3: Ebola Treatment Center in Katwa, DRC, is Shut Down Due to Damage from Violence, 2019**
Source: MSF

To promote community support, organizations introduced new procedures within infectious disease centers such as recording and sharing video of care practices between health workers and patients in ETU's to prove to community members that care was being given. Burial proceedings were also a point of contention within communities, as outside organizations coming in to help control the disease outbreak were not trusted and were rather suspected of helping spread the disease and harvesting the dead to enrich Western economies and pharmaceutical industries.[27] The mistrust of health workers has even led to their murders and attacks on medical centers set up and operated by organizations foreign to the community.

*Road Infrastructure*

Due to the political instability and years of violence in the DRC, much of the transport infrastructure within the country has been destroyed or lost to disrepair. Even in densely populated areas in the DRC, such as cities Goma and Butembo, the road infrastructure is poor and the topography is rough, yet roads are the primary source of transportation and trade of goods and services in the region. Past volcanic eruptions have left sizeable cooled igneous rock deposits on roadways in Goma, making it difficult for people to move around (Fig. 3.4). Despite the poor conditions of the roads, the populations are highly mobile, which can be problematic during times in which populations are at risk of spreading infectious disease.

[27] Alison Mack, *The Ebola Epidemic in West Africa: Proceedings of a Workshop* (Washington, DC: National Academies Press, 2016), 25-26, EBSCO

**Figure 3.4: Cooled Igneous Rock Left From 2002 Volcanic Eruption in Goma**
Source: WHO

*Industry*

In terms of construction project initiatives taken on the African continent in 2017, Central Africa contributed to 6.6% of the continental projects by constructing 20 projects. Out of these 20 projects, the DRC contains four, accounting for 28.3% of the total value of projects constructed in Central Africa.[28] Healthcare projects do not seem to be the priority in Africa (Fig. 3.5), with the favored projects revolving around power, transportation, and harvesting natural resources. This is a problem considering the dire need for improved healthcare services in Africa.

[28] Deloitte, *Africa Construction Trends Report 2017* (Deloitte Touche Tohmatsu Limited, 2017), 28, accessed November 15, 2019, https://www2.deloitte.com/za/en/pages/energy-and-resources/articles/africa-construction-trends-report.html

| Projects by sector (number of projects) | Number of projects | Share of projects by number (%) | Value of projects (US$bn) | Share of projects by value (%) |
|---|---|---|---|---|
| Energy & Power | 58 | 19.1% | 67.4 | 21.9% |
| Transport | 109 | 36% | 71.6 | 23.3% |
| Real Estate | 68 | 22.4% | 42.3 | 13.8% |
| Water | 14 | 4.6% | 3.8 | 1.2% |
| Mining | 10 | 3.3% | 7.8 | 2.5% |
| Oil & Gas | 13 | 4.3% | 76.9 | 25% |
| Shipping & Ports | 24 | 7.9% | 36.3 | 11.8% |
| Social Development | 2 | 0.7% | 0.4 | 0.1% |
| Healthcare | 3 | 1% | 0.4 | 0.1% |
| Education | 2 | 0.7% | 0.6 | 0.2% |

**Figure 3.5: Projects in Africa by Sector**
Source: Africa Construction Trends Report 2017, Deloitte

In the past five years, there is no record of any new healthcare projects in the DRC. In 2017, the majority of construction projects within the DRC mirrored the priority throughout the rest of the continent, such as projects focused on power, transportation, and resource harvesting (Fig. 3.6).

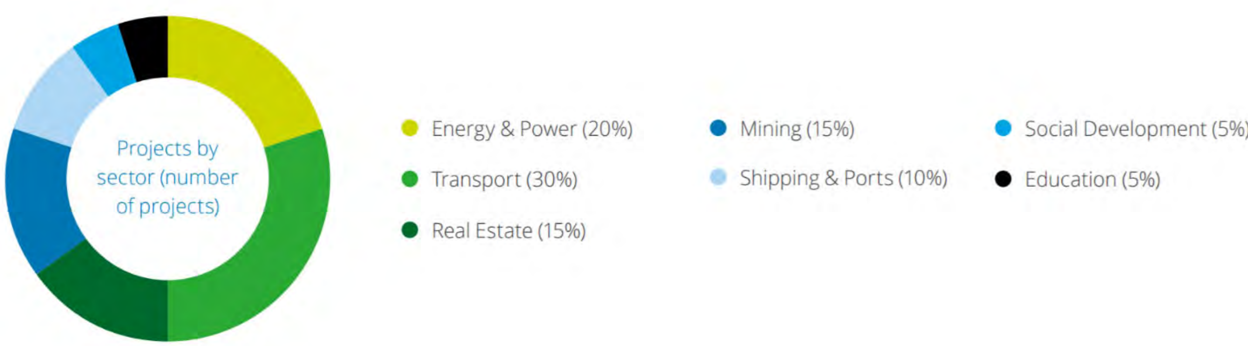


**Figure 3.6: Projects in the DRC by Sector**
Source: Africa Construction Trends Report 2017, Deloitte

*Healthcare*

The DRC is separated into 26 provinces, and then it can be further separated into health zones. The current Ebola breakout is primarily affecting the Ituri and North-Kivu provinces, and then within those provinces the cases are clustered within specific health zones (Fig. 3.7). The health system in the Democratic Republic of Congo is organized into three levels: the implementation level, the intermediate level, and the central level. At the implementation level there is 516 health districts, each of which covers populations ranging from 100,000 to 200,000 people. Within these health districts is a district hospital and a network of health centers. The intermediate level contains provincial health departments responsible for technical and logistical support to the health districts within the implementation level, and the central level has a normative role.[29]

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[29] World Health Organization, *Democratic Republic of The Congo: Improving Aid Coordination in the Health Sector* (Geneva: WHO, 2015), 7, accessed November 15, 2019, https://apps.who.int/iris/bitstream/handle/10665/186673/WHO_HIS_HGF_CaseStudy_15.4_eng.pdf;jsessionid=C92A67FCED0E2539B018071F1692C15F?sequence=1

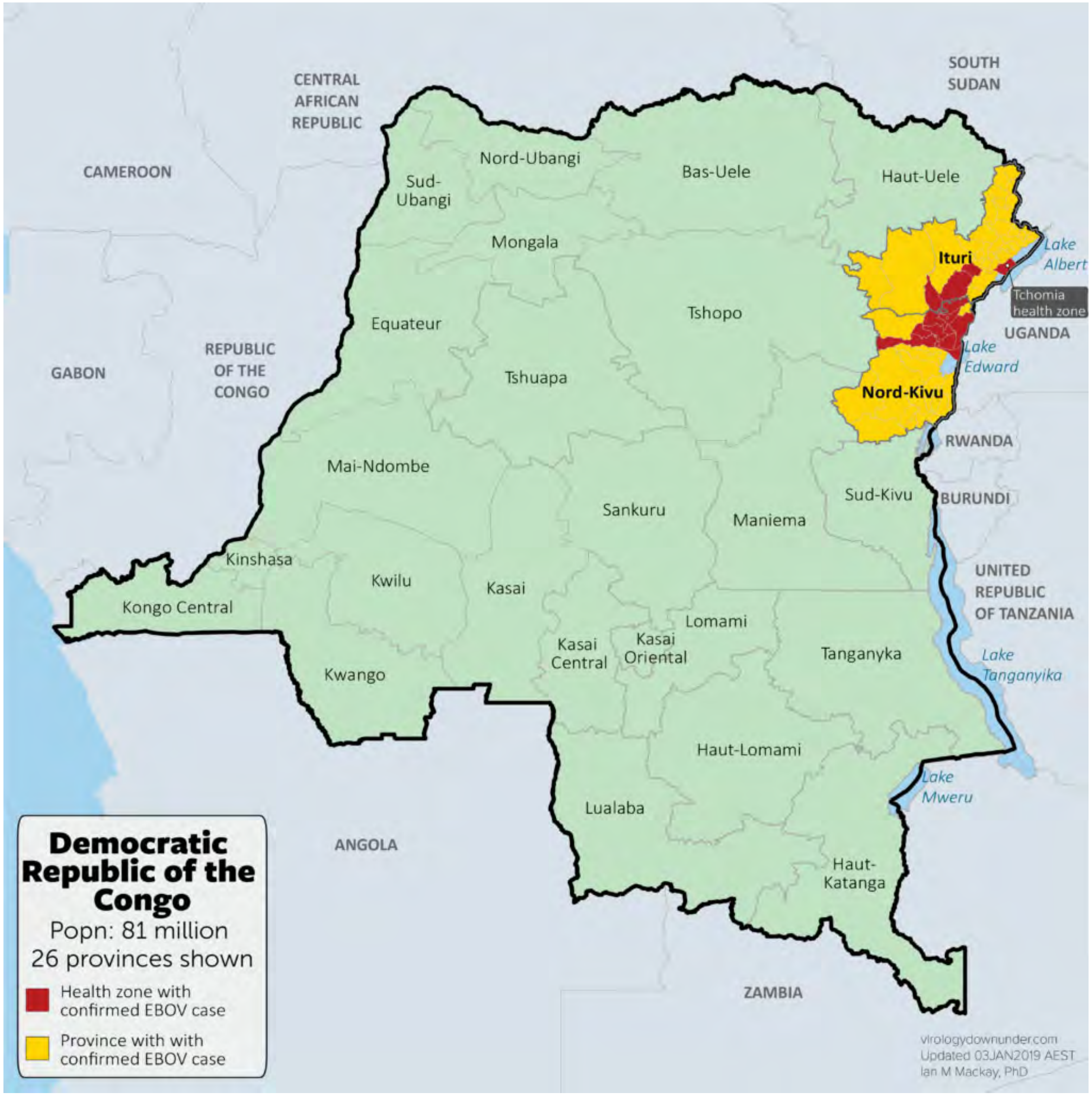


**Figure 3.7: Cluster of Ebola Hotzone within DRC Provinces, 2018-2019**
Source: Virology Down Under

Healthcare systems have been disrupted in some areas within Central Africa, and unfortunately, data on prevalence and incidence is unavailable for many diseases in the region.[30] The most prominent killers of children in Central Africa are diarrhea (19%), pneumonia (18%), malaria (16%), AIDS (4%), and other infections (6%).[31]

[30] Eskild Petersen, Lin Chen, and Patricia Schlagenhauf-Lawlor, *Infectious Diseases: A Geographic Guide* (Hoboken, NJ: John Wiley & Sons Inc., 2017), 78, ProQuest
[31] Eskild Petersen et. al., *Infectious Diseases: A Geographic Guide*, 89

These diseases are exacerbated among children due to the socioeconomic and living conditions that perpetuate malnutrition and other factors that lead to a higher susceptibility to disease.

The poor condition of existing health facilities in Africa perpetuated the spread of disease, in conjunction with other factors. In addition to a lack of laboratory equipment to properly diagnose disease, existing facilities are incapable of supplying the resources necessary to control the medical demands during an outbreak. Additionally, many existing health facilities in Africa and elsewhere are not suitable for handling patients of highly infectious diseases, such as Ebola, simply due to logistical issues of layout, circulation, disposal of waste, and other key considerations.

# Chapter 4: Infectious Disease Centers in Africa

Facilities that foster the ability to diagnose and treat a variety of infectious diseases are imperative in Africa, which has a high susceptibility to infectious and outbreak. A modular and mobile system is beneficial to provide a flexible response in any location necessary. This applies to a global scale as well, as it is expected that the world will see at least one pandemic in the next century, and there is a 20% that we will experience at least four.[32] Future threats, especially new and emerging infectious diseases, will pose a challenge to our increasingly interconnected and urbanized planet, therefore our outbreak response must shift from 'reaction' to 'readiness'.

## *Current Practices*

Historically, the primary purpose of infectious disease centers and ETUs have been to isolate infected persons as early as possible after the onset of symptoms in an attempt to break the chain of disease transmission within a community.[33] However, these facilities are not doing their best to optimize patient care as early as possible, partly due to the resistance of community members to voluntarily check in to these centers. According to Chertow et. al., "Resistance by infected people to voluntary admission will persist unless the treatment facilities are seen as a place to go for treatment and recovery and not as a place to die isolated from loved ones and the community."[34] The message that a center for infectious disease sends to the

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[32] Sabeti Pardis, *Outbreak Culture: The Ebola Crisis and the Next Epidemic* (Cambridge: Harvard University Press, 2018), 179, ProQuest

[33] Daniel S. Chertow et. al. "Ebola Virus Disease in West Africa — Clinical Manifestations and Management." The New England Journal of Medicine 371 (November 2014): 2054. DOI: 10.1056/NEJMp1413084.

[34] Daniel S. Chertow et. al. "Ebola Virus Disease in West Africa"

community can greatly influence the success of the control operation. When the message of 'there's nothing you can do for me' is sent, rather than coming to the health centers for treatment, people tend to hide out of fear. When this occurs, laboratory research, data collection, and overall containment of the outbreak is hindered while the disease continues to spread under the radar.

During an outbreak, possible cases are transported to ETUs for care and diagnosis for confirmation of infection. Diagnostic testing is typically performed by outside organizations and laboratory partners, such as the National Institute of Health (NIH) or the Center for Disease Control and Prevention (CDC).[35] Depending on the case definition for the disease, who stays, who receives treatment, and who gets sent home will vary for every outbreak. The needs of every disease are different, but the thought is being adopted that the protocol for handling Ebola outbreaks should be the standard for approaching any emerging infection.[36] Therefore, in most cases, the safest way to reduce transmission and control the outbreak from the start is to immediately isolate unconfirmed patients until a diagnosis is made. Thus, there would need to be a diagnostic unit within the health center where it is determined whether a person will need to be admitted into the facility as a patient. There may be the need for additional health services to be available for special populations, in the event that the infected are in need of labor and delivery services or pediatrics.[37]

[35] Alison Mack, *The Ebola Epidemic in West Africa*, 25
[36] Alison Mack, *The Ebola Epidemic in West Africa*, 32
[37] Alison Mack, *The Ebola Epidemic in West Africa*, 32

The main goal of any infectious disease facility is infection control, and this can be achieved through simplifying various activities within the center: moving patients, staff circulation, transportation of material, having access to water, and proper disposal of waste.[38] When moving about a facility, minimizing contact with other people is the best possible means of circulation.

For community members that are unable to travel to health centers, the CDC has set up call centers in the past to help identify possible case patients over the phone, and also to gather reports of deaths of the infected that are in need of safe burials.[39] For those recovering from infection, convalescent care may be provided to the survivors and psychosocial support could be offered to their families and even to the entire community ravaged by the disease. When the outbreak is perceived as over, the external organizations tend to leave; however, with more dangerous diseases, some organizations may continue to provide services and maintain active surveillance if there is funding to do so.[40]

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[38] Alison Mack, *The Ebola Epidemic in West Africa,* 31
[39] Alison Mack, *The Ebola Epidemic in West Africa,* 35
[40] Alison Mack, *The Ebola Epidemic in West Africa,* 30

*__Treatment Center Precedents__*

*The ‘Ideal’ Treatment Center*

According to WHO, the ideal Ebola Treatment Unit is comprised of areas separated by risk levels, including a staff ward (low risk), a suspected cases ward (medium/high risk) and a confirmed cases ward (high risk) (Fig. 4.1). The layout connecting these zones should be organized so that low-risk patients do not come into contact with high risk patients. This model suggests that the facility will be capable of caring for 125 patients per day, fluctuating between 100-200, and that this would require 300-600 staff members.

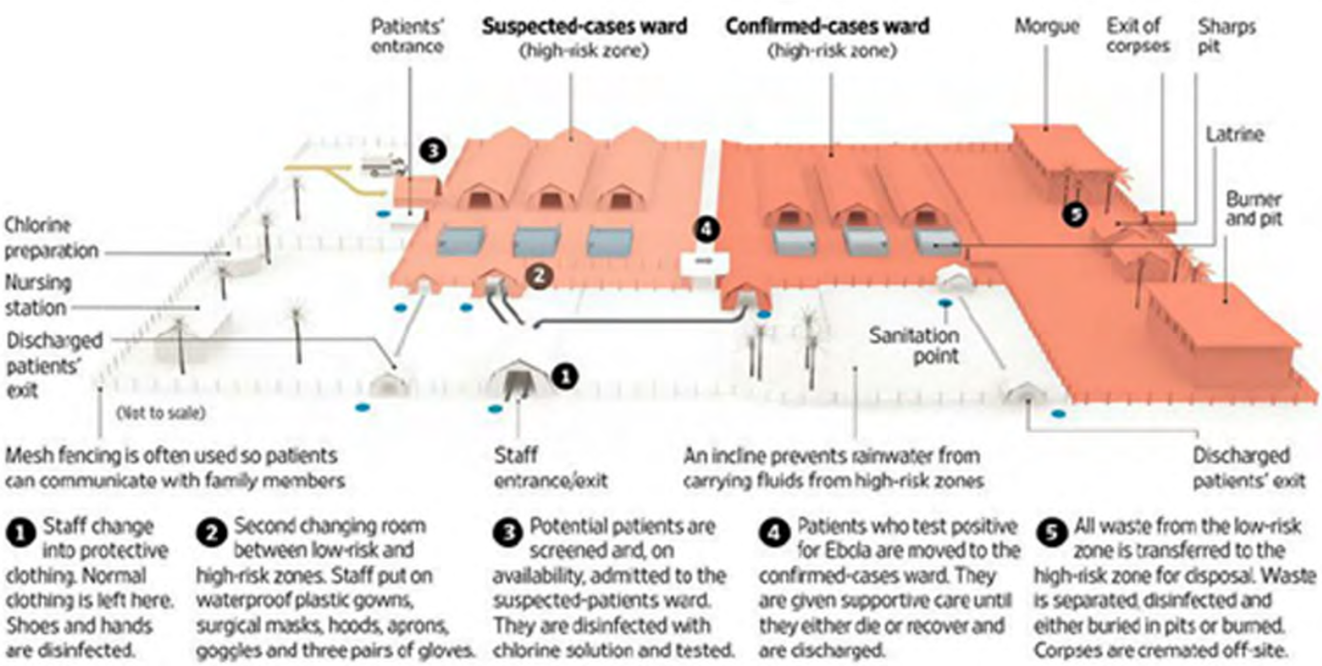


**Figure 4.1: WHO Layout for Ebola Treatment Units**
Source: World Health Organization

*Chinese ETC*

The Central Military Commission of China used lessons learned from the 2014 West Africa Ebola outbreak to develop an Ebola Treatment Center (ETC) in Monrovia, Liberia with improved architecture to enhance the safety of health care workers while enhancing the treatment of patients. Their ETC utilized movable, prefabricated boards to meet standard requirements of infectious disease units. The design of the ETC intended to reduce the risk for health care workers that are providing care to infected patients.[41] Existing models of ETC's tended to be tent structures (Fig. 4.2), referred to as community care centers, that were each capable of treating up to 30 patients at one time. The organization within these structures were not very strong, as they were simply divided by a fence into a 'hot zone' and a 'cold zone' that separated health care workers from patients suspected of being infected by the disease. These centers did not have an extensive program and thus did not optimize patient care.

[41] Jianping You and Qing Mao, "An Improved Ward Architecture for Treatment of Patients with Ebola Virus Disease in Liberia," *The American Journal of Tropical Medicine and Hygiene* 94, no. 4 (April 2016): 701, https://doi.org/10.4269/ajtmh.15-0209

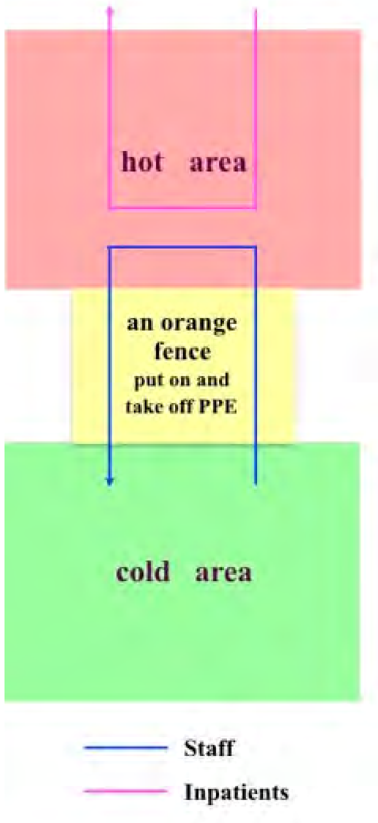


**Figure 4.2: Standard Tent Structure Model for ETCs**
Source: An Improved Ward Architecture

Their improved model consisted of 16 individual buildings at 5,000 m2 each included clinics, inpatient wards, a patient disinfection area, morgue, stock rooms, a distribution desk, and training centers.[42] The main building within the complex contained 100 beds separated into an observation ward and two confirmed wards. The inpatient wards had separated areas divided by contaminated, partially contaminated, and clean classifications (Fig. 4.3). In their model, circulation between the spaces of various risk to infection is considered, and they determined that a one-way flow

[42] Jianping You and Qing Mao, "An Improved Ward Architecture"

between the clean areas of the staff to the contaminated areas of the patients must be followed. This flow between zones also determines when health care staff put on and take off various levels of personal protective equipment (PPE). The various zones are an attempt to limit cross-contamination between staff and patients. The buffer zone between 'clean' and 'contaminated' zones was determined to be successful in slowing traffic and improving care practices of equipment removal and sanitization.[43]

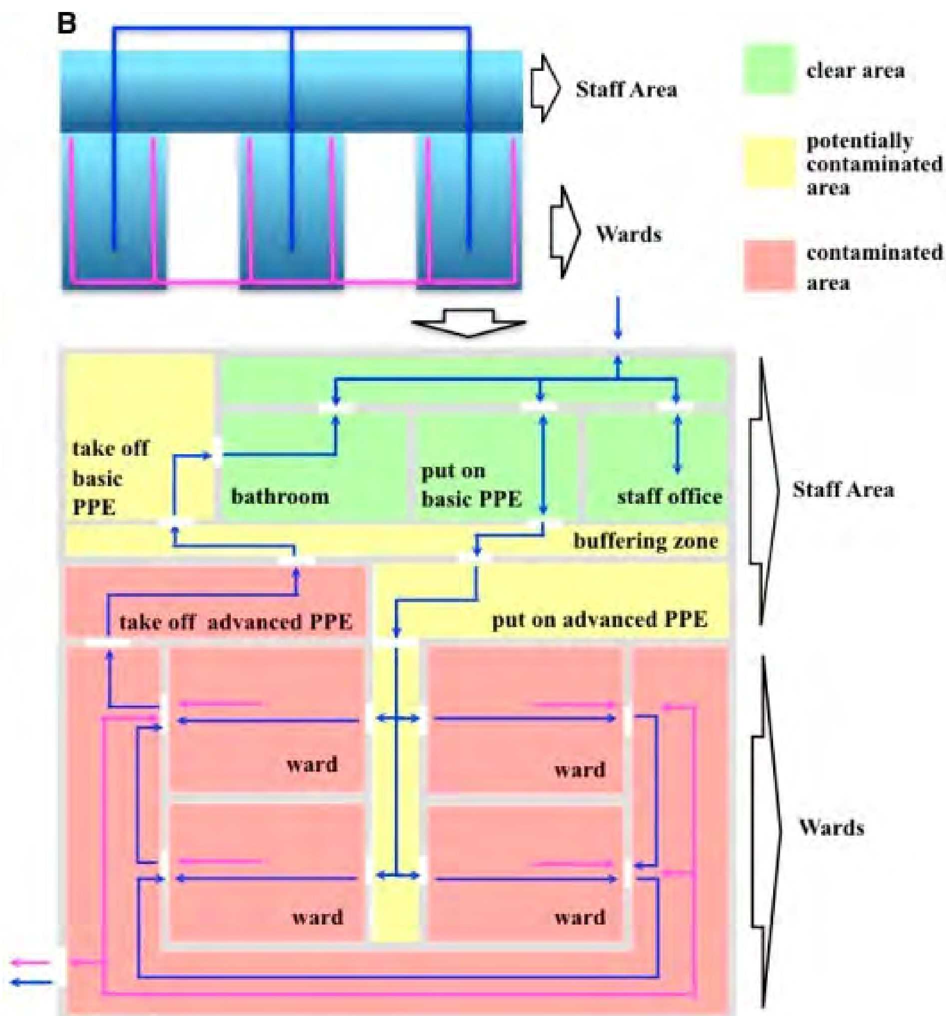


**Figure 4.3: Chinese ETC Showing Main Building and Inpatient Ward**
Source: An Improved Ward Architecture

[43] Jianping You and Qing Mao, "An Improved Ward Architecture"

In contrast to the commonly used tent structures, the ward proposed by the Central Military Commission of China uses a solid construction structure that withstands the effects of direct sunlight and sever weather. Some of the lessons learned with this proposed design is that the solid structure design reduced the air flow that tent structures receive, and this especially needs to be taken into consideration due to presence of cleaning supplies and chemicals.

*ELWA 3 Ebola Management Center*

The ELWA 3 Ebola Management Center (Fig. 4.4) in Monrovia, Liberia was the largest Ebola treatment unit in Monrovia, Liberia during the 2014 West Africa Ebola outbreak. During the time period from August 23 to October 4 2014, the facility treated 700 patients of Ebola virus disease (EVD).[44] The goal of this center was to achieve a rationalized approach to EVD management on a large scale in a resource-limited setting. Patients of infectious disease are categorized by suspected, probable, and confirmed diagnoses and treatment centers are often organized based on this categorization.

[44] Daniel S. Chertow et. al, "Ebola Virus Disease in West Africa "

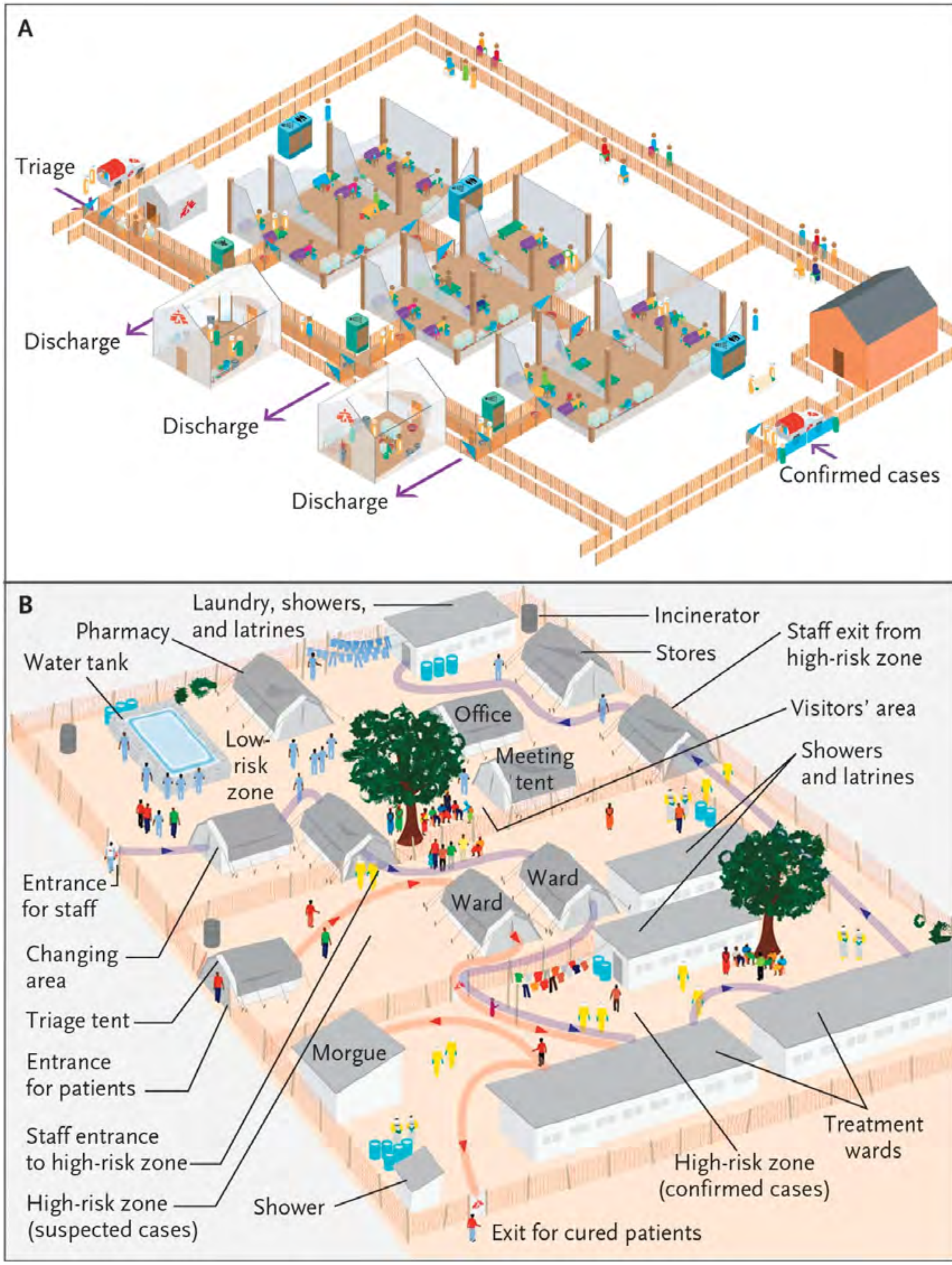


**Figure 4.4: The ELWA 3 Ebola Management Center in Monrovia, Liberia**
Source: Ebola Virus Disease in West Africa — Clinical Manifestations and Management

Those working in this facility found that the symptoms of EVD progressed rapidly, and patients would typically check into the facility after 2-3 days of sever vomiting or diarrhea, in which case the patient was already in phase two of the illness (Fig. 4.5). Considering how highly infective EVD is, by the time patients are in the second phase of illness they are already posing a great risk to family, friends, and the community. The disease rapidly affects those infected, causing most deaths to occur within 7-12 days of infection. If a patient lived until day 13 of infection, they ultimately survived.[45]

**Clinical Features of Ebola Virus Disease.**

| Phase of Illness | Time since Symptom Onset | Clinical Features |
|---|---|---|
| Early febrile | 0–3 days | Fever, malaise, fatigue, body aches |
| Gastrointestinal | 3–10 days | Primary: epigastric pain, nausea, vomiting, diarrhea<br>Associated: persistent fever, asthenia, headache, conjunctival injection, chest pain, abdominal pain, arthralgias, myalgias, hiccups, delirium |
| Shock or recovery | 7–12 days | Shock: diminished consciousness or coma, rapid thready pulse, oliguria, anuria, tachypnea<br>Recovery: resolution of gastrointestinal symptoms, increased oral intake, increased energy |
| Late complications | ≥10 days | Gastrointestinal hemorrhage, secondary infections, meningoencephalitis, persistent neurocognitive abnormalities* |

**Figure 4.5: Clinical Features of Ebola Virus Disease**
Source: Ebola Virus Disease in West Africa — Clinical Manifestations and Management

Within the facility, each physician was responsible for the care of around 30-50 patients. Due to the heat stress and fluid loss that physicians would experience while working in personal protective suits, direct contact with all patients was limited to intervals of 45-60 minutes 2-3 times per day. This means that the physicians were only in contact with each patient to evaluate their condition approximately 1-2 minutes per interval.[46]

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[45] Daniel S. Chertow et. al. "Ebola Virus Disease in West Africa"
[46] Daniel S. Chertow et. al. "Ebola Virus Disease in West Africa"

*Programmatic Elements for Infectious Disease Centers*

A health center capable of accommodating any infectious disease would require distinct administrative, research, treatment, and back of house spaces. Administrative spaces would include check-in and waiting areas for patients and family members. Visitor areas are one of the most important areas within an ETU. Since many patients lack human interaction while undergoing treatment, some connection to visitors helps improve mental health while in the facility. Also, since safety and violence are concerns due to the mistrust of ETUs, maintaining a good relationship and transparency between health care workers, patients, and visitors is ideal (Fig. 4.6). Transparency is important to generate community acceptance of ETUs, and to help patients feel connected to communities during treatment or isolation. Allowing visitors to be close enough to patients while still maintaining degrees of safety through fencing or other barriers helps keep the facility transparent for all.


**Figure 4.6: Visibility of Health Care Workers Inside an ETU**
Source: Financial Times

Research areas in close proximity to medical treatment areas allow teams to routinely analyze extracted data while minimizing transportation on infected samples. Exam, treatment, and isolation areas would all be considered ‘hot zones’ where infected patients reside until deemed clean by health workers. These areas must be visible to visitors to increase transparency for both groups.

Back of house spaces include sanitation areas and equipment storage. These areas could potentially be between ‘hot zones’ where infected patients are and ‘cold zones’ where doctors and health workers are headquartered.

# Chapter 5: Modular Construction

Infectious disease centers and ETU's need to be quickly deployable to successfully intervene in the transmission cycle of communicable diseases. The current standard model of tent structures varies widely in materiality and construction techniques depending on the organization setting it up. In my exploration, modular construction would help to standardize emergency facilities and less time would have to be spent between the analysis of the extent of the outbreak and the moment the organization decides how it will proceed in its intervention.

Boris Lushniak, the Dean of the University of Maryland School of Public Health, spent time working at the Monrovia Medical Unit (MMU), a U.S. military-operated Ebola treatment facility in Monrovia, Liberia during the 2014 West Africa Ebola outbreak. The facility that he worked at spent more than a week analyzing how many people they intended their facility to serve, what materials they would use, and where they would construct the facility.[47] Modular construction would expedite the decisions that need to be made during this process so that the facility can be implemented to serve its purpose as quickly as possible.

During the West Africa Ebola outbreak, treatment centers were urgently needed and once constructed, they would quickly fill up and it would take weeks until others were finished construction. During this time, many people go without care due to a lack of completed and available units, and considering the severity of EVD, every day matters. Four pillars considered integral to interrupting Ebola transmission and

[47] Boris Lushniak, Interview, December 9, 2019.

spread can be helped by the quick implementation of ETU's: 1) early detection, isolation, and treatment of cases; 2) safe transport of patients with suspected cases; 3) safe burial; and 4) infection prevention and control (IPC) in healthcare settings.[48] Isolating patients is a top objective in an outbreak, and ETU's are an essential tool in containing the disease.

The 2014-2015 Ebola outbreak began when the Guinea Ministry of Health (MOH) reported an Ebola breakout in March 2014, and in the same month Liberia also reported cases of Ebola. As of July 2014, only 2 ETU's with a capacity of 20 beds each were available to treat patients in Liberia, and the rush of disease was so overwhelming by the end of July that patients had to be turned away from these facilities and many sick perished on hospital grounds, in the streets, or elsewhere. The dangers of this experience is dire, as the dead are still infectious to those around them, and if patients pass outside of ETU facilities, then the disease remains difficult to contain. Initially, the number of available beds in ETU's lagged behind the need for them, but by September of 2014, bed capacities ended up exceeding new cases (Fig. 5.1).[49] In the current epidemic, as of December 4, 2019, the DRC has had 3,318 total cases of Ebola reported since August 1, 2018, and 2,207 of those reported cases have perished.[50]

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[48] Nyenswah, Tolbert G. et. al., "Ebola and Its Control in Liberia, 2014–2015," *Emerging Infectious Diseases* 22, no. 2 (February 2016), https://doi.org/10.3201/eid2202.151456
[49] Nyenswah, Tolbert G. et. al., "Ebola and Its Control in Liberia, 2014–2015," *Emerging Infectious Diseases* 22, no. 2 (February 2016), https://doi.org/10.3201/eid2202.151456
[50] "Crisis Update – December 2019," MSF, accessed December 9, 2019, https://www.msf.org/drc-ebola-outbreak-crisis-update

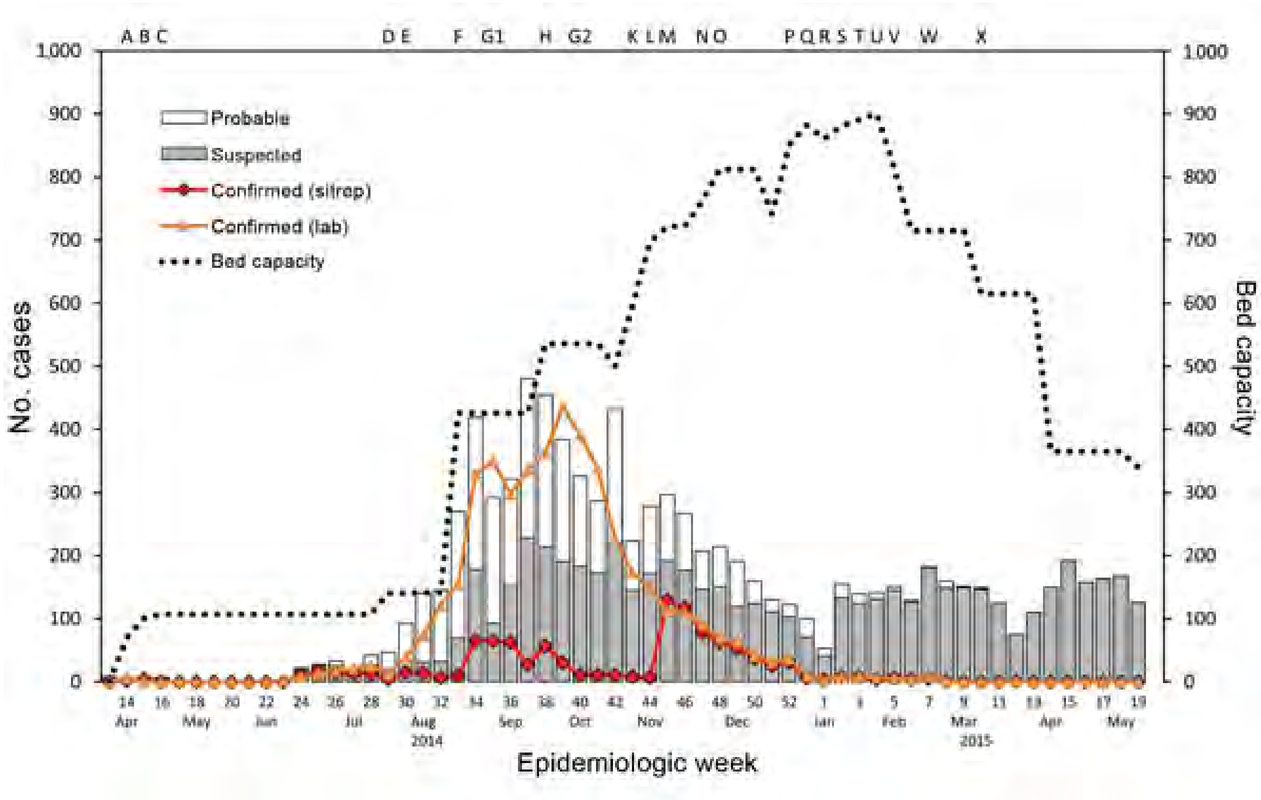


**Figure 5.1: Relationship of Ebola Cases to ETU Bed Capacity, 2014-2015**
Source: "Ebola and its Control"

The modules of the facility can also be either permanent or temporary structures depending on the programmatic elements they serve, which can be designated as being 'cold' or 'hot' depending on its interaction with sick patients. 'Cold' modules would contain staff spaces only, free of any potential Ebola contamination, whereas 'hot' modules would house and circulate both probable and confirmed patients and is assumed to be completely contaminated by EVD. Anything that passes into a designated 'hot' zone must be burned after its use, including all equipment and materials. The only potential for a more permanent structure to live on the site after the use for the health facility is over is by repurposing the 'cold' modules.

During the 2014 Ebola outbreak, the U.S. promised to construct 18 field hospitals to help treat the infected in September of 2014, when the number of cases in Liberia was increasing but had not yet reached its peak. Progress on construction was slow and by the time many of the hospitals were constructed, or even when the first U.S. hospital was constructed in November 2014, the disease had already run its course and there were no longer enough sick to fill the facilities (Fig. 5.2). Part of the delay in this process was due to the need for construction overlapping with Liberia's rainy season, which hampered official's ability to construct the facilities on-site.[51] Had the additional facilities been constructed right away, then countless lives would have been saved. According to Jeremy Konyndyk, who headed the Ebola response for the United States Agency for International Development, there was no template for implementing aid during an epidemic emergency, unlike more typical disasters such as famines, earthquakes, or floods.[52]

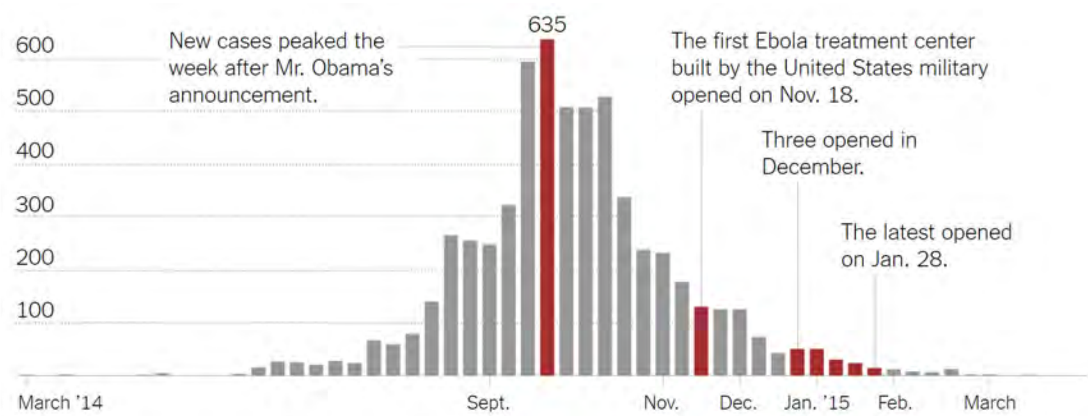


**Figure 5.2: Weekly Ebola Cases in Liberia, 2014-2015**
Source: WHO, NY Times

[51] "U.S. Military Response to Ebola Gains Momentum in Liberia," NPR, accessed December 12, 2019, https://www.npr.org/sections/goatsandsoda/2014/11/05/361796044/u-s-military-response-to-ebola-gains-momentum-in-liberia
[52] "Empty Ebola Clinics in Liberia Are Seen as Misstep in U.S. Relief Effort," The New York Times, accessed December 12, 2019, https://www.nytimes.com/2015/04/12/world/africa/idle-ebola-clinics-in-liberia-are-seen-as-misstep-in-us-relief-effort.html

In the event that too many units are constructed and they are no longer needed, as was the experience in the U.S.'s intervention in the 2014-2015 Ebola outbreak, then it is important that the units are modular so that they may be repurposed rather than wasted.

*Prefabrication*

Modular construction is gaining traction throughout the African housing market due to its affordability, quick construction timeline, and mobility. Organizations such as DMS Africa, which specializes in emergency structures used in housing projects after a disaster event, provides prefabricated modular structures to partners throughout the continent. According to the AIA, the total time and cost of labor for modular construction is significantly lower than traditional on-site construction.[53]

The benefits of assembling prefabricated modules not only speeds up the construction time so that the facility can become operational sooner, but this method of construction is also more reliable considering Africa's building sector skills gap.[54] The modular components are also constructed in a temperature-controlled setting, which means that fluctuations in weather will not affect the timeline of the construction process.

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[53] "Design for Modular Construction:
An Introduction for Architects," The American Institute of Architects, accessed December 13, 2019, http://content.aia.org/sites/default/files/2019-03/Materials_Practice_Guide_Modular_Construction.pdf
[54] "How to Tackle Africa's Housing Challenges with Modular Building," Prefabmarket, accessed December 10, 2019, http://www.prefabmarket.com/modular-building-africa/

*Assembly and Disassembly*

Modular building elements that are constructed at an off-site location are generally designed to be volumetric modules or non-volumetric components (Fig. 5.3). For volumetric construction, the entire three-dimensional unit is typically constructed off-site and is then transported to the site and assembled to connect to adjacent modules. For non-volumetric construction, the individual building elements (including wall, floor, and roof assemblies) are created off-site and then the components (called sub-assemblies) are flat-packed and transported to be assembled on site.  Some projects use a combination of both volumetric and non-volumetric assemblies.[55]

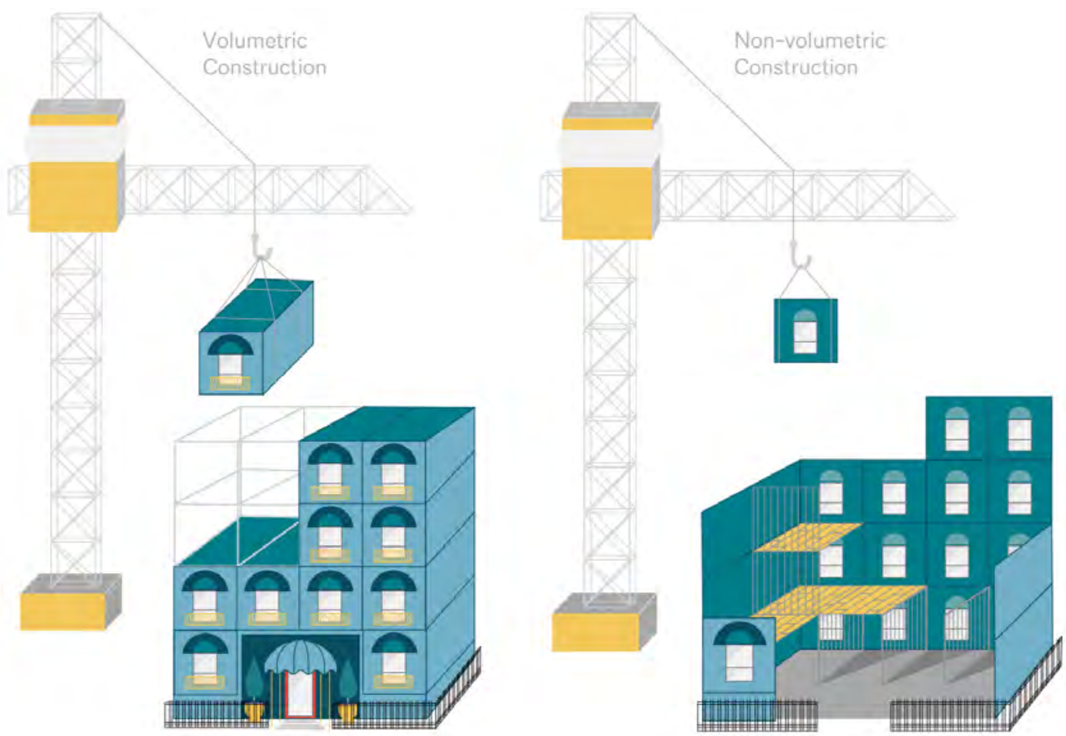


**Figure 5.3: Volumetric vs. Non-Volumetric Construction**
Source: AIA

[55] "Design for Modular Construction:
An Introduction for Architects," The American Institute of Architects, accessed December 13, 2019, http://content.aia.org/sites/default/files/2019-03/Materials_Practice_Guide_Modular_Construction.pdf

Modular buildings can be designed to be capable of disassembly in the future, in the case that the structure will be repurposed or relocated. For this to be feasible, the building design must be simpler so that the modules are more repetitive and there is less variety in material connections. Disassembly requires a majority of the building, about 90%, to have been constructed off-site since this would mean there are more modular components and would need less demolition to deconstruct. Potential future disassembly would also require an understanding of how the building was constructed and how it is intended to be deconstructed, and documentation would be required for future parties to successfully deconstruct the project.[56]

*Permanent vs Temporary*

*RAPIDO Housing Model*

Rapido is a modular housing typology intended for rebuilding houses after their destruction due to natural disasters. The Rapido model is centered around a temporary-to-permanent approach in order to bridge the gap between the relief phase and the recovery phase following a disaster.[57]

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[56] "Design for Modular Construction:
An Introduction for Architects," The American Institute of Architects, accessed December 13, 2019, http://content.aia.org/sites/default/files/2019-03/Materials_Practice_Guide_Modular_Construction.pdf

[57] Omar Hakeem, University of Maryland Lecture, Rapido: Designing a New System for Disaster Reconstruction, November 8, 2019.

RAPIDO's housing model deploys a temporary 'Core' unit (Fig. 5.4) to a family's property as soon as possible following a disaster.

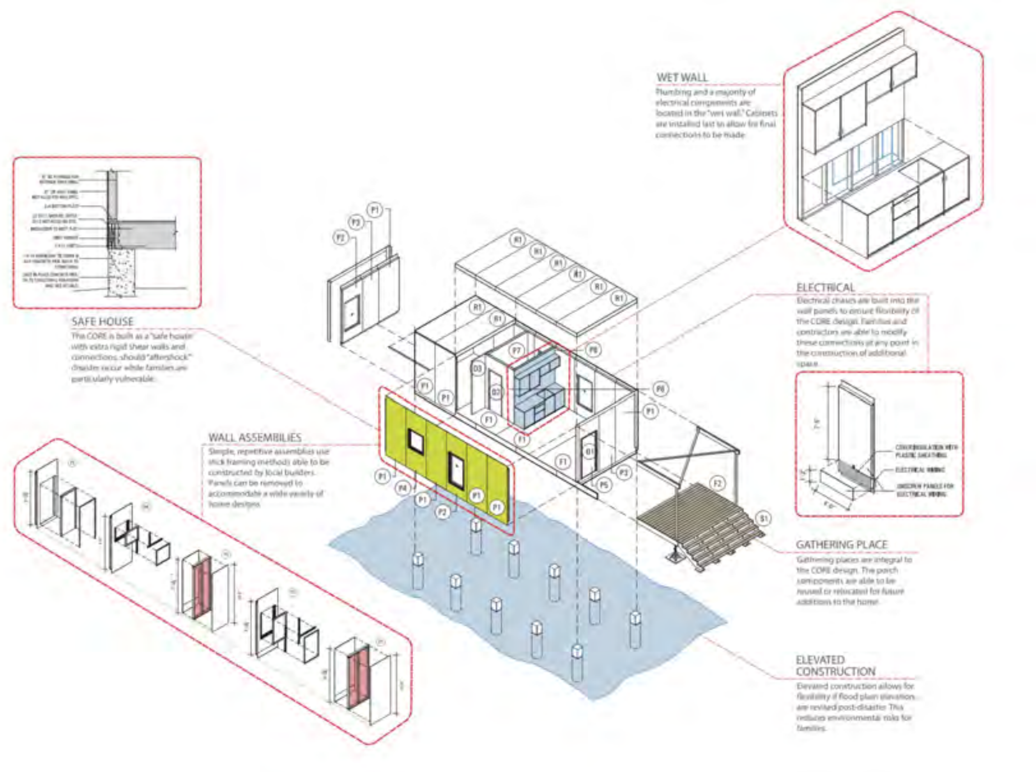



**Figure 5.4: Core Module of Rapido Housing System**
Source: Omar Hakeem Lecture

To be quickly deployable, the core is made of simple, repetitive, panelized wall assemblies (Fig. 5.5) that may be constructed by local builders and then transported to the site. The core can be expanded to become a more sizable, permanent home through a system of semi-custom additions (Fig. 5.6). The family will live in the core following a disaster, and then once the family is able and willing to, they are able to expand their house off the core structure to meet their needs. The core is a 'temporary' structure, and then once the family settles in and customizes their home with additions, the home becomes 'permanent'.

**Figure 5.5: Panelized Wall System of Rapido's Core Module**
Source: Omar Hakeem Lecture

**Figure 5.6: Wood Frame Addition onto Core Module**
Source: Omar Hakeem Lecture

The core panels are constructed in advance of storm disasters in order to meet demand. After a disaster, a lot of decisions must be made, and Rapido attempts to pre-plan and make response efforts quickly deployable. The core modules are intended to replace FEMA trailers that would typically be dropped in as a response following storm events. The construction techniques that Rapido employs (Fig. 5.7) is intended to house people sooner after a disaster occurs and help them rebuild their lives through shelter with a more permanent approach. The panels are designed to be easily assembled, so that local contractors and even community members or volunteers can help assemble a home. Once the core is either shipped in or constructed on site, the family immediately has a home to live in.[58]

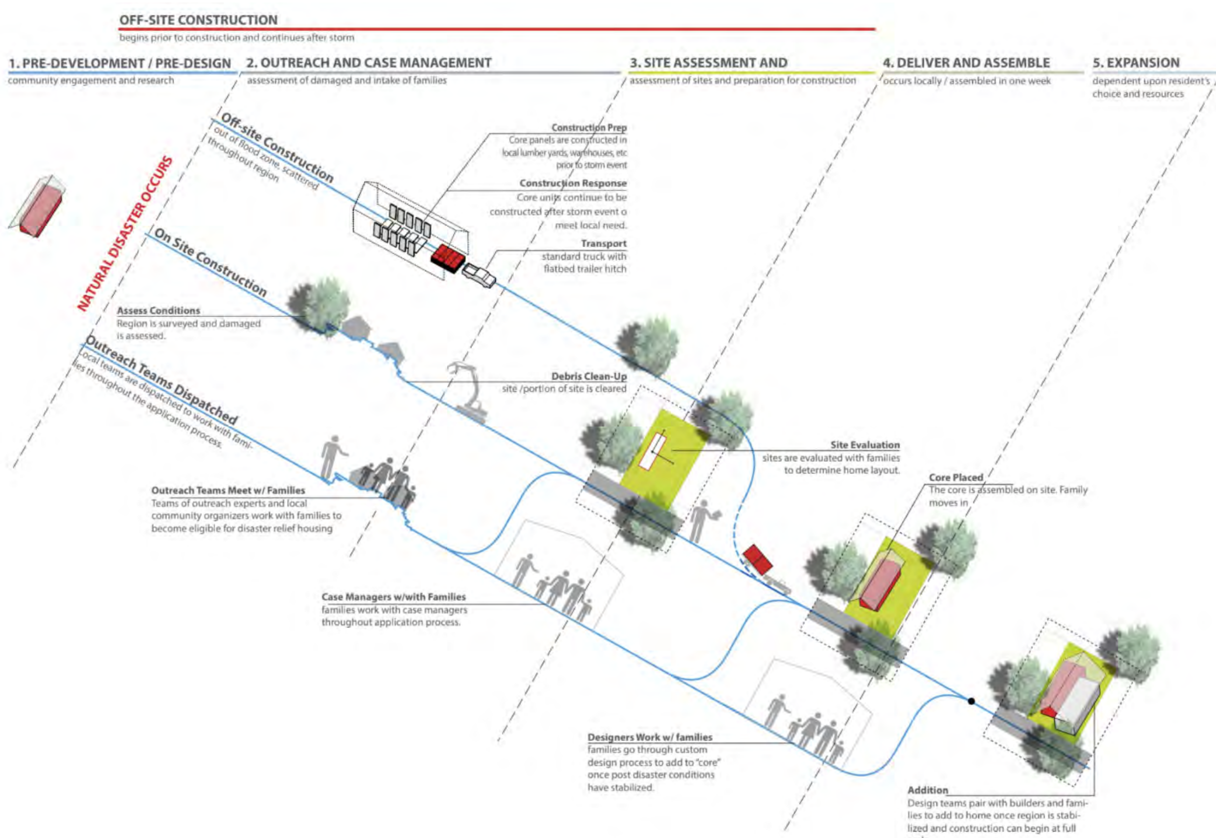



**Figure 5.7: Construction Methodology of Rapido Housing**
Source: Omar Hakeem Lecture

[58] "Rapido," Rapido Recovery, accessed October 15, 2019, http://www.rapidorecovery.org/

Modules

*Effekt + IKEA*

EFFEKT Architects worked with IKEA's global research and design lab, SPACE10, to create a vision for a modular 'urban village'. The project is intended to tackle a multitude of current issues, including rapid urbanization and a lack of affordable housing. The design utilizes cross-laminated timber and is based on a standardized modular building system. The 'pre-fabricated, mass-produced, and flat-packed system' can be combined in numerous ways to create anything from one-story homes to towers (Fig. 5.8).[59]

**Figure 5.8: Stacking Capabilities of SPACE10's Urban Village Project**
Source: Designboom

[59] "SPACE10 + EFFEKT Envision 'Urban Village Project' as a Sustainable, Shared Living Community," Designboom, accessed October 15, 2019, https://www.designboom.com/architecture/space10-effekt-urban-village-project-ikea-06-04-2019/

The system and its modular components are designed for disassembly, and pieces of the structure may be replaced, reused, or recycled at any point if necessary. Prefabrication of materials (Fig. 5.9) is intended to be done off-site, with wall panels and equipment being trucked to the site and quickly assembled. The footprint of one module is 6 meters by 6 meters, which is approximately 20 ft x 20 ft. This gives each module a surface area of 36 meters squared, or about 400 sq. ft.

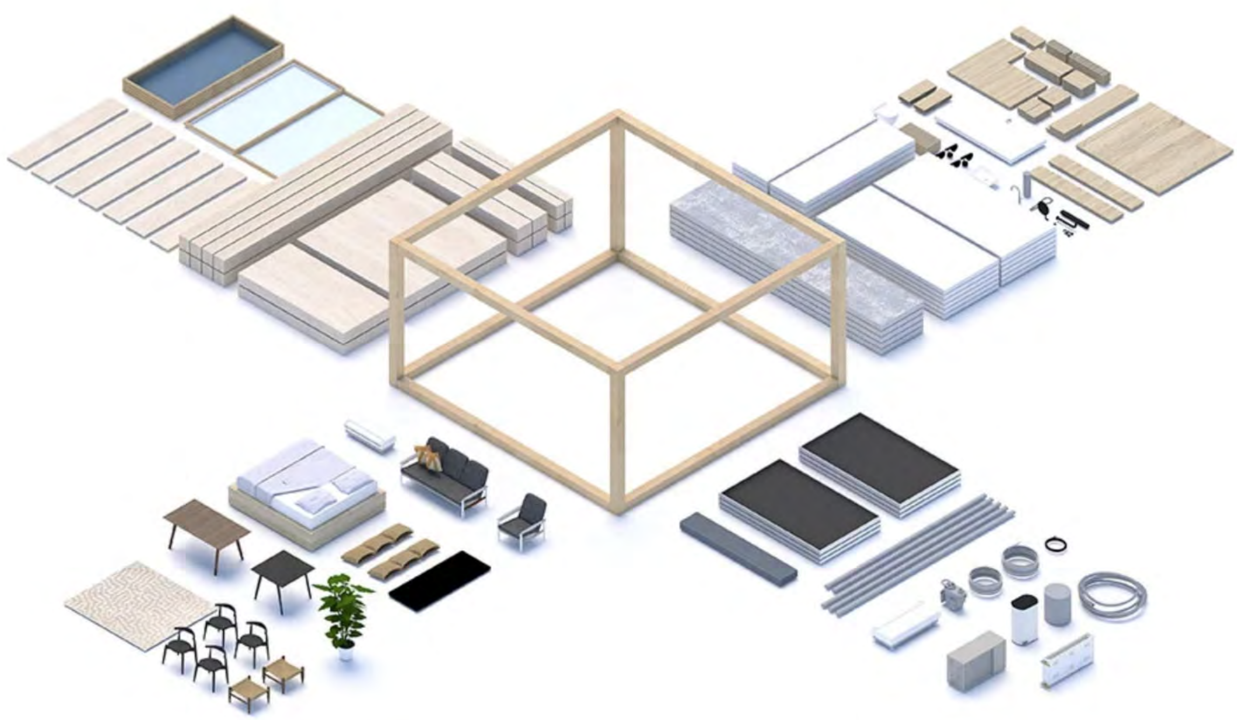


**Figure 5.9: Modular Component of SPACE10's Urban Village Project**
Source: Designboom

# Chapter 6: Materiality

Material choices for health care facilities are important to limit the transmission of disease through the material, and so materials can be easily cleaned and repurposed. This concept is most important in the 'cold' modules where the structure and materials have the potential to be repurposed, but in the 'hot' modules, materiality is less important because everything is assumed to be temporary and disposable. An important consideration with the composition of the materials as well as the systems of the building is breathability and ventilation, as the heat of the building and humidity of the African climate makes it difficult for healthcare workers to work long durations within the current field treatment center models.

## *Modular Models*

Typical modular facilities tend to be made of a steel structure, but some modern examples, including RAPIDO and IKEA's SPACE10 models, are showing modular units constructed with wood. Wood is a good product from an affordability and sustainability standpoint.

## *ETU's Implemented in Liberia, 2014-2015*

As ETU's are operated by a variety of international organizations, they vary widely in their choice of materials, construction techniques, bed capacity, location (urban vs rural), and other considerations. They range from simple tent structures to more elaborately constructed facilities. Although every ETU varies in setup and materials, most contain elements such as wood and tarps due to their low price, wide availability, and simplicity to construct. Many items are burned after their use during the time when the ETU's are operational, but according to WHO protocols, Ebola virus can't survive on materials or equipment for longer than a week, and so disinfection of materials after that duration of time is sufficient for their reuse.

The Monrovia Medical Unit (MMU) in Monrovia, Liberia is a 25 bed field hospital in a rural setting meant to solely care for medical workers who had been infected with Ebola virus. The structure of the facility was a series of semi-circular tents (Fig. 6.1) constructed by assembling steel rods (Fig. 6.2) and then fitting and tying down a tan tarp over top (Fig. 6.3). Construction on the MMU began on October 7 and deconstruction occurred in April.

**Figure 6.1: Series of Wards at MMU**
Source: United States Africa Command

**Figure 6.2: Structure Assembly of MMU**
Source: United States Africa Command

**Figure 6.3: Military Tying Down Tarp Over MMU Structure**
Source: Designboom

The interior of the wards consisted mostly of tarp, with no interior partitions to separate space. All equipment was simply organized within the open interior space of the wards and facilities (Fig. 6.4).

**Figure 6.4: Interior of MMU Ward**
Source: United States Africa Command

At the end of October 2014, a new ETU opened at the former Ministry of Defense compound in Monrovia, Liberia. The new structure is actually two adjacent units, each with 100 beds to add a total of 200 beds to the almost 500 that were available at the time for Ebola patients in Monrovia.

The buildings are made of a steel-frame structure on top of sealed concrete foundations, with the façade being a white tarp wrapping, creating multiple long, rectangular A-frame structures (Fig. 6.5).

**Figure 6.5: U.S. ETU in Monrovia, Liberia**
Source: WHO

On the interior, partitions are created using wood 2'x4's, with the 'wall' also being wrapped by a tarp (Fig. 6.6). These facilities were not modular, rather individual materials (steel beams, tarps, wood beams, etc.) were transported to the site as individual components and were assembled on-site by local builders.


**Figure 6.6: U.S. ETU on Former Ministry of Defense Compound in Monrovia, Liberia**
Source: WHO

*<u>ETU's Implemented in DRC, 2018-2019</u>*

MSF has constructed and operated numerous ETU facilities throughout the DRC to combat the current Ebola crisis. One facility in Mangina, located in the DRC's North Kivu province, contains 30 beds and primarily contains white tent structures (Fig. 6.7)

**Figure 6.7: Isolation Tents in Mangina ETU**
Source: MSF

Other structures within the Mangina ETU include existing buildings being used as a part of the treatment center (Fig. 6.8) and a structure made of wood with corrugated metal roofing (Fig. 6.9).

**Figure 6.8: Existing Building in Mangina ETU**
Source: MSF

**Figure 6.9: Staff Building in Mangina ETU**
Source: MSF

*Equipment*

Aside from the materials used to construct the ETU, equipment is also an important consideration for the success and quality of the facility. The China ETU, for example, implemented air conditioning in its facilities and a monitoring system so that nurses could communicate with and monitor patients without putting themselves at risk and prolonging the process of putting on and taking off the required PPE. The buildings do not need to be insulated due to the heat and humidity of the African climate; however, ventilation and cooling of these structures tends to be an issue.

*Vernacular of African Architecture*

Materiality of vernacular African architecture varies depending on building type, region, and era. For the purposes of this exploration, the analysis of African vernacular will be limited to the Democratic Republic of Congo and other regions in Africa within a similar climate zone.

Many homes and buildings in rural regions utilize earthy materials, such as clay (Fig. 6.10), stone, or mudbricks (Fig. 6.11) for walls, and thatching for roofs.

**Figure 6.10: Vernacular of Clay and Roof Thatching in Rural Buildings in DRC**
Source: African Vernacular Architecture Data Base

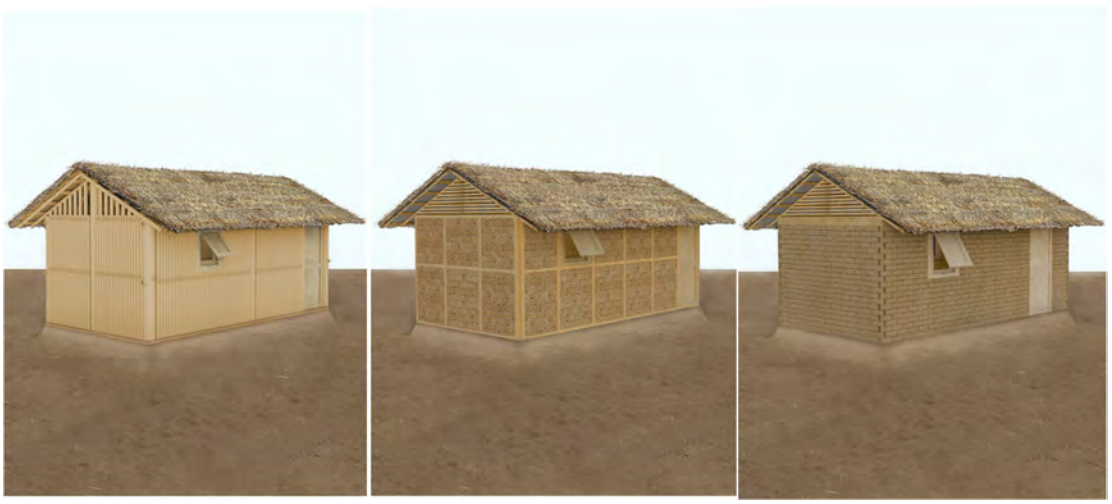
**Figure 6.11: Vernacular of Mudbrick in Rural Buildings in DRC**
Source: African Vernacular Architecture Data Base

These materials vary greatly from the examples of emergency facilities brought in by international agencies, but in order to combat the resistance and distrust from African communities, relating to the vernacular of the regions is necessary. The difficulty lies in merging the gap between the vernacular and creating a modular system. Some ideas to consider are the reliance on the vernacular to promote natural ventilation (Fig. 6.12) and also the tendency to built above-ground in both hot/dry climates, to increase air flow, and wet climates, to move away from pooling water (Fig. 6.13).

**Figure 6.12: Open-Air Construction in DRC**
Source: Architectural Review

**Figure 6.13: Above-Ground Construction in DRC**
Source: Architectural Review

Shigeru Ban explored African vernacular in his explorations for a proposed Kalobeyei Settlement in Kenya. He developed three models of homes based on precedents in materiality (Fig. 6.14): A paper tube structure (a), timber frame structure (b), and a compressed earth block structure (c).



(a) (b) (c)

**Figure 6.14: Shigeru Ban Materiality Explorations**
Source: Shigeru Ban

# Chapter 7: Site Considerations

The primary considerations that need to be taken into account when selecting a site for an emergency medical facility in Africa are: rain and areas prone to flooding, transportation and access to the site, population density near the site (both for patient access and staff: will they be living on-site or are they able to commute in to work), and if the site is able to be connected to utilities or if it will require hookup to generators. These considerations will affect the longevity of the facility and the number of patients it will be capable of serving.

As the health facility will likely be in the same site for a few years, it is assumed that the building will go through both wet and dry seasons experienced in both the DRC and Africa as a whole. The wet season in Africa includes monsoons, which may flood facilities in in a low-lying site. The combination of wet and dry seasons may also affect rainwater collection if the facility depends on collecting and treating rainwater as opposed to using bottled water transported to the site.

The current Ebola breakout has been primarily affecting the Democratic Republic of Congo, and most recently has infiltrated the highly populated city of Goma, located in the North Kivu region and adjacent to the border of Rwanda. Goma is currently the largest city in the DRC experiencing an outbreak of Ebola, with other cities including Beni and Butembo. On the other hand, many rural areas have also been hit hard in the pat by Ebola outbreaks, as was the case in Jene Wonde, Liberia. These two sites, Goma and Jene Wonde, will be explored as urban and rural examples for design integration (Fig. 7.1).

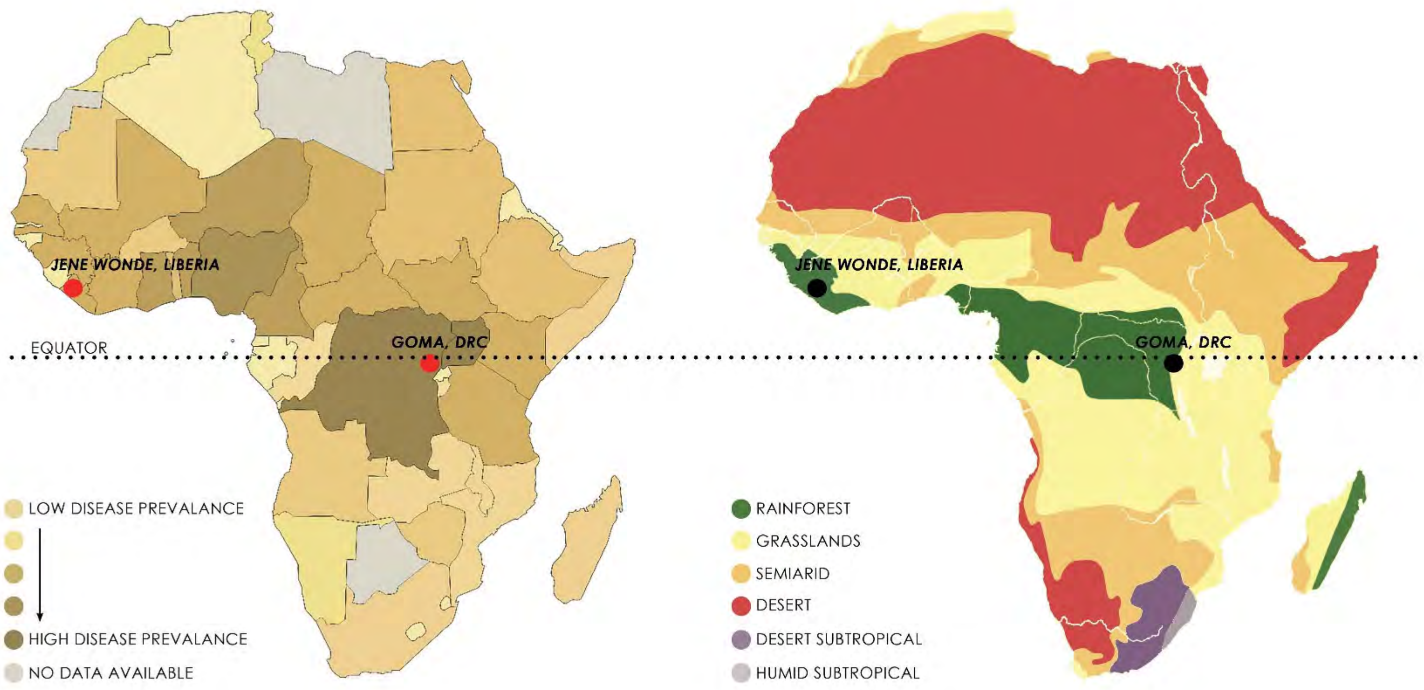



**Figure 7.1: Disease Prevalence and Climate in Goma and Jene Wonde**
Source: Author

*Sites*

The urban site, in Goma, Democratic Republic of Congo, is in close proximity to two primary roads that cross perpendicularly through the city of Goma as well as an airport, all of which increase the accessibility to the site for staff and materials. While being near the airport can be a great resource for bringing outside resources into the site, it is also important to consider noise of airplane traffic when developing a successful healing environment.

It is typically best for an infectious disease center to be near much of the sick population so that it is accessible. Being connected to a primary road network is also beneficial so that materials and equipment can be brought into the site without difficulty. The site's proximity to the Goma airport means that materials could be dropped off by international aid organizations, and there is a short commute to the site which means a quicker path towards treatment and recovery. A successful ETU situated in a prominent urban location means that there will be a large demand for bed space, so the facility will need to be large with a high capacity for patients.

The rural site, in Jene Wonde, Liberia, is naturally more secluded due to the nature of the rural town being far from any city and having a low population, but the site being explored is still adjacent to the ‘hub’ of the town and on a primary road for easy access for patients and visitors.

### *Program*

No matter the site, each ETU requires specific programmatic elements and circulation patterns to control the spread of disease. Circulation for staff (Fig. 7.2) varies from the permitted circulation for patients (Fig. 7.3). Patients that are only suspected of having the disease are also kept separate from patients that are confirmed to have EVD in order to prevent patients from becoming infecting if they weren’t prior to coming to the facility.

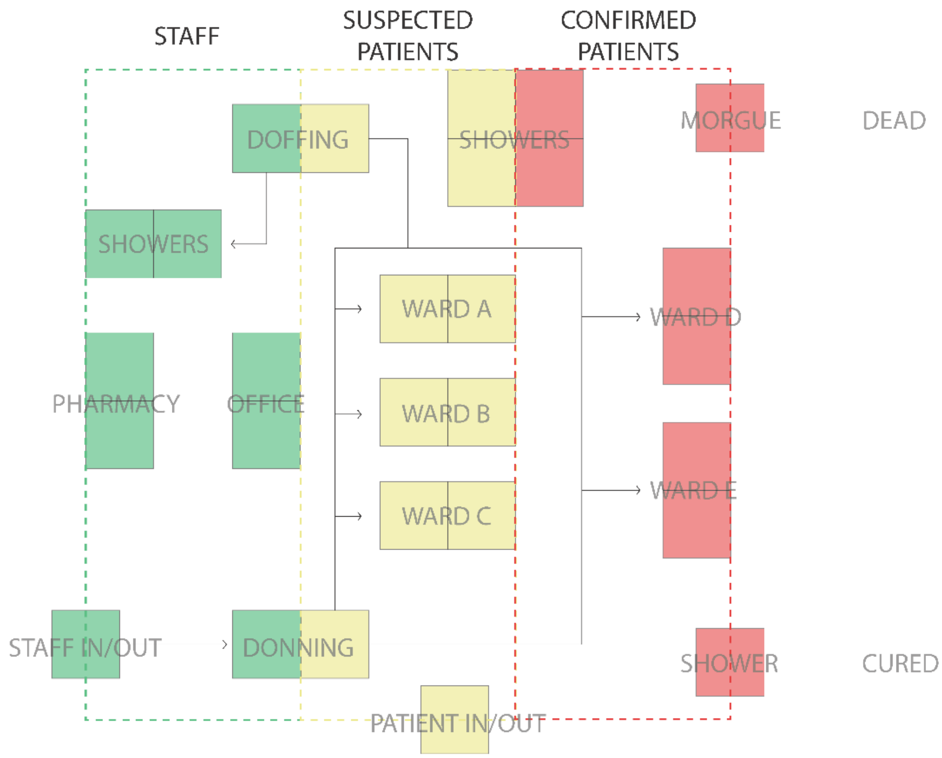



**Figure 7.2: Staff Circulation Through Standard ETU Program**
Source: Author

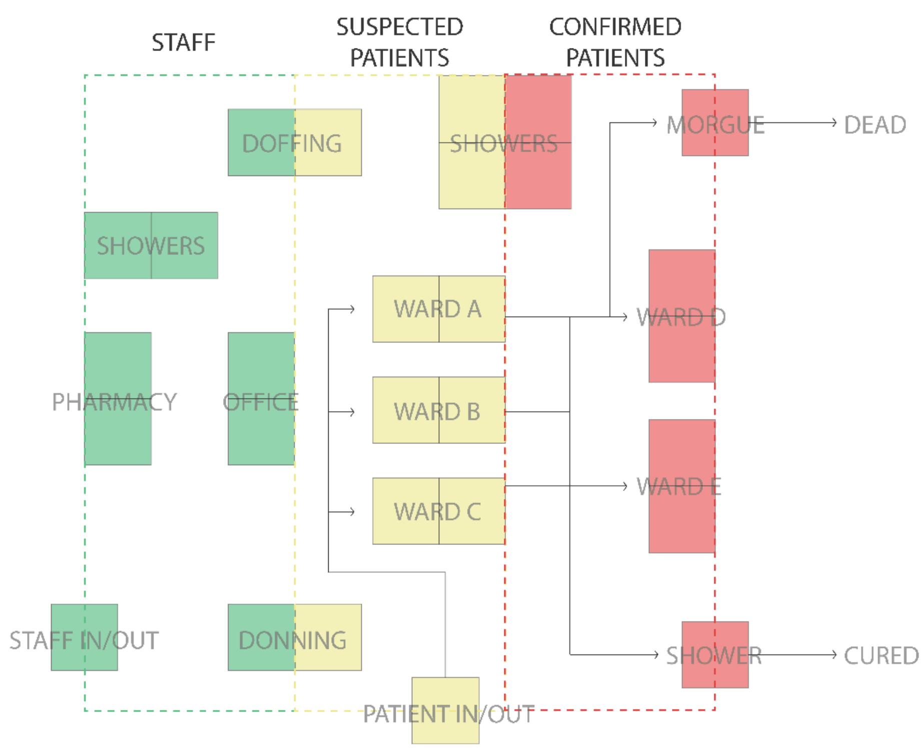



**Figure 7.3: Patient Circulation Through Standard ETU Program**
Source: Author

# Chapter 8: Precedent in African Healthcare Architecture

## *Mass Design Group: The Butaro District Hospital*

The Butaro District Hospital in Rwanda was constructed in the Burera district, which has a population of over 340,000 people and had no existing hospital or doctors at the time of this facility's construction. The hospital, completed in 2011, is an example of a modern hospital design that integrates traditional African design elements. It is designed as a campus of buildings on a terraced hillside (Fig. 8.1), centered around an umuvumu tree.

**Figure 8.1: The Butaro District Hospital on a Terraced Hillside**
Source: Mass Design Group

The hospital primarily focuses on maternal health, integrating 150 beds (Fig. 8.2), a laboratory, neonatal intensive care unit, and operating rooms into its facility.

**Figure 8.2: A Bed Ward in the Butaro District Hospital**
Source: Mass Design Group

The project is 6,000 sq. meters. The layout of the complex, staff and patient circulation, open corridors, and cross-ventilation within the buildings reduces the transmission of airborne diseases (Fig. 8.3).

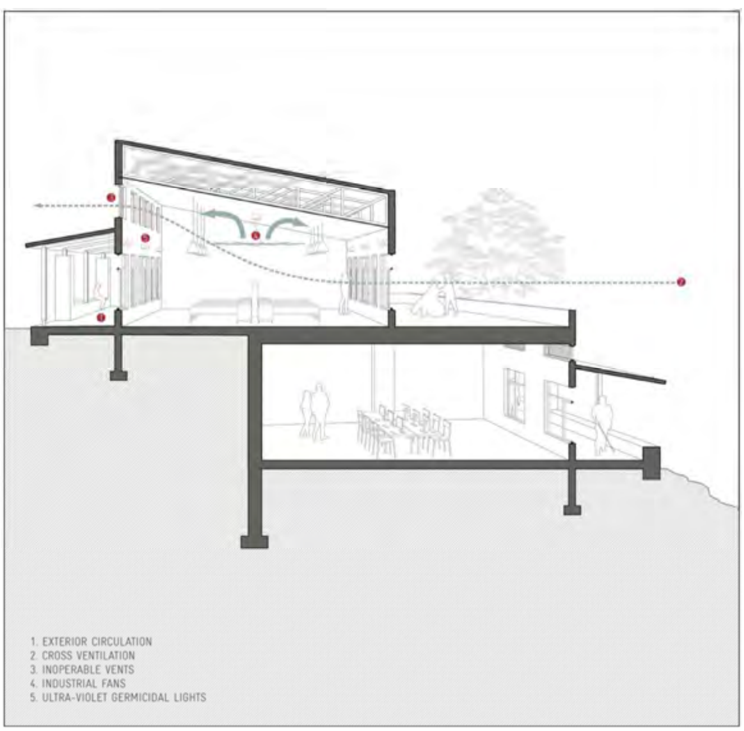



**Figure 8.3: Cross-Sectional Layout of Butaro Hospital**
Source: ArchDaily

The project utilizes local materials, including volcanic rock (Fig. 8.4) from the Virunga mountain chain, and it also depended 100% on local builders and craftsmen to help construct the project. The hospital emphasizes community from start to finish, from conception to construction and the design's emphasis on community spaces (Fig. 8.5).

**Figure 8.4: Volcanic Stone Used at Butaro Hospital**
Source: ArchDaily

**Figure 8.5: Community Space at Butaro Hospital**
Source: Mass Design Group

The layout of Butaro District Hospital (Fig. 8.6) is most relevant to this analysis, as the program is broken up into separate units surrounding communal outdoor spaces. Despite being a traditional permanent installation constructed on-site rather than being a modular construction project, this project can be studied to retrofit different programmatic elements into separate modules. This project is also designed for maternal health as opposed to infectious disease control. The size of each of the wards in this project would successfully fit within repeated modules of 6 x 6 meters, which is the size of the modules used in Effekt + IKEA’s Urban Village Project.


**Figure 8.6: Plan of Butaro District Hospital**
Source: Mass Design Group

# Chapter 9:  Design Proposal

## *Kit of Parts*

A Kit of Parts (Fig. 9.1) was utilized for the design of the modular infectious disease village. The use of a kit of parts means that the building components could be constructed in advance, stored, and implemented at the first sign of an outbreak. The kit of parts consisted of a roof system, wall system, floor system, concrete cylinders, and fencing. No matter the location of the outbreak, the kit of parts components and type of materials would remain the same, but the materials would be gathered and assembled locally.

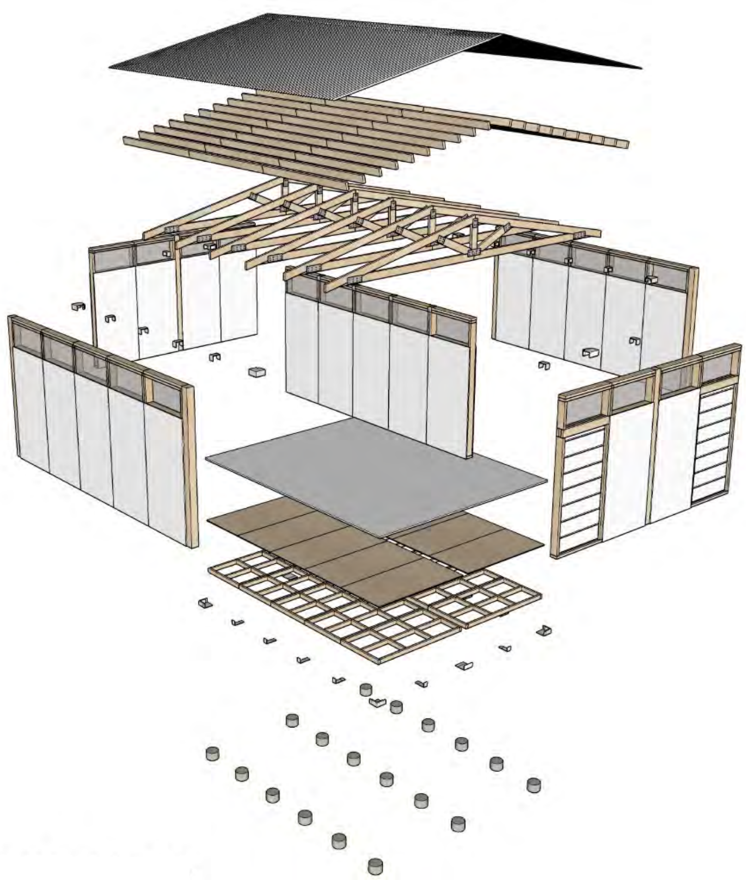


**Figure 9.1: Building Kit of Parts Elements**
Source: Author

**Concrete Cylinders.** The use of concrete cylinders is to bring the buildings above ground to evade water infiltration in wet regions, to increase air flow and ventilation under and around the buildings, and to move piping under the floors without needing to dig on the site. The concrete cylinders are to be created using standard 5-gallon buckets, and the poured concrete can be between 8”-18” in height depending on the slight topographic changes on the site (Fig. 9.2). The above-ground construction typology is common in Africa due to the ability to use wind to cool the structure in hot and humid regions and to lift the house away from water in wet regions.


**Figure 9.2: Above-Ground Construction**
Source: Author (Photo by Architectural-Review.com)

**Floor Modules.** The concrete cylinders are organized in a grid that 4’x8’ floor modules are then placed on (Fig. 9.3). The layers of the floor modules are comprised of a 2”x4” dimensional lumber base that is covered with a standard size 4’x8’x ¾” plywood sheet, and then once these modules are placed (and after the wall system is in place) the floor is then coasted in 2” of dex-o-tex fluid-applied flooring for easy cleaning of the floor.

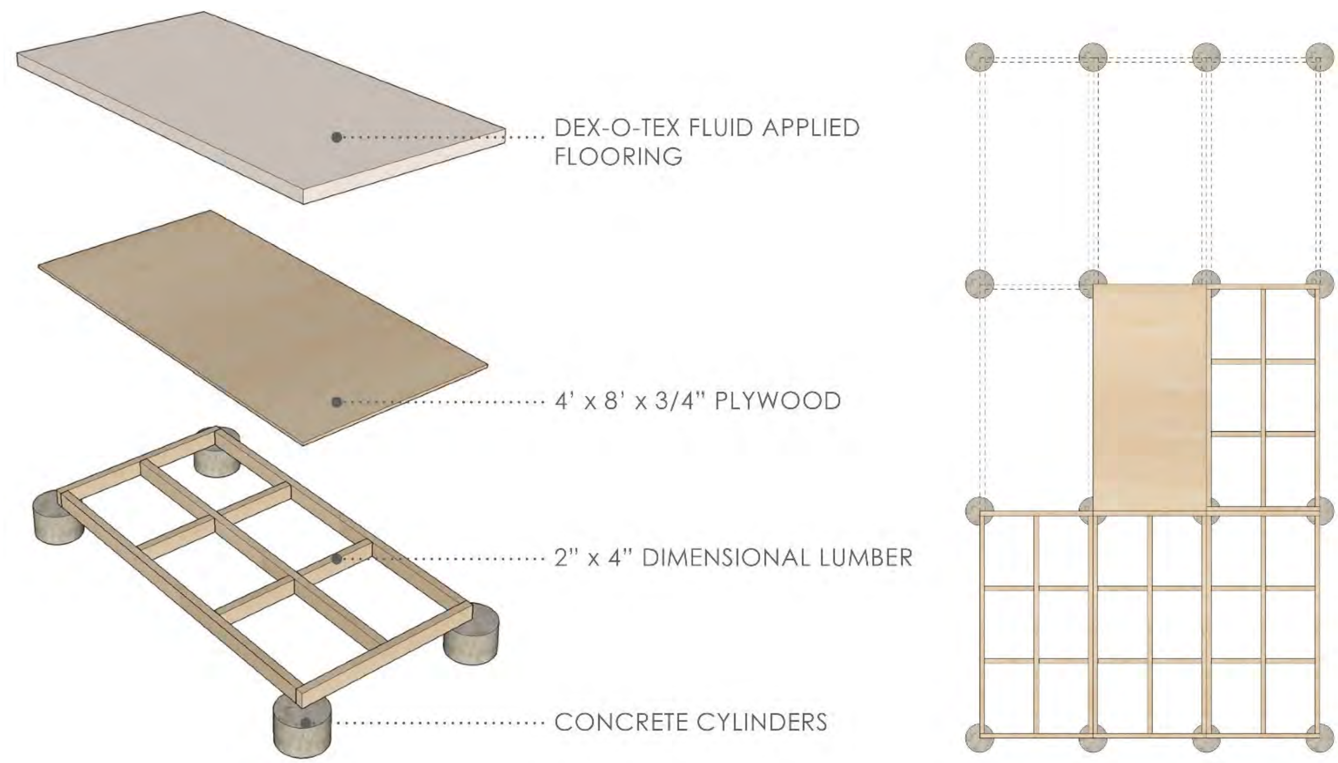



**Figure 9.3: Floor Modules**
Source: Author

**Wall Modules.** There are four wall module types (Fig. 9.4), each at 4'x10': the wall module, the door module, the window module, and the corner module, each with their own purpose within a building system. Vertical 10' posts stand at the corners of each building, and on either side of those posts are the corner modules. Window modules create the window openings, door modules create the door openings, and wall modules are used in any remaining panel locations. Each wall module type is comprised of 2"x6" dimensional lumber. The modules are further stabilized by ¾" plywood sheeting and then wrapped in polyethylene plastic. The plywood sheeting and polyethylene plastic only covers the wall modules up to 8' out of the 10' height (except on the window module where they cover up to 3' high), and then the rest of the module is open air, only being covered by mosquito-netting.

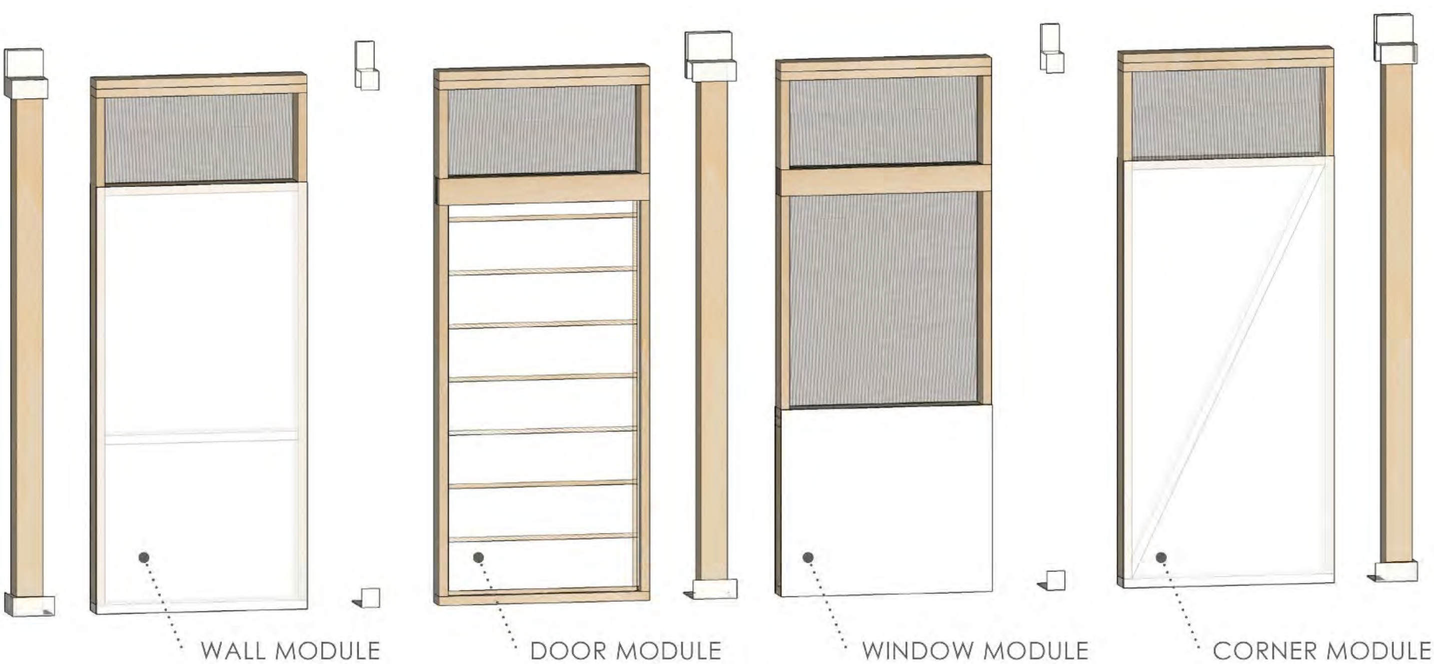



**Figure 9.4: Wall Modules**
Source: Author

The wall modules are then fit together using automotive-grade plastic connectors, with three distinct types at the roof (Fig. 9.5) and three at the floor (Fig. 9.6).

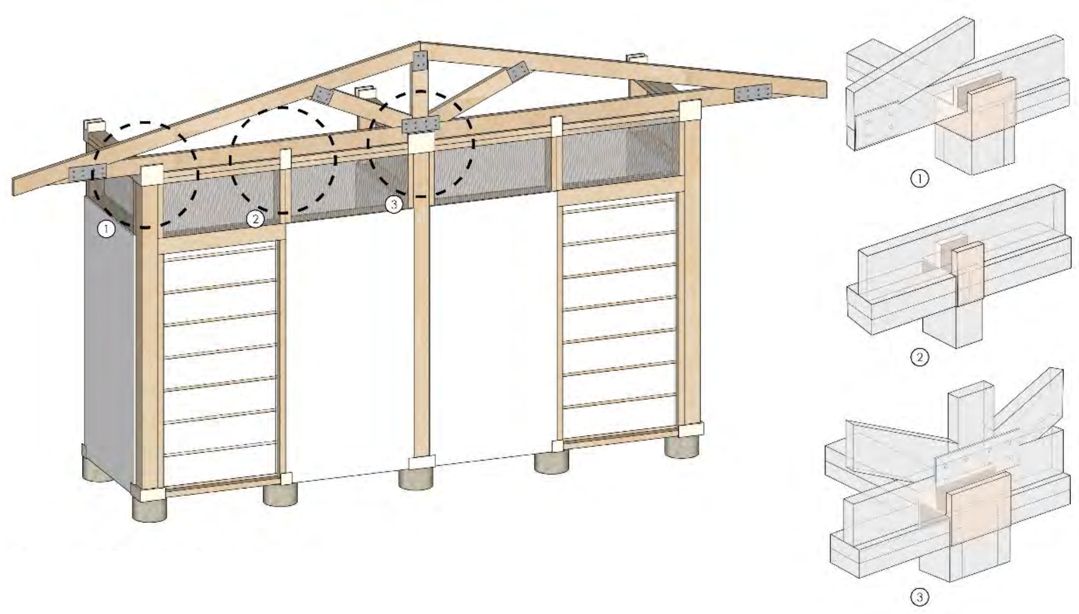



**Figure 9.5: Wall Module Connectors at Roof**
Source: Author

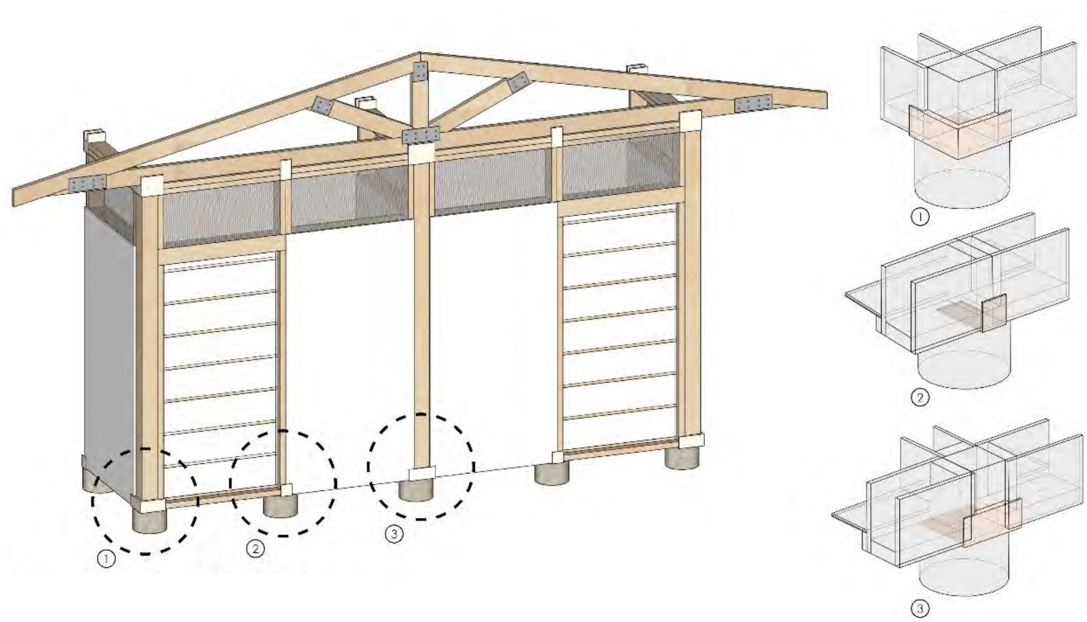



**Figure 9.6: Wall Module Connectors at Floor**
Source: Author

**Roof System.** The roof system (Fig. 9.7) is comprised of prefabricated trusses, and then assembled on-site with 2”x2” wood purlins and either aluminum sheeting or polyethylene plastic.

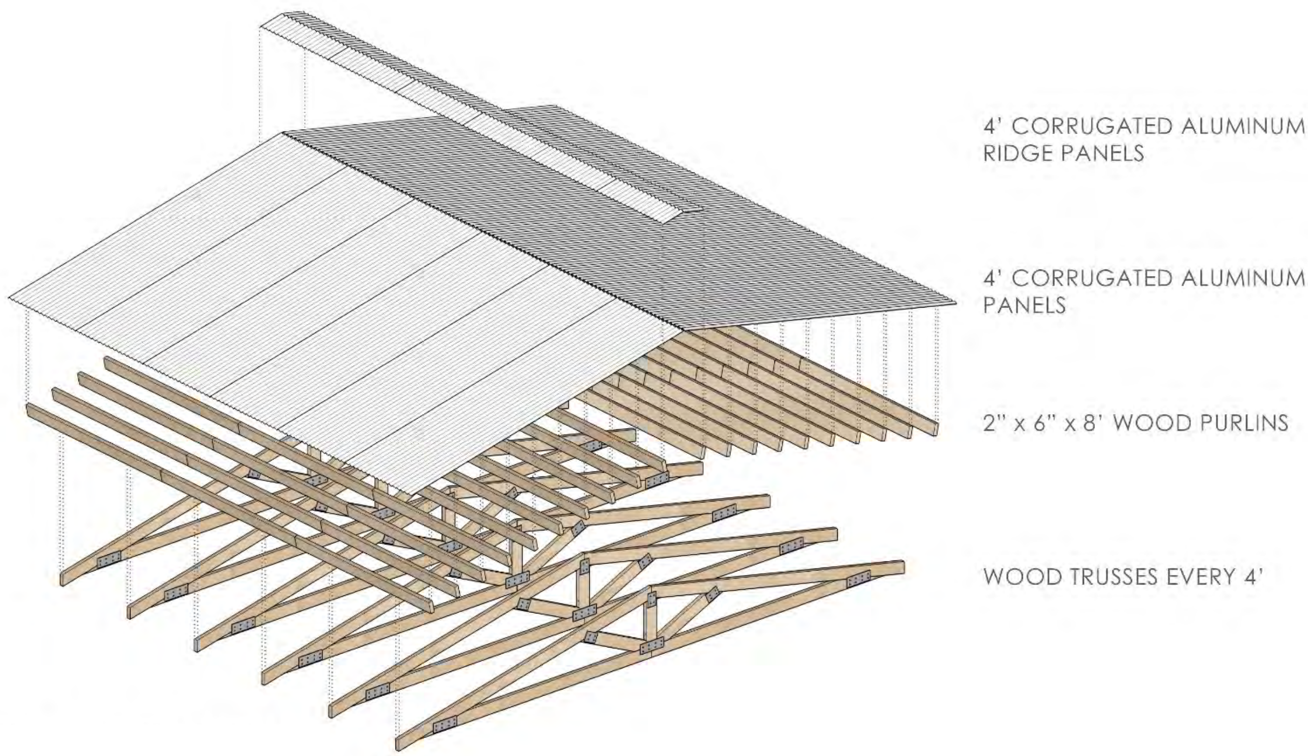



**Figure 9.7: Roof System**
Source: Author

**Fencing.** A major component of an outdoor infectious disease center is fencing, because the patients within the various sections must be separated at least 6' from each other as well as from staff and visitors in the 'clean' areas. The fencing incorporated in this village is 4'x4' fence segments crafted locally from 2"x2" wood pieces and woven plastic (Fig. 9.8).

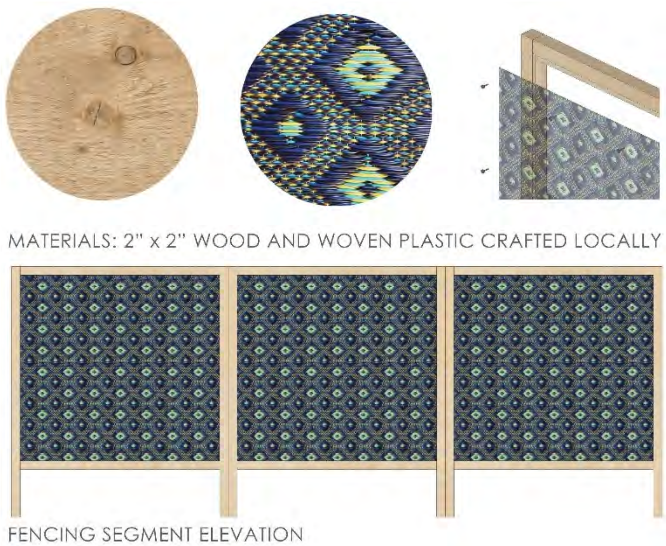



**Figure 9.8: Fence System**
Source: Author

The modules may be preconstructed using local materials, such as an abundant species of local wood, certain colors or patterns for the woven plastic, or widely available stone for the memorial wall. The preconstructed modules may be brought into the site and assembled by community members to bridge a gap between the facility and the community (Fig. 9.9). To ease tension and fear of the uncertainty for when their sick loved ones go here, there needs to be a sense of ownership of this facility by the community and the community should be aware of exactly what this facility is.

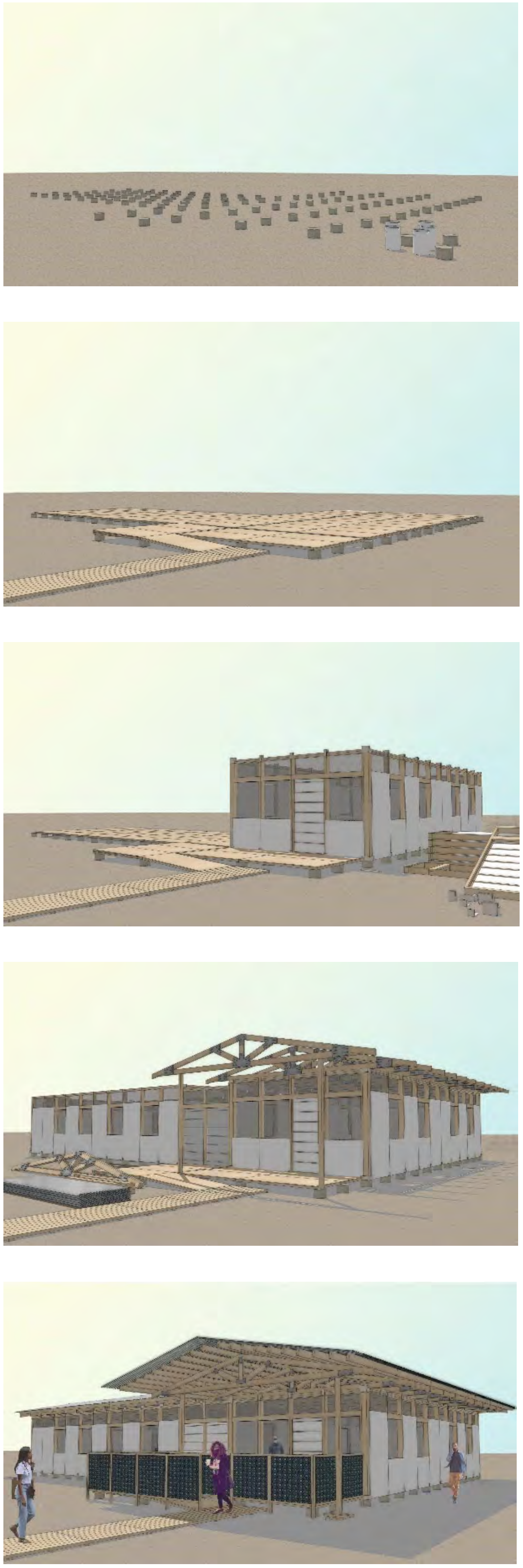


**Figure 9.9: Assembly of Modules**
Source: Author

*Layout*

There is a standard layout (Fig. 9.10) for the infectious disease village that is considered an ideal based on resources and facility sizing; However, buildings can be added to or subtracted from this standard to meet the area's programmatic needs, so long as the circulation ideals remain intact.

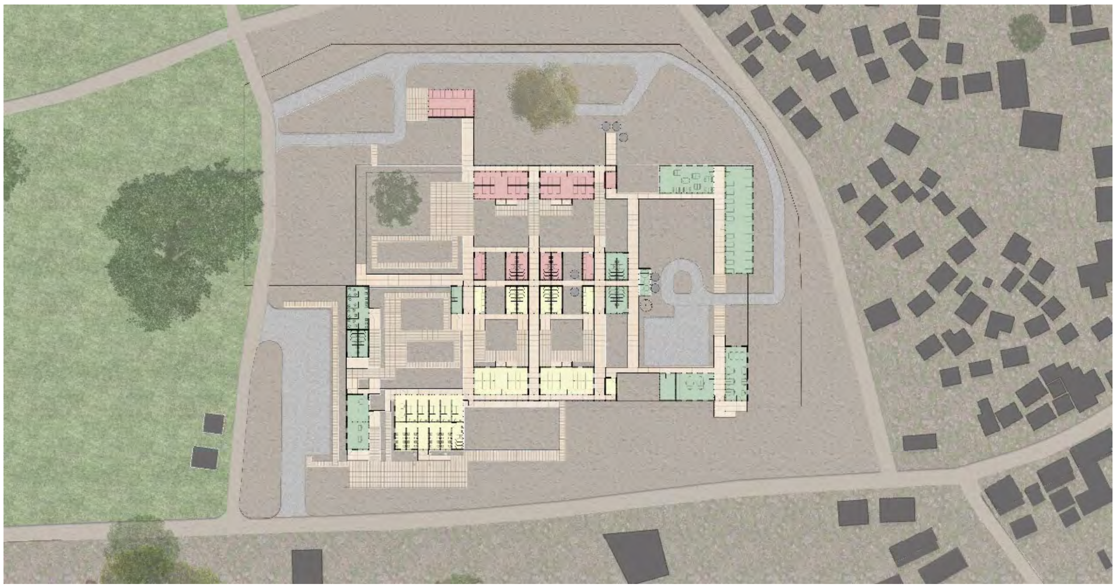


**Figure 9.10: Typical Center Layout**
Source: Author

The infectious disease village is designed to be modular in both construction components and layout, as there may be a need for a facility like this in both high-density urban areas as well as smaller, more rural areas. Both urban and rural areas may equally need an infectious disease center, but rural areas will have a smaller population as well as less available staff to run operations, leading the facility to be smaller in size. The urban facility (Fig. 9.11), placed into the context of Goma, Democratic Republic of Congo, is most like the typical center layout. This center can care for a maximum of 50 patients. The rural facility (Fig. 9.12) represented within the context of Jene Wonde, Liberia, is reduced in size because of fewer resources in rural areas but contains all the key programmatic needs of the infectious disease village to properly care for patients, staff, and the community. This center is fit to care for a maximum of 12 patients at any given time.


**Figure 9.11: Urban Infectious Disease Village**
Source: Author


**Figure 9.12: Rural Infectious Disease Village**
Source: Author

*Organization*

The organization of the infectious disease village is designed with three distinct zones: green (confirmed clean), yellow (suspected infected), and red (confirmed infected) (Fig. 9.13). Circulation between the zones is linear, with patients and staff moving one way from green to yellow to red with no backtracking. Within the three zones, there are a few more subdivisions due to public vs private relationships and infection levels. There are two green zones, one for staff only, and one for visitors. There are also three yellow zones for patients going through infection testing, one is for patients awaiting triage and isolated patients who are awaiting test results, the second is for patients who have tested negative for a virus and are awaiting their second test results (test is given 48 hours after first test), and the third is for patients who are confirmed negative for the highly infectious virus but are still sick, and will either be treated at the facility or transferred to another local health center (Fig. 9.14).


**Figure 9.13: Village Zones**
Source: Author

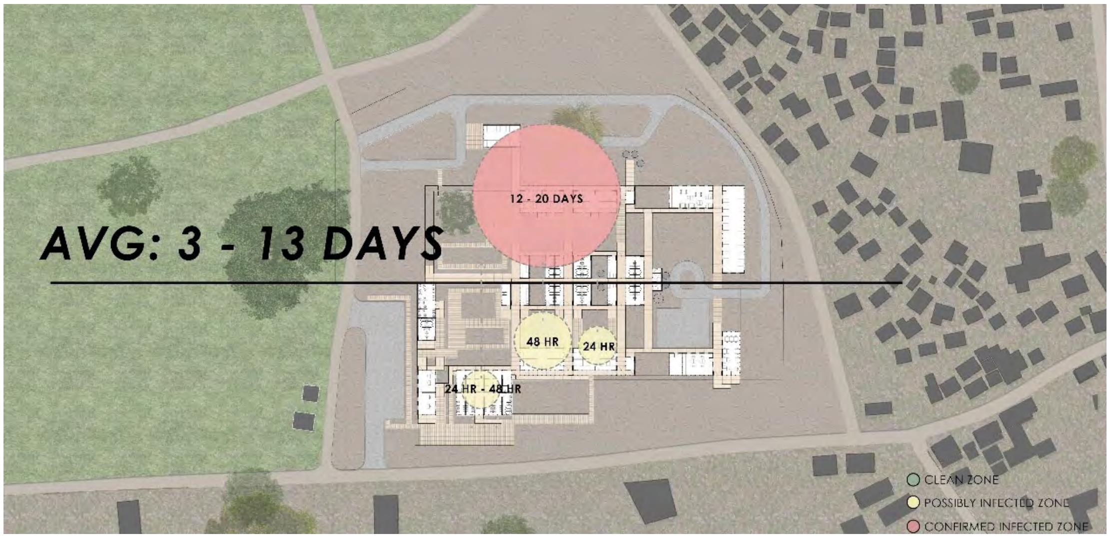



**Figure 9.14: Time Spent in Zones**
Source: Author

The infectious disease village (Fig. 9.15) is organized with the visitor's green zone meeting the street, and then patients and visitors are separated (Fig. 9.16) upon arrival to the main entrances (Fig. 9.17). The visitors, once within the visitor courtyard, have visibility to both the red zone courtyard and yellow zone courtyard, and they are able to speak with their sick friends and family beyond a 6' gap separated by fencing (Fig. 9.18).

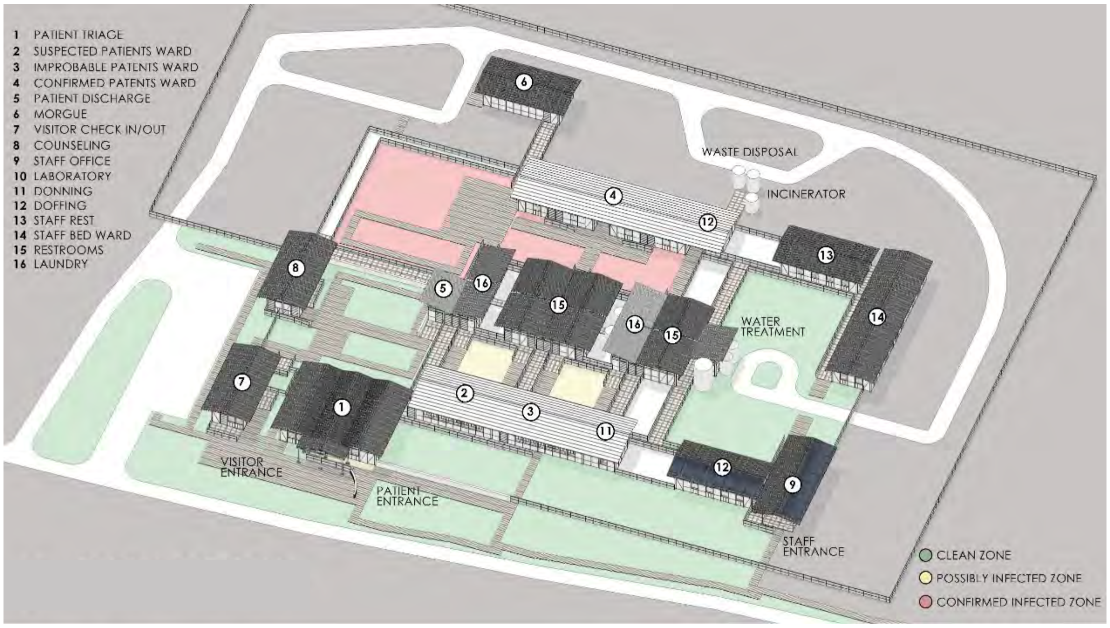



**Figure 9.15: Village Spatial Organization**
Source: Author

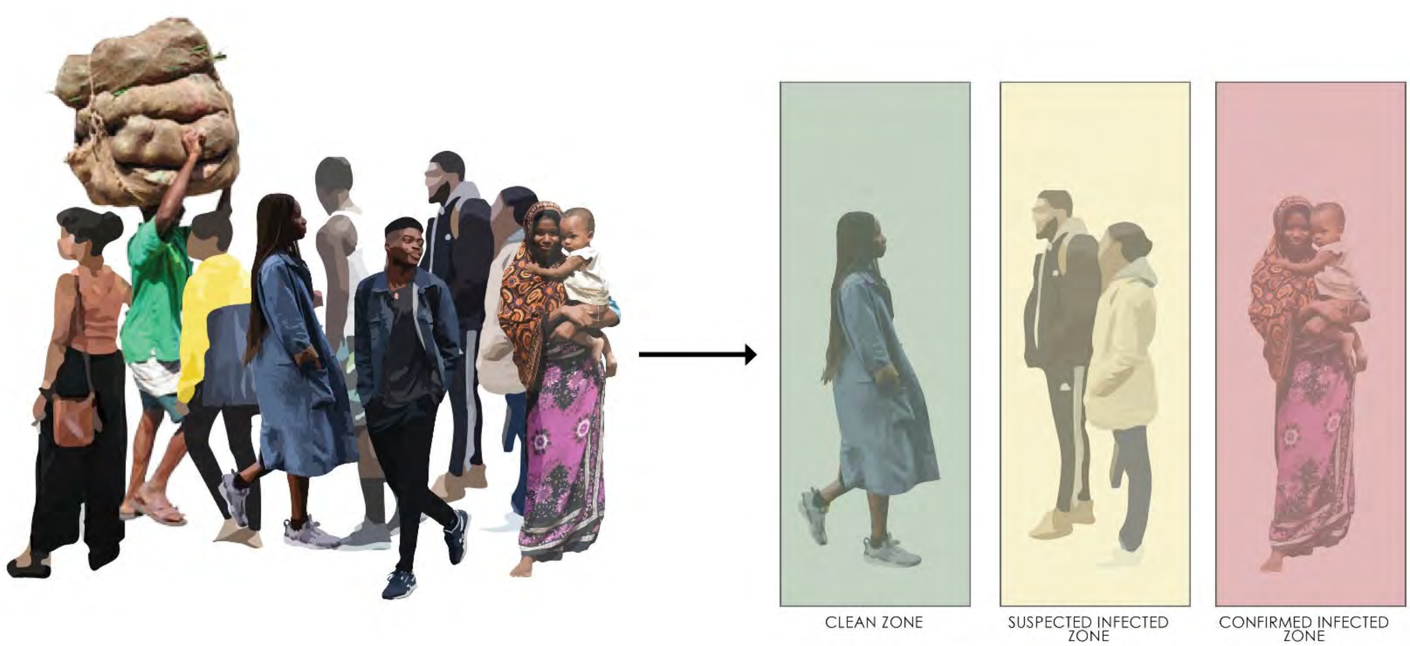



**Figure 9.16: Visitors Separated into Zones**
Source: Author

**Figure 9.17: Visitor View of Patient and Visitor Entrances**
Source: Author

**Figure 9.18: Visitor View of Red Zone Patient Courtyard**
Source: Author

*Utilities*

The Kit of Parts for the infectious disease village also includes utility equipment for water, waste, and electricity (Fig. 9.19).

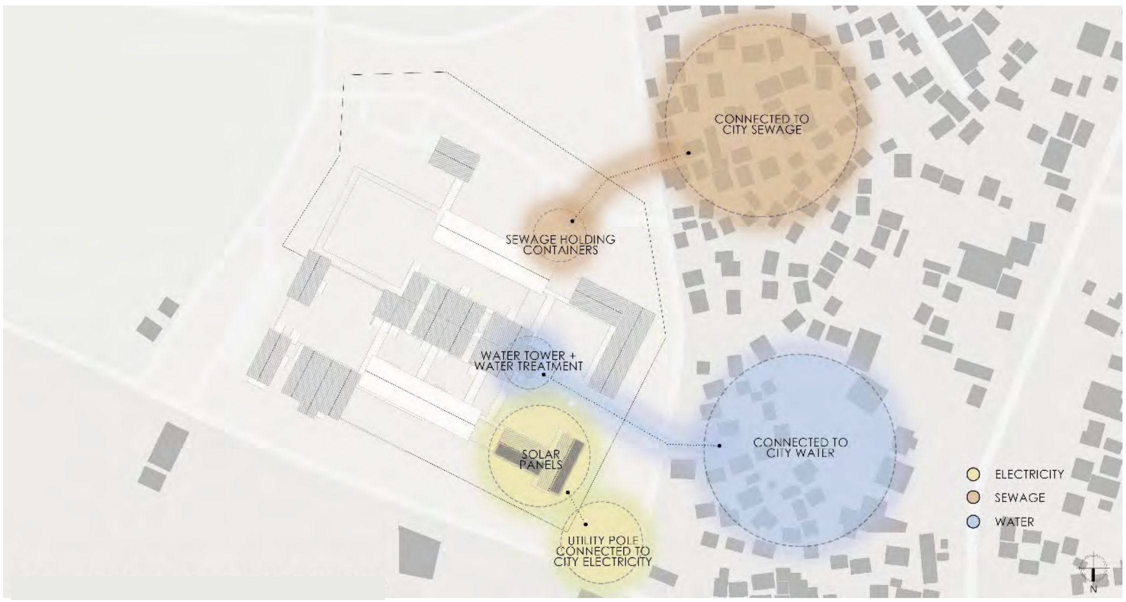



**Figure 9.19: Utility Systems**
Source: Author

**Water.** The water system (Fig. 9.20) is comprised of a water treatment facility using UV treatment techniques and equipment to treat collected rainwater, and there is also a water tower for water brought onto the site and storage tanks for 0.5% and 0.05% chlorinated water solutions. The pipes for the rainwater collection system run at the roofline, and the piped for the distribution of water after treatment or chlorination run under the floor modules (Fig. 9.21)

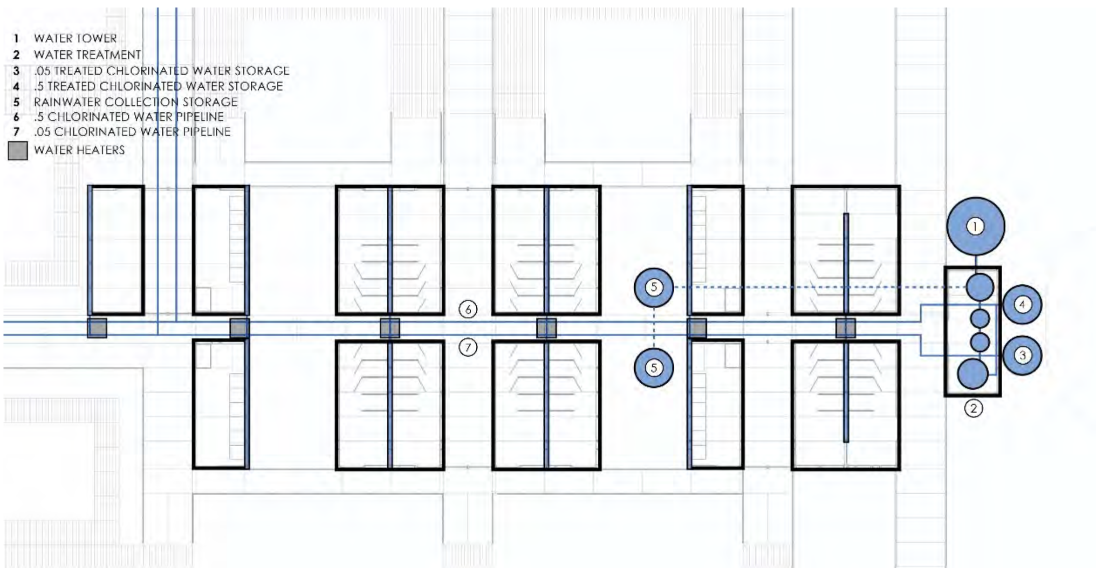



**Figure 9.20: Water System Plan**
Source: Author

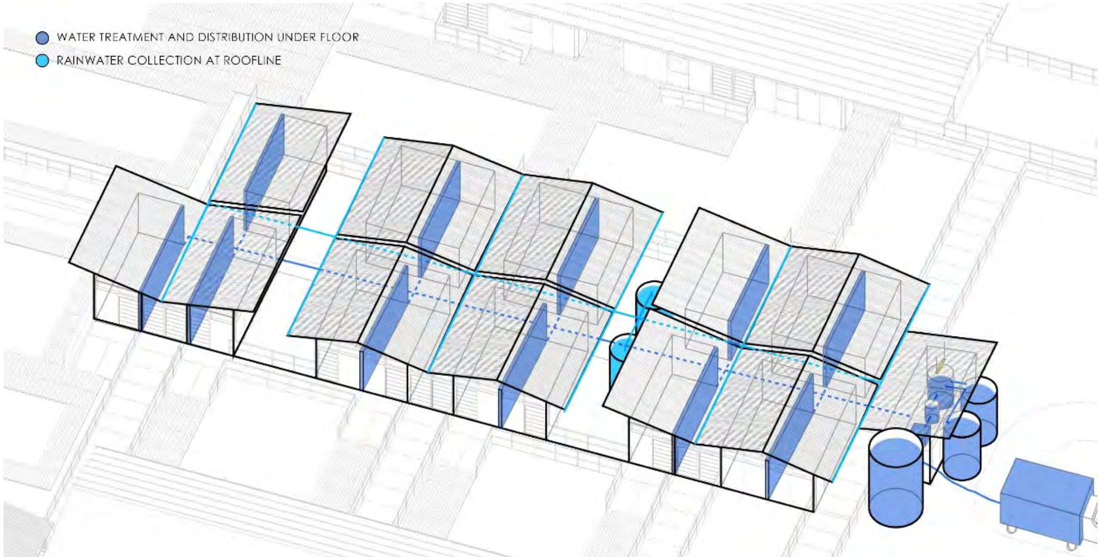



**Figure 9.21: Water System Axon**
Source: Author

**Waste.** The waste system is comprised of liquid and solid waste pipes carrying waste from the village restrooms to storage containers, where it sits and decontaminates until a truck comes to the site to carry the waste to an off-site location. Another waste that is dealt with in the facility is non-human waste, such as materials, objects, or equipment that is no longer needed or is broken. These items are disposed of through an on-site incinerator.

**Electricity.** The electricity system is comprised of solar panels, as well as on-site generators and in urban sites, a utility pole connecting the facility to city power. Since the equator is in the middle of Africa, countries on the North of the equator will place solar panels so that they primarily face South, and countries on the South of the equator will place solar panels so that they primarily face North or optimal sun exposure and collection.

*Conclusion*

In conclusion, the Modular Infectious Disease Village is designed to help distribute a high level of safety, comfort, and care to everyone involved in an infectious disease outbreak. The modular construction implements a quick, high-quality response; Community involvement in prefabrication and construction as well as the circulation and sightlines within the facility develops a sense of trust and ownership between the treatment village and the community, and lastly; The circulation and procedures implemented within the facility creates a sense of health and safety for the patients, staff, and visitors alike. The integration of the facility within the vernacular of the place and the customs of the community is an effort to instill a sense of hope for everyone affected by the hardships of an outbreak.

**Figure 9.22: Modular Infectious Disease Village**
Source: Author

# Glossary

| | |
|---|---|
| Bioterrorism | A situation in which a biological agent is intentionally released to cause illness. |
| Endemic | A disease or condition regularly found among particular people or in a certain area. |
| Epidemic | A widespread occurrence of an infectious disease in a community at a particular time. |
| Outbreak | A sudden rise in the number of cases of a disease. |
| Pandemic | A widespread occurrence of an infectious disease that is prevalent over a whole country or the world. |

# Bibliography


African Vernacular Architecture Data Base. "Democratic Republic of the Congo." Accessed December 13, 2019. http://www.africavernaculararchitecture.com/democratic-republic-of-the-congo/

Ameli, Jonathan. "Communicable Diseases and Outbreak Control." *Turkish Journal of Emergency Medicine* 15, no. 1 (October 2015): 20-26. https://doi.org/10.5505/1304.7361.2015.199702452247316600596

The American Institute of Architects. "Design for Modular Construction: An Introduction for Architects." Accessed December 13, 2019. http://content.aia.org/sites/default/files/2019-03/Materials_Practice_Guide_Modular_Construction.pdf

CDC. "Infographic: International Health Regulations (IHR) Protecting people every day." Global Health. Accessed October 18, 2019. https://www.cdc.gov/globalhealth/infographics/global-health-security/ihr.htm

Chertow, Daniel S. et. al. "Ebola Virus Disease in West Africa — Clinical Manifestations and Management." *The New England Journal of Medicine* 371 (November 2014): 2054-2057. DOI: 10.1056/NEJMp1413084.
World Health Organization. "Democratic Republic of The Congo: Improving Aid Coordination in the Health Sector" Geneva: WHO, 2015. Accessed November 15, 2019.

Climatezone.com. Democratic Republic of the Congo. CIA World Fact Book. https://www.climate-zone.com/climate/congo-democratic-republic/

Deloitte. "Africa Construction Trends Report 2017." Deloitte Touche Tohmatsu Limited, 2017. Accessed November 15, 2019. https://www2.deloitte.com/za/en/pages/energy-and-resources/articles/africa-construction-trends-report.html

Designboom. "SPACE10 + EFFEKT Envision 'Urban Village Project' as a Sustainable, Shared Living Community." Accessed October 15, 2019. https://www.designboom.com/architecture/space10-effekt-urban-village-project-ikea-06-04-2019/

DMS Africa. "Modular Buildings." Accessed December 12, 2019. http://www.dms-africa.com/modular-buildings.html

Doctors Without Borders. "Without Trust of Local Communities, Ebola Response Risks Failure." Accessed November 11, 2019. https://www.doctorswithoutborders.org/what-we-do/news-stories/story/drc-msf-shuts-down-ebola-treatment-center-following-violent-attack

Fenollar, F., and Mediannikov, O. "Emerging Infectious Diseases in Africa in the 21st Century." *New Microbes New Infect.* 26 (Sep 2018): S10-S18. https://doi:10.1016/j.nmni.2018.09.004

"Infectious Disease Outbreaks, Epidemics, and Bioterrorism/ Environmental Health Emergencies." https://www.aap.org/en-us/Documents/proresources_id_outbreaks.pdf

Mack, Alison. *The Ebola Epidemic in West Africa: Proceedings of a Workshop*. Washington, DC: National Academies Press, 2016. EBSCO.

MSF. "Crisis Update – December 2019." Accessed December 9, 2019. https://www.msf.org/drc-ebola-outbreak-crisis-update

The National Academies of Science, Engineering, Medicine. *Global Health Risk Framework: Resilient and Sustainable Health Systems to Respond to Global Infectious Disease Outbreaks – Workshop Summary*. Washington, D.C.: The National Academies Press, 2016. https://www.nap.edu/read/21856/chapter/6#76

The New York Times. "Empty Ebola Clinics in Liberia Are Seen as Misstep in U.S. Relief Effort." Accessed December 12, 2019. https://www.nytimes.com/2015/04/12/world/africa/idle-ebola-clinics-in-liberia-are-seen-as-misstep-in-us-relief-effort.html

NPR. "U.S. Military Response to Ebola Gains Momentum in Liberia." Accessed December 12, 2019. https://www.npr.org/sections/goatsandsoda/2014/11/05/361796044/u-s-military-response-to-ebola-gains-momentum-in-liberia

Nyenswah, Tolbert G. et. al. "Ebola and Its Control in Liberia, 2014–2015." *Emerging Infectious Diseases* 22, no. 2 (February 2016): 169-177. https://doi.org/10.3201/eid2202.151456

Okeke, Iruka N. *Divining Without Seeds: The Case for Strengthening Laboratory Medicine in Africa*. Ithaca: ILR Press, 2011. EBSCO.
Osoro, Eric. "How an Outbreak of Ebola in the Democratic Republic of Congo Was Contained." *Slate*, July 13, 2017. https://slate.com/technology/2017/07/how-an-outbreak-of-ebola-in-the-drc-was-contained.html

Pardis, Sabeti. *Outbreak Culture: The Ebola Crisis and the Next Epidemic*. Cambridge: Harvard University Press, 2018. ProQuest.

Petersen, Eskild; Chen, Lin; and Schlagenhauf-Lawlor, Patricia. *Infectious Diseases: A Geographic Guide*. Hoboken, NJ: John Wiley & Sons Inc., 2017. ProQuest.

Prefabmarket. "How to Tackle Africa's Housing Challenges with Modular Building." Accessed December 10, 2019. http://www.prefabmarket.com/modular-building-africa/

Rapido Recovery. "Rapido." Accessed October 15, 2019. http://www.rapidorecovery.org/

Ross, Philip. "Ebola Death Toll Tops 4,000, Seven Countries Affected." *International Business Times*, October 10, 2014. https://www.ibtimes.com/ebola-death-toll-tops-4000-seven-countries-affected-1703049

The Sphere Project. "The Sphere Project: Humanitarian Charter and Minimum Standards in Humanitarian Response." Southampton: The Sphere Project, 2011. Accessed December 9, 2019. https://www.ifrc.org/PageFiles/95530/The-Sphere-Project-Handbook-20111.pdf

United Nations. "DR Congo Ebola Centre Attacks Could Force Retreat Against the Deadly Disease, Warns UN Health Chief." Sustainable Development Goals. Last Modified March 14, 2019. https://www.un.org/sustainabledevelopment/blog/2019/03/dr-congo-ebola-centre-attacks-could-force-retreat-against-the-deadly-disease-warns-un-health-chief/

United States Africa Command. "U.S. Air Force Airmen Help Construct MMU in Liberia." Accessed December 13, 2019. https://www.africom.mil/media-room/article/23746/u-s-air-force-airmen-help-construct-mmu-in-liberia

USAID Land and Urban Office. "Democratic Republic of Congo." Land Links. Accessed November 11, 2019. https://www.land-links.org/country-profile/democratic-republic-congo/

World Health Organization: Regional Office for Africa. "The Health of the People: What Works—The African Regional Health Report 2014." Geneva: WHO, 2014. Accessed October 16, 2019. https://www.who.int/bulletin/africanhealth/en/

World Health Organization. "WHO Report on Global Surveillance of Epidemic-prone Infectious Diseases – Introduction." Emergency Preparedness Response. Accessed October 16, 2019. https://www.who.int/csr/resources/publications/introduction/en/index4.html

World Health Organization. "Managing Epidemics: Key Facts About Major Deadly Diseases." Luxembourg: World Health Organization, 2018. Accessed October 16, 2019. https://www.who.int/emergencies/diseases/managing-epidemics-interactive.pdf

World Health Organization. "Supporting the delivery of healthcare in the Democratic Republic of the Congo". Emergencies. Accessed December 11, 2019. https://www.who.int/emergencies/crises/cod/news-features/delivery-of-healthcare/en/

World Health Organization Regional Office for Africa. “Standard Operating Procedures for Coordinating Public Health Event Preparedness and Response in the WHO African Region.” 2014. Accessed October 17, 2019. https://www.who.int/hac/techguidance/tools/standard_operating_procedures_african_region_en_2014.pdf?ua=1

You, Jianping and Mao, Qing. “An Improved Ward Architecture for Treatment of Patients with Ebola Virus Disease in Liberia.” *The American Journal of Tropical Medicine and Hygiene* 94, no. 4 (April 2016): 701-703. https://doi.org/10.4269/ajtmh.15-0209