Design Specification for Toilet Blocks

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Executive Summary

Biopolus' project, WaterHubs, is developing a community structure that provides basic needs to individuals living in high-density, low-income global communities. This project aims to design a 3D modular solution for water-based services that incorporates specific design features tailored to meet the personal needs and preferences of users. As WaterHubs seeks to implement a pilot project in India, the team travelled to Mumbai in order to gather information directly from potential users.

In order to determine key design features, existing sanitation solutions were researched and a human-centered design process was established to conduct with users in the Dharavi and Santacruz slums of Mumbai. Methods included receiving guided tours of affected areas, conducting interviews with experts, facilitating focus group sessions with toilet block users, and gathering user feedback on preliminary prototype concepts. Key design features and environmental considerations were extracted from this information in order to develop a final design.

The final design includes a 3D model of a sanitation facility that provides toilet, shower, and laundry services to users while leveraging Biopolus' waste-recycling systems. Selected design features address a range of issues including privacy, smell, and lighting, improving the overall conditions of this community block. In addition, a supplementary implementation guide was developed to outline environmental considerations and critical steps required of WaterHubs, both before and after the block is introduced into a community. A key consideration is to develop the facility as a community based organization to increase the likelihood of acceptance by the users.

It is recommended that future work be conducted to further enhance the design. This work includes determining the feasibility of building the design in storage containers, integrating the design with Biopolus' technology, prototype testing, and investigating other design alternatives.

The 3D model and implementation guide will provide WaterHubs with knowledge of key design features and environmental considerations for a successful facility that maximizes the likelihood of user acceptance. Biopolus will be able to install their pilot WaterHubs project in Mumbai and the design may serve as a template for future initiatives around the globe.

1.0 Introduction

The client, Biopolus, is a not-for-profit research and technology institute based in Budapest, Hungary, that aims to create a higher quality of life for individuals through their innovative water technologies. Their project, WaterHubs, aims to develop a community modular water and sanitation modular infrastructure solution for high-density, low-income communities. With this technology, urban communities will not need to build a water system infrastructure from scratch. Biopolus' goal is to provide WaterHubs to 100 million high-density, urban-slum inhabitants by the year 2035 [1].

Aside from Biopolus, there are many other not-for-profit organizations that work to improve the quality of living to the urban population. One of these organizations is Triratna Prerana Mandal (TPM), based in Mumbai. They deliver a multitude of services to the community including access to public toilets. Biopolus is currently working with TPM to further develop WaterHubs by using their facility to benchmark the design off of.

Working with Biopolus, the University of Toronto (U of T) Capstone design team travelled to Mumbai, India to do further research. Field studies were conducted in two neighbourhoods of the Greater Mumbai area - Dharavi, the largest slum in Asia, and Santacruz (TPM). The findings from these studies are presented in this report and will be used to determine critical design features required in the facility model and to develop an implementation guide of WaterHubs for Biopolus.

1.1 Problem Statement

Currently the urban slums in India lack an affordable solution that can address the issue of basic sanitation needs and access to water in these communities. Furthermore, there is a lack of sustainable solutions to address the operations and maintenance of these facilities. Biopolus is trying to address this issue through their development of the WaterHubs infrastructure. However, they are requesting the service from the U of T Capstone team to help design WaterHubs modules that meet these growing needs of India's communities. Biopolus needs the design team to develop appropriate design features and implementation techniques for these modules in order to further improve the lives of thousands.

1.2 Scope

Biopolus would like to work with the U of T Capstone team on their WaterHubs implementation in India. The toilet sanitation module will incorporate respective defined user-centered design features to increase the likelihood of user acceptance. To accurately design these modules, the capstone design team conducted an industry analysis related to these needs alongside user

interviews and field observations in the Dharavi and Santacruz urban slum environments in India. This Final Design Specification report will include the 3D final design prototype and implementation guidelines.

2.0 Literature Review

Prior to the development stages of design, it is important to gain a comprehensive understanding of the existing sanitation solutions in India as well as the results of sanitation improvement studies by nonprofits that is outlined in this section.

2.1 Current Sanitation Solutions

While having access to clean, private, and safe toilets is important to many living in slums, building more toilets is only the first step of the solution. Appropriate education on hygienic practices in communities is needed to attempt to change the cultural perception of open defecation.

2.1.1 Private Toilets

From a physical toilet standpoint, the most convenient solution is for individuals to have a private toilet installed in their home. In many densely crowded regions of urban cities, there is simply no room for a toilet to be installed in a home. A larger problem is that users simply do not aspire to own a private toilet. Construction of these toilets is seen as the government's responsibility [3]. For low-income families, there are other financials burdens that take priority over the cost of constructing a private toilet. In response to this, the Ministry of Urban Development of India developed an incentive program where a household would receive Rs. 4,000 for the construction of a toilet, on top of what the state may already pay (Rs. 2,000 would be provided up front for the construction itself and the additional Rs. 2,000 would be provided after proof of the facility was sent to the government) [4]. To many who do not prioritize their defecation needs, this additional cash incentive is used otherwise. For example, some reports discuss how individuals may convert their newly constructed toilet facility into a small store. At this point, a potential profit is more enticing than a toilet if, in their perspective, defecating in the open is an acceptable alternative [5].

From a community engagement standpoint, the Indian Government created a campaign called 'No Toilet, No Bride' [6] that encourages women in India to ensure that their future husband has a toilet installed in their home prior to getting married. While some western reporters describe this as a bizarre approach to addressing this issue, it is a sensible one. If women want to feel truly safe, being able to relieve themselves in private is ideal. This then allows the entire household to have access to one toilet and have ownership over the sanitation of it. However, an ideal solution is not always a realistic one. Solutions still need to be provided to women and children who do

not have access to toilets. The reality is that there isn't enough room in slums for every single home to have access to a toilet.

2.1.2 Government Toilet Blocks

On January 1st, 1995, the Government of India introduced the Slum Rehabilitation Scheme (SRS) [7] which classified slums into notified or non-notified. The notified slums are formally recognized by the government and have access to government services including access to water and slum-improvement initiatives. The non-notified slums are perceived to be illegal and those residing in these areas do not have a right to their land and could be evicted at any moment. As of 2012, 59% of slums in India were non-notified [8]. Non-notified slums receive far less assistance than the notified ones.

In the Mumbai region, the Brihanmumbai Municipal Corporation (BMC) assists on a municipal level and the Maharashtra Housing and Development Authority (MHADA) provides help from the State government. MHADA's Slum Improvement Board was one of the first governmental agencies to begin constructing toilets in the slums of Mumbai. The toilets constructed were entirely free for use but most of them lacked water, electricity, soap, sinks, appropriate ventilation and adequate sewage disposal [7]. In order to use the facility, individuals were required to bring their own water container from other sources. Many of these toilets were also built using a pit system which required the pit to become 'desludged' by hand, posing serious health risks to the individual in charge of this task. for In 1997, the BMC implemented the Slum Sanitation Programme funded by the World Bank [7]. This was an improvement to the MHADA's toilet system. The BMC has an official recommendation of 1 toilet per 50 people (and other researchers even recommend 1 toilet per 20 people [9]) but in reality, this ratio is much closer to 1 toilet per 500 people or 1 toilet per 1,500 people [7]. It implemented a demand-based model rather than a supply-based one. By working alongside the communities, they were able to accurately understand the requirements of each slum pocket.

2.1.3 Non Governmental Toilet Blocks

Governmental facilities are certainly not the only types of toilet blocks that are found throughout the country. Many nongovernmental organizations have constructed toilet blocks in communities and these are operated on a pay-per-use system, as opposed to the governmental facilities which are typically free. Through various articles and publications online, it has been cited many times where users express their willingness to pay a nominal fee in order to use a clean and safe toilet facility. These facilities often hold higher standards and offer water and electricity to the users. Families are beginning to understand how by paying a nominal fee, they end up saving money in the long run by reducing other major family fees like doctor expenses from resulting health issues [10]. The cost of these facilities typically ranges from Rs. 2 - 5 [7]. Some facilities also

offer free urination for men and women, but ultimately the overall pricing structure is different for each facility.

2.1.4 Results of Poorly Maintained Facilities

From a resident's perspective, there is little to no interest as to whether a facility was developed by a governmental or nongovernmental agency. As long as the conditions are kept up to a decent and manageable standard, the facility is deemed to be 'useable'. A drastic instance that exemplifies the poor conditions some toilet blocks are left in came from an instance of a toilet block in Mankhurd in 2015. In an attempt to sanitize the toilet, community members would pour acid down the porcelain bowl. Without them knowing it, this would erode the bowl and the foundation underneath. Kalpana Pingle, a 45 year-old woman, went to use the toilet when the floor collapsed underneath her and the feel into the septic tank below [11]. After four hours were spent attempting to rescue her from the 8-ft septic tank, she was unfortunately pronounced dead at the scene. This is not the first report of an individual falling into a septic tank. There have been numerous reports of children falling into the septic tanks underneath as well [12][10]. This raises a key problem when trying to teach children about proper sanitation practices. How can a child be taught about appropriate techniques when they are also being told to practice open defecation due to their safety? During a key development stage of their growth, they are being taught two contradictory ideas. There should be a safe solution for children that enforces hygienic practices.

2.1.5 Eram Scientific - The eToilet Solution

Eram Scientific has developed India's first self-cleaning, electronic public toilet [13], as seen in *Figure 1*. The toilet itself is programmed based off the usage time of a user. If the user spends more than 3 minutes using the toilet, 1.5L is used to flush the contents. If the user spends more than 3 minutes, 4.5L are used. For every 5 or 10 users (depending on how it is programmed), the toilet will perform a full wash cycle of the unit. The single unit design allows the system to fit in the pockets of a slum where space is available. The platform is slightly lowered, as seen in *Figure 2,* in order to allow the entire squatting plate to be rinsed as opposed to simply the contents inside the bowl itself. The hose is also used inside the facility allowing users to use a more sanitary practice than rinsing themselves using their hand and a bucket of water. It only requires 2-4 hours of installation per unit. It operates and unlocks when a user inserts a coin into the unit. The eToilet is a recipient of the Bill and Melinda Gates Foundation Reinvent the Toilet Challenge.


[14]

Figure 1 - The exterior of the eToilet


[15]

Figure 2 - The interior of the Eram Scientific eToilet. The platform itself is lowered to allow the top of the squatting plate to be rinsed on each flush.

2.2 Sanitation Improvement Studies

The design team found several studies that investigated the current sanitation situation by interviews with users of public toilets in parts of India. Two studies stood out from the rest which heavily used human factors methods and were useful for the design team to understand before travelling to India to conduct similar studies. The design team incorporated recommendations from these studies into the final design prototype and implementation guide.

The first report that was reviewed was called 'The Potty Project', which is a paper that reports on the behaviours, attitudes, and beliefs surrounding sanitation in 5 low income urban cities across India. The project analyzed 4 areas; defecation behaviour, toilet infrastructure, health and hygiene, and property rights [5]. The document consisted of findings that could be shared with potential stakeholders interested in innovating designs in this domain. The design team used these findings to gain an understanding on the cultural barriers and preferences within the communities in low-income, high-density areas of India.

Another document that was reviewed was a collaboration from IDEO and the Bill Gates Foundation which served to public officials, designers, and academics [16]. This study consisted of results from interviews with over 100 users as well as staff, government official and sanitation experts. This study provided design insights to consider to account for when designing future sanitation solutions for low income high density areas. To name a few areas, the report covers plan for maintenance, design for cleanliness, picking a good location, and creating privacy. The design team incorporated recommendations from this study into the final design prototype.

A study conducted by the Observer Research Foundation Mumbai stresses the importance of community ownership and the involvement of women in the design process [17]. This study included a questionnaire that the design team utilized during the field study in India. This report also provided additional environmental considerations to incorporate into the implementation guide.

2.3 The Human-Centered Design Approach Advantage

A human centered design process can be used to tackle a wide range of design problems. IDEO, a global innovation firm, has launched The Field Guide to Human-Centered Design [18]. This toolkit was developed to be used for problems around design in the social sector, and can be used to create solutions that will appeal to and be accepted by the community. Using the human centered design approach allows designers the chance to interact with communities in order to create innovative solutions that address the user's requirements. The approach revolves around believing that the users themselves hold the key to the answer to their problems and there are three main sections; inspiration, ideation and implementation. The inspiration phase involves the collection of data from users and the various methodologies surrounding it. The ideation phase outlines how this key information will be extracted from the collected data in order to develop solutions to meet user requirements. Lastly, the implementation phase defines the steps required to support the project coming to fruition. In many cases, it is important to get the feedback from the users who are directly affected by the problem, as they generally will have the best ideas to solve that problem. The process involved heavy iteration, as it involves acquiring constant feedback from the users involved in the design process and constantly improving the design to better suit the user's needs. Human centered design involves heavy collaboration, and create a positive impact.

The design team will be using tools provided in this guide and methodologies from the Industrial Engineering curriculum at the University of Toronto to prepare the final deliverables for Biopolus.

3.0 Field Study Overview

This section outlines the design team's trip to India including what was studied and a summary of the primary observations made on the trip.

3.1 Trip Overview

The team travelled to Mumbai, India in November 2015 to visit sanitation facilities existing in current high-density, low-income urban areas. On the first day (November 17th 2015), the team visited government officials in charge of implementing sanitation infrastructure in Mumbai. After interviewing the officials, the team was guided to visit Dharavi, Asia's largest slum. This site visit primarily consisted of observations, and some interviews with the users. On the second day, the team visited the TPM facility in Santacruz, India. The day was mainly spent understanding TPM operations, and talking to facility managers and subject matter experts on the topic of sanitation facilities. On the third and final day, the team went back to TPM to conduct focus group sessions with male and female users of the facility to gather design requirements.

Interviewing the government officials, users, and facility managers provided the team with insight not only on the design requirements, but also on their general lifestyle. Most residents in these areas lived in extremely small rooms with 4-8 other family members. The residents did not have space to build a toilet in their homes, and if they were given the space, they would have utilized it for starting a shop to do work in and earn money. In Mumbai, the ratio of people to one toilet is approximately 1 to 300 [19]. During peak hours such as the morning, approximately 12,000 additional toilets are required to effectively serve the area's population. Over the course of the trip, the team learnt various design requirements and preferences that will be incorporated into the final design prototype and implementation guide.

3.1.1 Day 1 - Field Studies, Dharavi

On November 17th 2015, the University of Toronto design team conducted interviews with three municipal government officials in charge of the toilet infrastructure facilities in Dharavi. The day began with an hour and a half formal interview in which the design team to gain an in-depth understanding of the government's role to the area and prevailing issues that residents face (Appendix A). A translator was present during this interview and for the rest of the day. Following the interview, a three hour guided tour of Dharavi began and was led by government officials. While visiting this area and seeing both non-profit and government sanitation blocks, interviews with residents took place. These varied from one-on-one interviews to group discussions. Through speaking with users first hand, the design team was able to conceptualize a

preliminary user-experience map for a user who did not have access to a private toilet and used a nearby sanitation block.

Figure 3: The design team receiving a guided tour through Dharavi

3.1.2 Day 2 - Field Studies, Triratna Prerana Mandal, Santa Cruz

After seeing the conditions in Dharavi, the following day (November 18, 2015) was spent seeing a different area of Mumbai, Santa Cruz. The main purpose of the visit to this location was to benchmark an existing sanitation facility, Triratna Prerana Mandal (TPM), that also delivered a range of community services to residents in the nearby area. This was a successful example of a multi-purpose facility, something WaterHubs is striving to achieve. The day was spent understanding how the facility works and how it came to be. This was done through a guided tour for an hour and a group expert interview that was four hours in duration. The experts consisted of the president of the facility, a partner and a government official who had spent tremendous amounts of time building the community-based-organization from the ground up. Notes of this interview can be found in Appendix A.

Figure 4: The design team interviewing TPM facility managers

3.1.3 Day 3 - User Study, Triratna Prerana Mandal, Santa Cruz

It was critical that the user study was developed to ensure users felt comfortable enough to talk about their preferences and critiques as the design team had not been in the community long enough to establish a sense of trust with the residents. In order to learn user needs from members of the community in an interactive way, a task was designed to better understand how facility users prioritize different potential design aspects of a sanitation facility. After benchmarking the sanitation improvement studies mentioned in section 2.2, the team developed a study that involved users collectively working together as a group to prioritize and rank different features of a sanitation facility. This information helped the design team create a list of attributes that could be incorporated in the facility. As a group, community members discussed and debated on the various components ranking the attributes. To accommodate for the language barrier, attributes were represented by universally understood symbols on a piece of paper and were explained to the users through a translator. This translator aided in moderating the discussion and explaining what was being discussed at each decision stage.

Two groups were interviewed separately. One group for men consisting of six male participants and one group for women consisting of six female participants. All participants were members of the local community who used the TPM facility on a regular basis and are exposed to other sanitation blocks in India.

In the activity, users were first asked to reflect on their experience using the toilet facilities provided by TPM and any other facility they may have used recently. The sticky notes were then laid out across a table for them to see. Each attribute was explained to the user to ensure they understood what each attribute meant. Users were then asked to discuss with each other and rank the attributes from most important to least. At the same time, the translator was asked to provide the design team with the commentary of the participants. This was done so that the design team could better understand the thought process and reasoning of the participants. The participants were also reminded to base their decisions off of current facility and other facilities they have used. Follow up questions were then asked based on the user's answers. The questions asked and responses from both users groups can be found in Appendix B.

Figure 5: User study with the female participants

Figure 6: The design team with some of the female participants of the user study

Figure 7: Design team interviewing more users of the TPM facility

3.2 Primary Observations

The high-level primary observations from the field study that drove the design decisions are presented in this section. Further details are outlined in design sections 4.0 and 5.0 in the document.

3.2.1 Primary Differences Between Sanitation Blocks

The sanitation facilities in India are owned by either the government or non-profit 3rd party organizations. The difference between the two is that the non profit organizations will charge users a nominal fee to use their facilities. In Dharavi, there were 150 free sanitation plots from the government and 130 pay per use sanitation plots. The team saw both of these facilities in Dharavi. The government facility generally had dirt and waste present in many of the stalls, while the facility that charged per use and was operated by a non profit organization was cleaner than the government facility. The caretaker was not initially present at either of the facilities, however the caretaker for the non-profit organization showed up a few minutes after the team was there.

The TPM facility in Santacruz is also operated by a non profit organization, however it was much more developed in comparison and served other functions for the community such as a daycare, and computer classes for the youth. This is why the team spent two days at the facility to understand its operations and unique features to be able to use the facility as a benchmark for the design. This facility was the cleanest that the team saw during the field study, and had mainly positive feedback from its users. The caretaker was also always present at the site and was seen interacting with the users.

3.2.2 Importance of Community Involvement

Upon gathering and analyzing all findings from Mumbai, the design team realized the importance of how a sanitation block is maintained and perceived to a community. A structure may always be built, and it may have applicable design features, but if it is not respected by the community and there is no sense of responsibility for the structure, it won't be used and will fail to provide a sanitary benefit to those who could use it.

Through discussions with facility managers and subject matter experts, the design team determined that an implementation guide should be created to complement the design. Many of discussions were about how facilities grew to be successful and who was involved in the process. It was observed that successful facilities were the ones that were operated by a non profit organization, consisting of members from the community itself. The implementation guide will detail the importance of allowing all stakeholders to participate in the design of the community block. Increasing community participation from the construction phase increases the value of WaterHubs to the community and helps to ensure good community use and buy-in.

3.2.3 Water Sources

The guided tour through Dharavi and Santacruz provided a lot of insight into the surrounding issue of the lack of water supply. For example in Dharavi, a large majority of homes that have toilets that are not connected to the underground sewage system but rather an open sewage system. This is a notorious problem for slums and a leading contributor to the spread of diseases within urban slums.

In addition to the lack of sewage connections, water only runs for a limited portion of the day (approximately 2-3 hours). Both residents and toilet blocks in these areas have to collect as much as possible in this time frame in order to have enough water supply for the day. Figure 8 provides a good example of how the collected water is stored. If they cannot collect enough water, other sources are explored such as water tankers, rainwater or water wells. However, there can be many issues with these sources such as the water tankers being too expensive, rainwater is not guaranteed and the water well could be drying up. In order to ensure the facility has enough water supply for the day, it should be located near municipal water lines.

Figure 8: Water Barrel Used To Collect Water For Toilet Block In Dharavi

3.2.4 Design Attributes

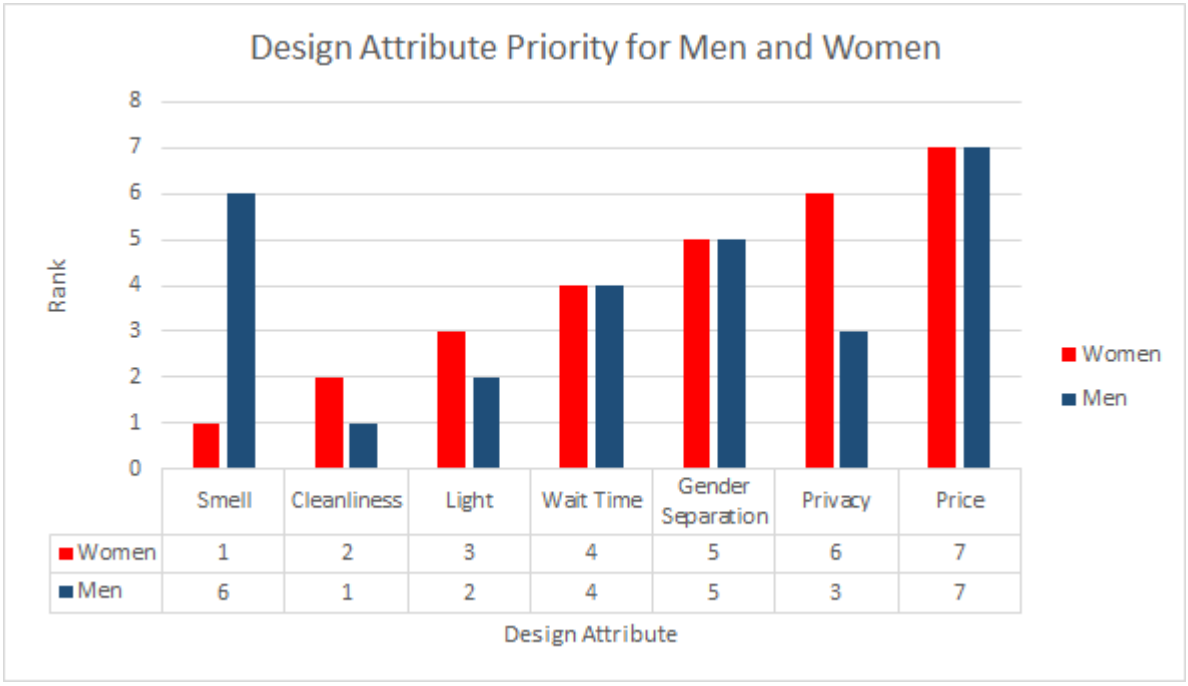

Figure 9: Priority Ranking of Attributes For Both Men And Women From The User Study

Women ranked 'smell' as being the most important factor while men ranked cleanliness as the most important. Although there isn't much discrepancy on cleanliness as women ranked that as their second choice, there are other startling differences in this list. It is inherent that a user would rank a design attribute as being the most important if they have often encountered

facilities that do not embody that attribute to the best extent. Women noted that they often have to use toilet blocks which have poor circulation. Even at facilities that are perceived as clean by users, such as TPM, this is a common complaint among women. They emphasized that TPM is much cleaner than other facilities they have visited or used in the area.

Men likely prioritized smell lower for three reasons: 1) They may not encounter an issue with smell often, 2) They often use the urinal rather than the individual toilet stall and 3) TPM has a modified system that increases the flow of water to rinse urine down the drain from urinals which reduces the odour.

Most other attributes had a similar ranking between men and women, however privacy stood out as a differentiator. It was expected that women would prioritize this feature much higher than men due to cultural constraints and the fact it is unsafe for a women to openly defecate in public. At TPM, women have private stalls while men can be seen from the street at the urinal if one looks closely. The team considered these results from the user study when developing the final design prototype.

4.0 Design of the Sanitation Block

The first part of the proposed design includes a 3D model of a sanitation block that incorporates toilet, shower, and laundry services. This section outlines the design prototype and explains the design features incorporated into the design.

4.1 Design Blueprint

The University of Toronto design team has built a 3D design using Google Sketchup to incorporate all the design features for a recommended solution tailored to the Mumbai region. There is one design for a male sanitation block and one design for a female sanitation block. The images this section show different views of the model. Some structural features of the model have been hidden to give a better perspective of the model. As the ratio of people to one toilet is approximately 1 to 300, it is estimated that the proposed sanitation block will be able to serve a community of 8700 people.

4.1.1 Model Overview

The overall sketch was modelled using 20 ft and 10 ft storage containers. The storage containers have standard dimensions. Using L x W x H convention, a 20 ft container is 8’ x 20’ x 8’ 6” and a 10 ft container is 8’ x 10’ x 8’ 6”. The overall footprint of the design is 40.5’ x 36’. These dimensions are based off of the overall footprint of the facility including the caretaker area. Dimensions for facility toilets and showers were benchmarked off of existing facilities. The individual block sizes are as follows:

Female Toilet Block: Two attached 20 ft containers joined lengthwise

Male Toilet Block: Two 20 ft containers joined lengthwise
Shower Blocks: One 10 ft container each
Biopolus Technology: Three 20ft containers
Office Space: One 20ft container

Figure 10: Aerial View (Roofs Hidden)

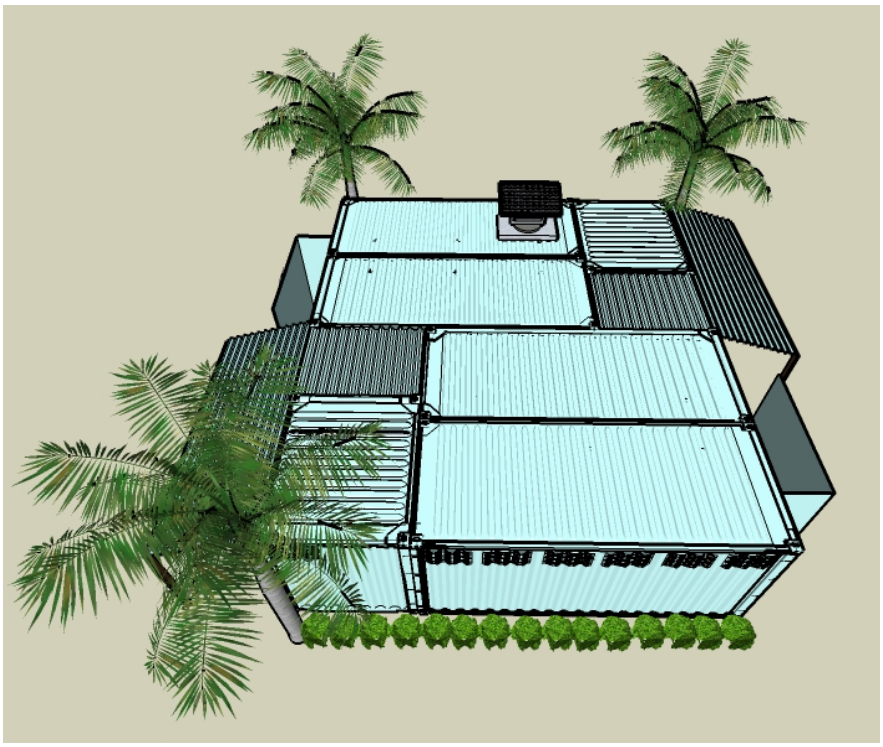

Figure 11: Aerial View (With Roofs)

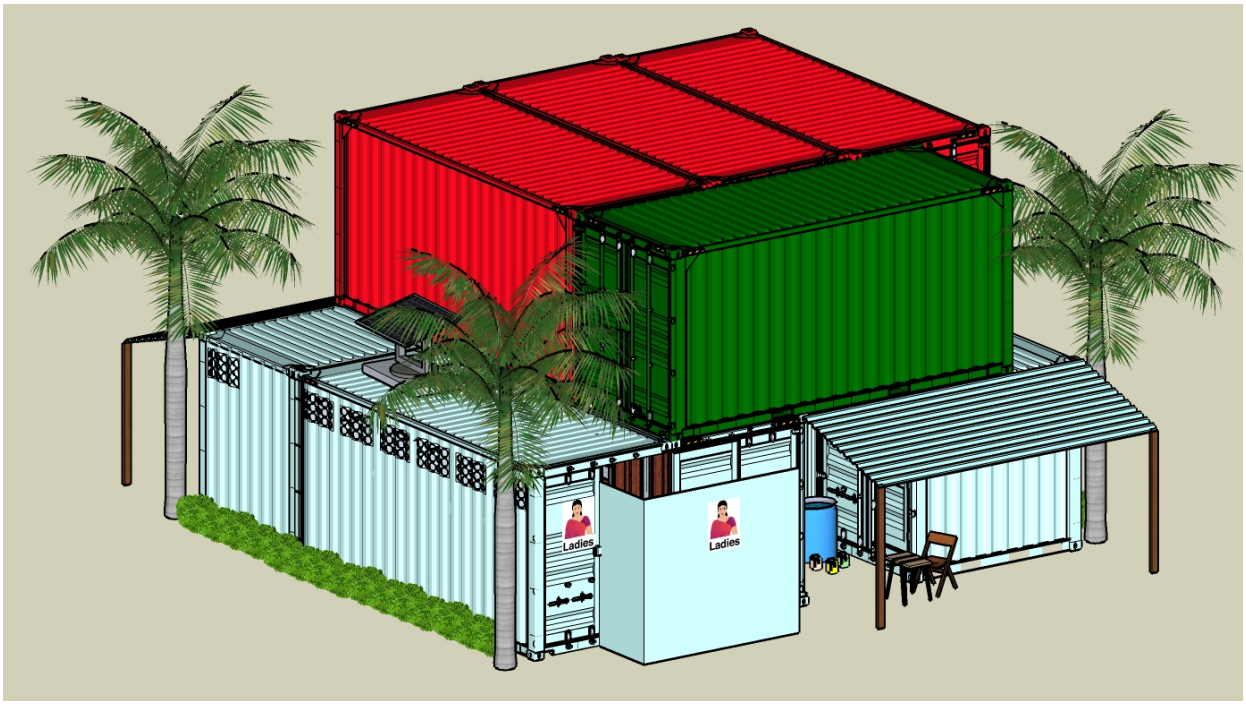

Figure 12: Aerial View With Containers Accommodating for Biopolus Technology And Office Space

4.1.2 Female Toilet Block

The female sanitation block entrances is located on the opposite side of the male sanitation block as seen in Figure 10. Dimensions for the entrances can be seen in Figure 22. The dimensions of the toilet stalls for the handicapped and regular stalls can be seen in Figure 16 and the dimensions are listed in Table 1. There are 10 regular stalls, 1 handicap stall, and 1 sink in the female toilet block.

Table 1: Toilet Stall Dimensions

Handicap Stall Dimensions Stall Width -39” Sanitary Waste Bin Height - 48” **Regular Stall Dimensions** Stall Width - 36” Sanitary Waste Bin Height - 66” **Entrance Dimensions** Entrance Width - 109” Entrance Depth - 44” Entrance Height - 99” Entrance Opening - 41”	**Overall Block Dimensions** Sink Wall Width - 37” Sink Height” Window Height - 36” Window Height from Ground 80” Window Width - 31” Door Height - 89” Door Width - 32” Outer Stall Height - 97” Inner Stall Height - 86” Left Side Stall Length - 231” Right Side Stalls Length 190” Stall Depth - 53”

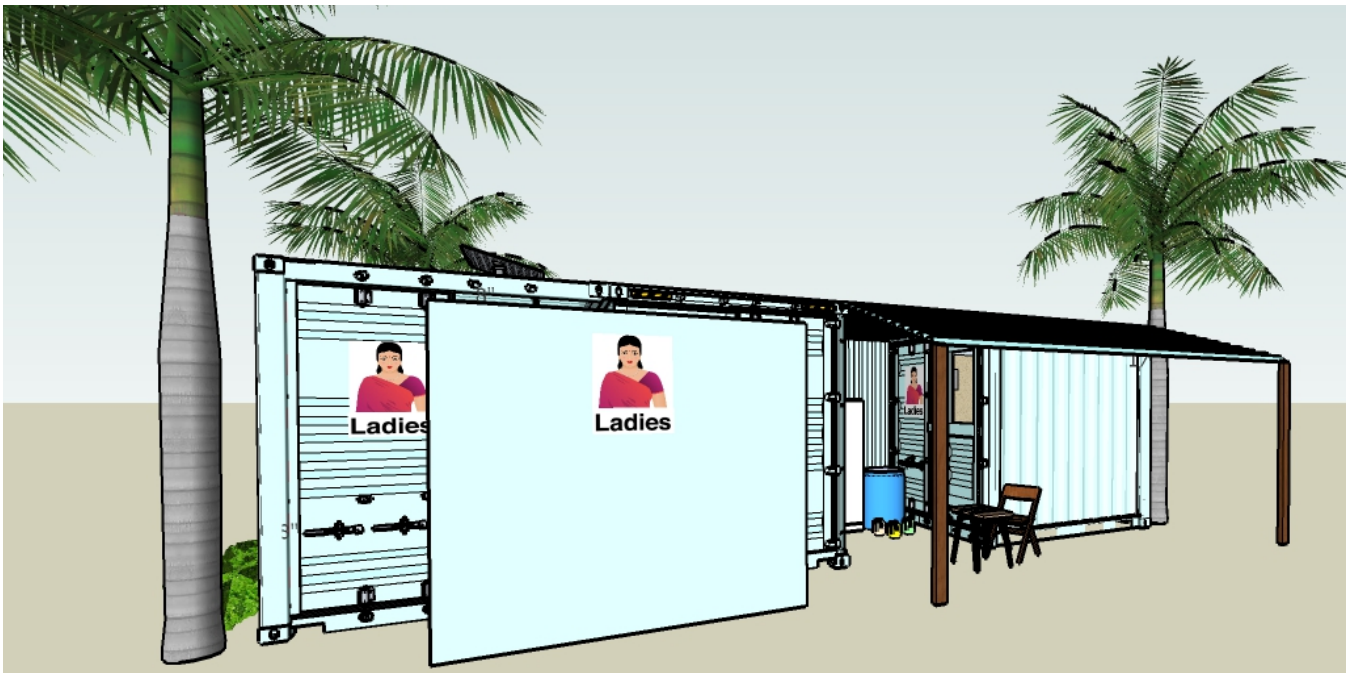

Figure 13: Outside Female Block

Figure 14: Inside Female Block View 1

Figure 15: Inside Female Block View 2

Figure 16: Women's Handicap and Regular Stalls

4.1.3 Male Toilet Block

The dimensions of the male toilet stalls are similar to the female toilet block. The male toilet block has 3 regular stalls, 1 handicap stall, 3 sinks, and 12 urinals. Additional dimensions can be found in Table 2.

Table 2: Male Toilet Block Dimensions

Handicap Stall Dimensions Stall Width -39" **Regular Stall Dimensions** Stall Width - 36" **Entrance Dimensions** Entrance Width - 109" Entrance Depth - 44" Entrance Height - 99" Entrance Opening - 47"	**Urinal Dimensions** Urinal Width - 15" Urinal Height - 30" Urinal Length -18" Total Urinal Length - 231"	**Overall Dimensions** Sink Wall Width - 75" Sink Height - 41" Window Height - 36" Window Height from Ground 80" Window Width - 31" Door Height - 89" Door Width - 32" Outer Stall Height - 97" Inner Stall Height - 86" Left Side Stall Length - 231" Stall Depth - 53"

Figure 17: Outside Male Block

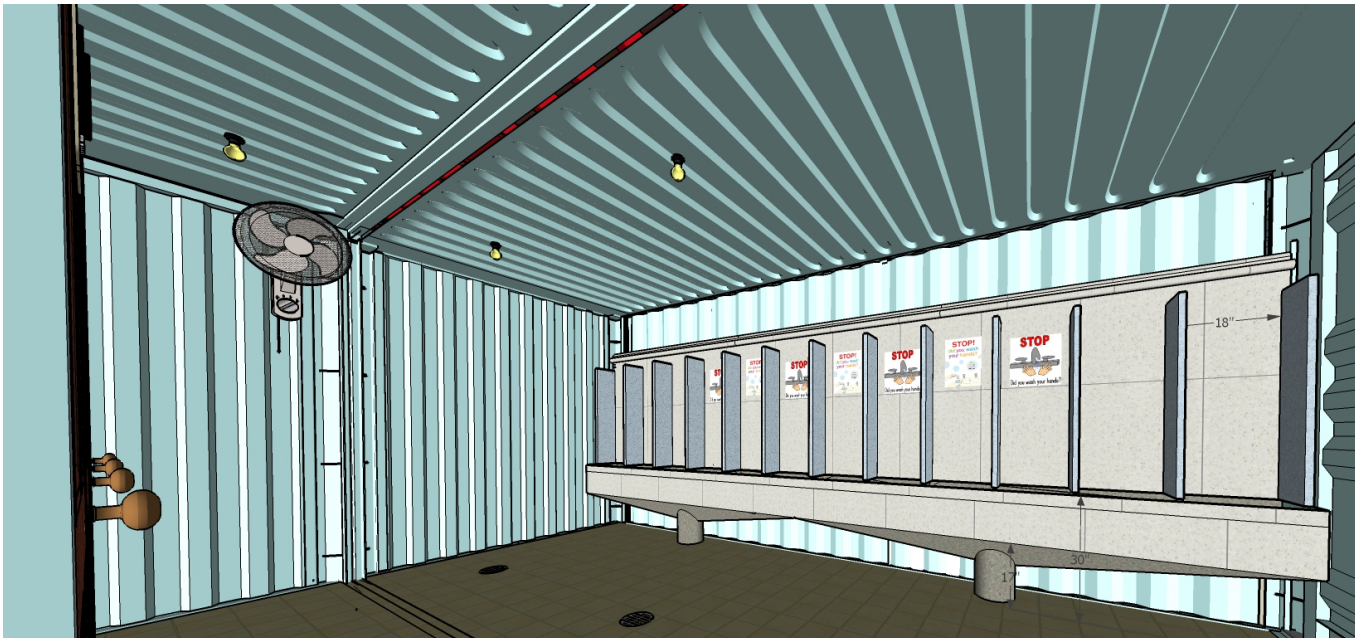

Figure 18: Men's Urinals

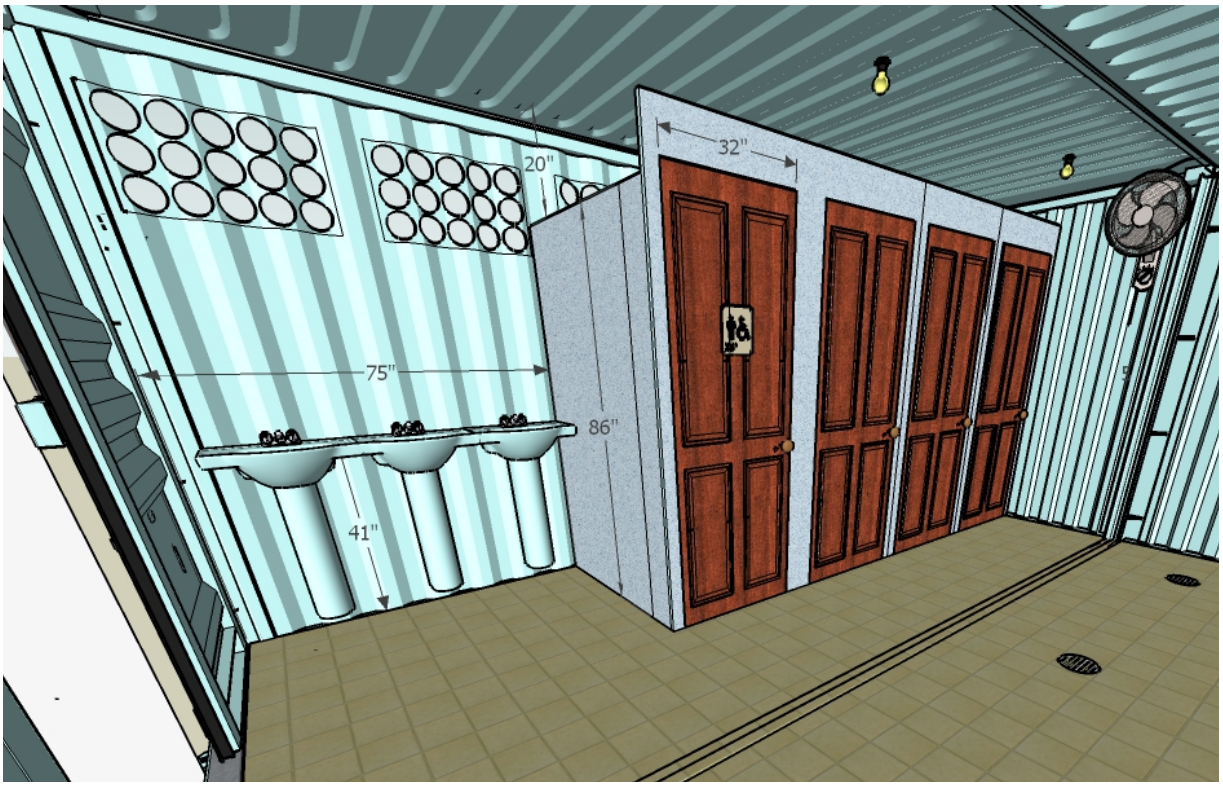

Figure 19: Mens Toilet Stalls and Sinks

4.1.4 Shower Block

Showers for both men and female are located next to their toilet blocks in 10 ft containers. A space between them is provided for the caretaker to store their cleaning materials and for users to collect water as seen in Figure 21. The stalls are the exact same for both men and females. The dimensions can be seen in Table 3.

Shower Stall Dimensions	**Overall Dimensions**
Stall Width - 52”	Door Height - 47”
Inner Stall Height - 86”	Outer Stall Height - 97”
Stall Depth - 53”	Total stall Length - 111”
Stall Ledge Height - 4”	Entrance Width - 32”
	Window Height from ground - 81”
	Window Width - 30”

Figure 20: Shower Stalls

4.1.5 Caretaker Area

The caretaker area has a closet to store cleaning materials, chair and table to sit at, shelter for cover, and a water barrel for users to collect water. Dimensions of the area can be found in Table 4.

Table 4: Caretaker Area Dimensions

Storage Area Dimensions	**Shelter Dimensions**
Storage Height - 109”	Shelter Width - 195”
Storage Width - 73”	Shelter Depth - 75”
Storage Depth - 91”	Shelter Height - 85”

Figure 21: Caretaker Sitting and Storage Area

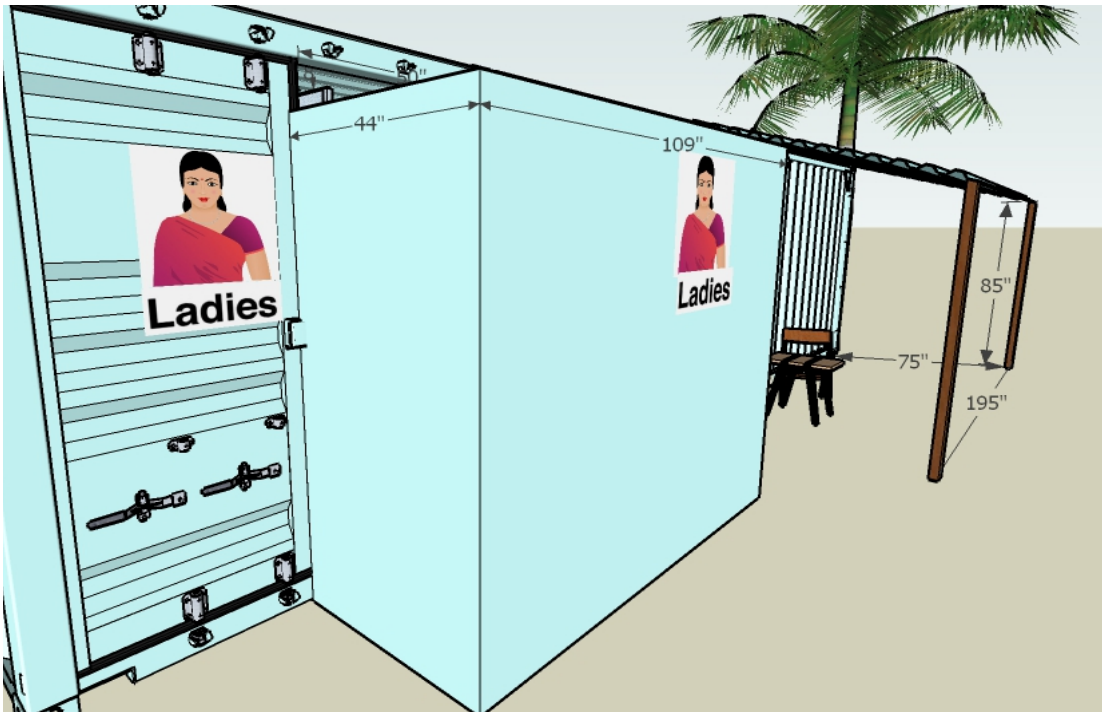

Figure 22: Dimensions of entrances and Caretaker Shelter

4.2 Design Features

Features were designed for the design attributes that were introduced to the users in the user study. This section explains the features and the significance of the features incorporated into the 3D model. Additional design considerations that were explored but not incorporated into the design can be found in Appendix C.

4.2.1 Cleanliness

Cleaning Equipment Available

Users will tend to remember which facilities are clean so they can use them in the future [16]. When users have an issue with the cleanliness of the facility, they should let the caretaker know so that it can be dealt with right away. There should be a caretaker at the facility that is responsible for maintaining the site [5]. The caretaker should clean the facility at least twice a day. In order to design for this, cleaning equipment should be stored where it can be accessed by the caretakers. The cleaning closet is located in the design behind where the caretaker sits as seen in Figure 21. The closet should be locked when the caretaker is not using it to prevent theft of the materials.

Boundaries

Another key aspect of the design is to create a distinct boundary surrounding the facility to separate the zone and create a clean space as seen in Figure 12 [5]. The team observed that garbage around the facility could cause a perception that the facility itself was dirty, or that users could leave a mess in the facility itself. The caretaker should also control what gets brought into the facility by stopping anyone with alcohol bottles or anyone that is smoking at the time.

Easily Sanitizable Materials

Other design features to consider are to use materials such as porcelain and metal that are easily sanitizable to reduce buildup of dirt. There also needs to be an area that can be accessed by the caretakers that stores all of the cleaning equipment. However, education needs to be delivered to the caretakers and to the facility managers on the hazards of certain cleaning equipment.

Drains

Users reported that during the rainy season, the hallways would be covered with mud and dirt that was brought in from people entering from outside. Users said that when there is sufficient water available, they use it to wash out dirt in the facility before they use it, which also keeps the facility clean. The design incorporates drains in the hallways for each storage container as seen in Figure 14 so that the water that is used to clean the facility will be washed down the drain.

4.2.2 Hygiene

Promote Safe Practices

Although hygiene was not something that ranked as important to the users, it is still important to incorporate design features that will create a hygienic environment. First and foremost, it is important to promote safe practices. Users will tend to emulate what they see others doing if they see that there are benefits to it [16]. Therefore, the design includes posters placed in both the men's and women's washrooms to encourage hand washing and inform them of the diseases that can be prevented as a result (see Figure 18).

Sanitary Waste Bin

In Dharavi, women would dispose of sanitary napkins by throwing them down the toilet. This would obstruct the sewage pipes. The TPM facility had tried several options for the placement of a garbage can in the stalls. When placed on the ground, it was found that women complained of being able to see inside the bin. Without a liner, the caretakers had difficulty keeping it clean as the garbage bins were sometimes knocked over by the women. Currently, the facility keeps the garbage bin attached to the wall at a height where most women can not look in as seen in Figure 1 in Appendix C. In the design, the bin is placed at a height of 66 inches (5.5 feet) as seen in Figure 16, so that women can reach up to dispose of their napkins. This solution will also increase awareness of proper waste disposal [17] [5].

Handwashing Stations

Handwashing stations should be placed in an area that is easily accessible for the users when they have completed using the toilet. The handwashing station in both the men and women's blocks are not in direct line of sight from the entrance. There is 1 wash basin in the women's stall (see Figure 14) and 3 wash basin's in the men stalls (see Figure 19). It was found that there was a high traffic of men coming in and out of the washroom, so a greater number of hand washing stations is required. The handwashing stations are located close to the entrance/exit of the facility so that the users are reminded to use it when they are leaving the block.

4.2.3 Privacy

Entrance Visibility

Defecation is regarded as a private, personal act. The design should allow users to use the facility with the highest level of privacy, without disturbance from others. It is important to choose a location to address safety concerns. The facility should be located in an area that the users feel familiar with, and isn't too secluded [17]. The main entrance should also not be placed within a direct line of sight from the street, and can be surrounded by shrubs to prevent visibility. An example of this can be seen in Figure 2 in Appendix C. In the design, the entrance is blocked by creating a walkway that requires the users to enter from where the caretaker is seated, this walkway prevents any visibility inside the facility from the street (see Figure 10).

Windows

In the design, the windows that are placed to circulate air are at a height of 80 inches (6.67 feet) as seen in Figure 16, this is high enough so that women don't feel like anyone can look in. The windows are also designed as small openings, so that outside users can not throw things in or climb inside.

Locks

Even though the gates to enter the washrooms remain open, each stall in the washroom needs to have a door and lock. Simple deadbolt locks installed for each stall can be seen in the design as women and men users noted that they always use the lock on the door.

4.2.4 Gender Separation

Separate Entrances

Both men and women users agreed that entrances to their washroom should be kept separate. Women noted that they felt safe at TPM because they never had any problems with the men in the area. The 3D model has two separate walkways leading to the separated men's and women's facilities as seen in Figure 10. The caretaker needs to be situated so that he can collect money from both sets of users. In the design, there is a separate caretaker for the women's facility and a separate caretaker for the men's facility. The design also considers that there should be no visibility for one gender to see inside the facility of the other gender. As women prefer to not be waiting in line next to women [17], the entrances distant from one another in the design.

Culturally Significant Signage

Aside from that aspect of gender separation, it is also important to incorporate design features that make the facilities suit each gender. One thing that was noted that signage for men and women was not the western washroom symbol, instead the symbol replicated the face of a woman or man, as can be seen in Figure 2 in Appendix C. The signage used in the 3D model can be seen in Figures 13 and 17.

Mirror for Women

Subject matter experts commented on how women would like to have a mirror in the facility to check themselves. In order for the toilet area to not get crowded, a mirror would need to be placed in a separate and private area. It was noted that women would not use the mirror if it were placed outside since they don't want the public watching them look at them self. In the design, the mirror is placed at the handwashing station, which is separated from the hallway and entrance as seen in Figure 14.

4.2.5 Light

Lit facility

Users prefer that the facility is lit when they are using it regardless of the time of day. Light bulbs are needed as the inside of the facility is dim as there is not much sunlight. The proposed design includes a solar panel to help to generate energy to keep the lights running. There are 6 light bulbs in each sanitation block (see Figure 15), which provide light to the stalls as the stall doors do not reach the top of the container. It is also recommended that a caretaker has access to the lights so they can ensure that the facility is well lit when any user needs to use it.

Windows

Some other design features can be considered to ensure the facility is well lit. The facility should be located in an area that has adequate lighting so that windows can be utilized to minimize electricity costs during the day. However, windows should not be the primary source of light, as they are a concern for safety and privacy. Motion sensored lights should be considered in order to conserve energy by only lighting when the stall is being used. The areas around the facility should also be lit so that women can feel safe walking to the facility. In the design, windows are located on the side that faces the area surrounding the sanitation block as seen in Figure 12.

4.2.6 Wait Time

Handicapped Toilets

There are times such as lunch time and in the evening where users will have to wait in a line to use the facility. As other facilities were located nearby TPM, users stated that they will walk to another facility if the line was too long since they did not have time to wait. In the design, one stall in the men's and one stall in the women's facility is allocated to a handicapped toilet, consisting of a standard western toilet (see Figure 16). This will help to alleviate long lines for those who may need to use the facility the most (i.e. elderly, handicapped and children).

4.2.7 Price

Payment Trust System

Many government operated TPM facility users had to pay 2 rupees when they needed to use the water from the facility for toilet use. The users that were interviewed all said that it was a fair price and they did not have trouble paying it. However, facility managers reported that there are users who do not pay sometimes because they do not have the money. Even in this case, the caretaker will allow the user to still use the facility, instead of sending them elsewhere. This creates a culture of trust and understanding. Users don't seem to take advantage of the system, since the caretakers are from the community itself, there is an understanding between them of their situation. In order to effectively solve the problem of these areas, the recommendation is to

not deny users access even if they do not have the funds. This will allow the users to respect the facility, and take care of it as their own.

Payment Options
Many facilities offered varied pricing options for the community, including pay per use and monthly subscriptions. This information needs to effectively be delivered to the community, so they are aware on how to pick the best option for themselves and their family [5]. During implementation, government funding and incentive programs should be considered to fund the project and cover expenses for users who can not afford it.

4.2.8 Smell

Fans
The users identified that there are times where they will have to use the facility even if there is a smell. However, when running water is available, the facility will likely not smell as the water cleans it out. In order to circulate the air, the key recommendation is to place fans and windows in each washroom to circulate the air and reduce odours. The fan will in the design is to be secured in a high enough location to prevent theft (see Figure 18). Windows can also allow for ventilation.

Urinal Cleaning System
As these toilets do not flush with running water, TPM has incorporated a way to reduce the odours in the men's washrooms. The water from the wash basin is connected to the urinal pipes, meaning that when someone washes their hands, that will in turn help to reduce the smell by washing the urine down the pipes. It is recommended that this feature be installed in the men's facility in the design shown in Figure 18.

4.2.9 Toilet

Seated versus Squatting Toilet
Many of the users did not have experience with western toilets. All 6 women preferred the squatting plate over the western toilets as they said it was more hygienic as they are not touching any surfaces when they are using it. One male user interviewed mentioned that the seated western toilet is better for those with leg or foot injuries. To accommodate these users, the 3D design includes one stall that has a seated toilet for both men and women.

Handicapped Toilet Accessibility
Each of the toilet blocks include a handicapped toilet, which consists of slightly different design features than the other toilet stalls as seen in Figure 16. The handicapped stall includes a western toilet to accommodate for users that are unable to squat. A rail is installed for users to hold on to

when entering the stall. Additionally, the sanitary waste bin in the female toilet block is located a lower height so that it is accessible for all users.

4.2.10 Shower

The team investigated the need for a shower module at the facility. None of the interviewed users used the facility to shower, but facility managers stated that some men who worked nearby did not have homes to shower at, so they would shower at the facility. This design incorporates 2 stalls for the women and 2 stalls for the men that can be used for showering. These stalls are located in a separate storage container so that the smell from the toilet block would not affect the shower stalls. Each caretaker would be responsible for collecting money when users collect water for the showers. All the users preferred to use a bucket to shower instead of a traditional wester overhead shower. Users said that they all like to save water and there is a lot of wasted water with the overhead, so buckets will be provided by the facility for users to collect the water before entering the shower stall. A view of the shower stalls incorporated into the design can be seen in Figure 20.

4.2.11 Laundry

Women from both slums had never done their laundry at a sanitation facility, instead, they all did it at home. This was because they had running water at home and would not think to carry their clothes to the facility. However, if users wanted to use the facility for laundry, they would be able to use the shower stalls (see Figure 20) as an area to wash their clothes with water provided by the facility.

4.2.12 Additional Design Features

Caretaker

In the design, there is a caretaker located by the men's sanitation block and a caretaker located by the women's sanitation block. Each caretaker requires a chair and a table, which should be secured by a chain to prevent theft when the caretaker is not around. The caretakers sit near the cleaning closet, water supply, and entrances to the toilet block, or the shower/laundry block as seen in Figures 21. As seen in the design, the caretakers are situated outside of the boundary of the storage containers.

Shelter from Weather Conditions

As India faces weather changes throughout the year, it is important that the facility have shelter from either the sun or rain. As seen in Figure 11 and 22, a canopy roof is situated over the area that the caretakers are situated. This would need to be installed connecting to the storage containers and be supported by pillars. The area between the toilet stall and the shower stall where the water supply and cleaning equipment is located is also covered with extra canopy roof material, which needs to be connected to the surrounding storage containers.

Biopolus Technology Containers
From the estimations relating to TPM that produces 15m3 of wastewater a day, two 20ft containers would be needed to accommodate the equipment for Biopolus' technology. Additionally, another 20ft container would be needed to produce biogas from the sludge of the waster. In order to conserve space, these 3 containers are placed next to each other, stacked on top of the facility as seen in Figure 12 in red.

Office Space
As there is additional space on top of the facility, another 20ft storage container is added on top of the facility that can be used as an office space for the facility managers. This is located on the same level as the Biopolus technology as seen in Figure 12 colored in dark green.

4.3 Environmental Considerations

This section provides considerations that can directly impact the facility and the structure itself. The environment is the area that directly surrounds the WaterHubs facility. These considerations include the type of required water supply, the regional impact of the design and how monsoon season affects the structure.

4.3.1 Water Supply

The WaterHubs initiative has a vision to expand globally, however there is no 'one-size-fits-all' model when it comes to analyzing the geographical and water supply considerations. Before the facility is built each potential community must be analyzed for a variety of factors including the public's access to running water, whether or not the piping goes directly into the homes, the sewage piping system of the community, physical layout of the community to determine potential plot sites and seasonal weather patterns.

As water supply can be very limited in slum areas, it is highly recommended that the water collected be placed directly outside the toilet blocks as seen in Figure 16. This way the water consumption of users can be controlled and it will reduce the amount of water wasted. A caretaker would be in control of the amount of water users are taking and be able to moderate the use of the water supply.

Using technology from Biopolus, the waste water from the facility can be treated and recycled back into the facility or surroundings. Recycled water from the treatment can be used as irrigation from nearby gardens or parks. Since the facility will be treating its own waste, it would not need to be located near a piped sewage system.

4.3.2 Regional Impact

When determining which region the WaterHubs facility will be implemented into, the physical constraint of the structure and available space in the slum will need to be considered. The minimum space required is 28 ft x 32 ft, but this does not include the additional canopy that acts as shelter for the caretaker area or additional walkways into the facility. Based on the model, the overall footprint would be 40.5 ft x 36 ft. This is a flexible constraint as the canopy and privacy wall sizing can be adjusted according to the physical space.

This is a very important consideration to keep in mind as the slums are generally densely packed. As there is very little room to install community toilet blocks, the reallocation of a few homes or buildings should be considered. This is not an ideal scenario, but it is an option to consider for some areas that are in dire need of a sanitation block solution. If the current solution in place is not providing much benefit to the users, the community can decide whether they want to tear it down and replace it with a WaterHubs facility instead.

4.3.3 Weather Impact

India is affected by the monsoon season from July until September. During these months, sanitation can pose increased health risks to members of a community. As many facilities use tiled floors which get during the season, they can become slippery and pose a serious health hazard. The proposed solution incorporates drains to prevent flooding within the block. The caretaker would be unable to dry a floor during these times but at least they would be able to warn users to be careful, and more importantly, be there to help in case an accident occurs. During these seasons, flooding is also quite common in slums. To reduce the risk of the facility flooding, it is recommended that the design solution sits at a higher elevation respective to its surrounding area.

5.0 Design of Community Acceptance

In India, the design team discovered that while the physical design of structure is important, the community design should be considered as the most important aspect as it will never be successful unless the community has a sense of ownership. The follow sections outline how a community based organization should operate the facility, how governmental incentives should be maximized and how facility security should not be compromised.

5.1 Community Based Organization

Interviews with facility managers at TPM and subject matter experts were highly focused around community involvement. The importance of involving the community was stressed as it could help ensure that the facility is well maintained and respected. Before the facility is built, the local homes and businesses should be consulted to address any of their concerns. The people who live

and work around the public toilet play a critical role in directing other users toward or away from it. If the community is given the responsibility of maintaining the facility, they are more likely to keep it in a better condition. For this to happen, the community needs to understand the benefit and value of having the toilet block integrated into their community.

TPM was able to facilitate this community involvement by filling the necessary roles for the various functions of the facility with people from the community. Aside from the community members who work at the facility, many of the users who live in the area also have an invested interested in keeping the facility clean as they are the ones who use it most often. However, many of these users mentioned that people who are passing by the area will create a mess in the facility. In these cases, residents take initiative and tell that person to clean up their mess, before notifying the caretaker. Integrating the facility into the community will help to ensure users respect it and that outsiders will be deterred from making a mess.

It was also found that while users are at the facility, they would spend quite a bit of time socializing with other users. This facility became a community centre for many of the local residents and a place they enjoy going to. The facility has had a positive impact on the lives of the locals and for this reason they respect the facility more.

In the user studies and interviews, it was found that the caretaker also played a crucial role in achieving some of the user design requirements. The caretaker is responsible for collecting money from the users and maintaining the facility. It is important to make sure that both men of women trust the caretaker so they would be more likely to use the facility. For this reason, the caretaker should be someone from the community that the locals will know and become familiar with. The caretaker should clean the facility at least twice a day, but also when they are asked to by the users. For the women's washroom, the caretaker should wait until all the women leave the washroom before cleaning the area. In addition to the importance of caretaker's role, it was found that just the presence of a caretaker made the women feel safe using the facility. At TPM, the caretaker was good at making sure men were not waiting around the women's area.

5.2 Governmental Support

Depending on whether or not a community is notified, recognized by the government, or non-notified is an issue that needs to be kept in mind. It is important to recognize that these non-notified communities make up 59% of India's slums and nearly half of Mumbai's population of 12 million people [20]. In Mumbai, the "1995 cut off rule" only allowed city services such as water supply access to slums that were built before January 1, 1995 [21]. It wasn't until 2014 that the Bombay High Court ordered that water supply must be extended to non-notified slums [21].

5.2.1 Incentive Programming

As a way of trying to reduce the high rates of open defecation in both notified and non-notified slums, the Swachh Bharat Mission (Clean India Mission) was launched in 2014 [22]. While patriotism and calls to action from citizens lie at the core of this mission, it of course needed a respective incentive program to build more sanitation and toilet facilities in the area. The World Bank has contributed $1.5 billion in funding this program which has helped contribute to the many incentive programs offered to non-profit and community based organizations to help build more toilets and sanitation facilities. The TPM facility is an exemplary model of having taken advantage of these incentivised offerings in order to provide a range of services for their community.

Depending on the specific location of the implementation site, the community-based organization that runs the WaterHubs facility should take advantage of governmental initiatives. The TPM facility in Mumbai attributes a large part of its successful expansion to these initiatives. Often subsidies are offered to organizations willing to incorporate various features that help the community. The community based organization (CBO) should have a trusted political advisor who can inform them of current programming and steps required apply it to their specific location. Rather than having higher costs by introducing different community programming themselves, the CBO may create a difference for locals at a fraction of the would-have-been price. For example, TPM specifically created a computer centre from a government incentive. Some solutions may simply be community solutions that exist at a low cost. At TPM, they offer local women the chance to earn financial income from grinding flour using a single machine on site.

WaterHubs can utilize these incentive programs to help fund different projects within the facility thus improving the overall quality of life for locals. They can also be used to help pay community members to work at the facility and ultimately help grow the facility into a community centre for the local residents.

5.3 Facility Security

Ensuring the facility has security features in place is essential to help deter theft or vandalism and to promote a safe environment for users. Depending on how many hours a day the facility will be open, gates with locks for toilets entrances should be added when the facility is closed. Grates should also be added to the windows in the facility to stop people from throwing garbage in or out. This was a design feature that was implemented throughout different sites in Dharavi as seen in Figure 23. To ensure the privacy of the facility, hidden security cameras can also be added. This practice was seen at TPM where facility managers installed security cameras around the plot, however the users were not aware of this. This was done to protect the privacy of the facility in addition to making sure the cameras were not stolen by the public.

Another deterrent of theft and vandalism that can be used is having a caretaker on duty at all times when the facility is open. As mentioned above, having a caretaker from the community would be able to guard the facility and stop the public from mistreating the facility. They would enhance the feeling of safety since the users know the caretaker and feel more comfortable going to the facility.

Figure 23: Grated Windows Used In A Toilet Block In Dharavi

6.0. Future Recommendations

The design itself will be used as a template for WaterHubs' pilot project, however, there are still recommendation that should be immediate next steps to continue allow for a successful implementation. This includes verifying the feasibility of the storage container, the incorporation of Biopolus' core waste recycling technology, verifying the final design with users through prototyping and proposing additional solutions to users for future projects. The following subsections go through these suggestions in detail.

6.1. Storage Container Feasibility

Biopolus has requested for the design of WaterHubs to be implemented in storage containers in order to reduce the cost of construction and decrease implementation time compared to conventional brick and mortar buildings. To implement such a design, the feasibility of it must be determined before the team can proceed to the next phase.

Further research has shown that shipping containers are becoming an increasingly common method for housing over the past couple of years. Storage containers can easily be retrofitted because they were designed to be stacked on top of one another for easy transport overseas. Although they can be easily stacked, there is a weight limit to each storage container - 24,000 kg for a 20 ft container [23]. If containers are stacked, the weight should also be evenly distributed to support the load of stacked containers [24]. If stacked in any other dimension, the container

would need to be reinforced with steel supports. A structural engineer would be required to retrofit the containers and ensure they are structurally sound. There are many companies that specialize in building shipping container homes and retrofitting them to the owner's desired needs. From these findings, the U of T design team finds it feasible to build the water sanitation block in stackable shipping containers.

When implementing storage containers in the slum areas, the footprint of the entire WaterHubs facility must be considered. Currently space is very limited in many slum pockets across India. Families end up living in unsafe structures built on top of one another as there is not enough room to build anywhere else. This is a key consideration that should be taken in account with deciding where to place the storage containers and their orientation. It should also be noted that this proposed design is for only the water modules of the WaterHubs facility, and therefore the overall design will be much bigger since other modules will be added on. With this in mind, WaterHubs must be designed to have a small footprint while maintaining structural integrity with stacking and retrofitting.

Another consideration for storage containers in the land that they will be built on. Depending on the area, the ground or foundation of the facility must be rigid. In many slums, the ground is primarily mud or dirt which can pose as a potential problem in the rain as the facility can shift if it is not built on rigid land. A land surveyor would be needed to ensure that the chosen location can support the foundation of the facility.

6.2. Biopolus' Technology Mechanics

It is expected that all of the water used from the system will be recycled using Biopolus' wastewater treatment technology. The feasibility of the block locations and design features need to be validated to be used in conjunction with the technology. The connections to collect the waste and water need to be placed to connect the various storage containers. Additionally, the connections between the technology containers and building accessibility to access the second level of the facility need to be considered before the implementation of this design.

6.3. Prototype Testing

The design for the WaterHubs facility should be iterated and improved with the feedback from users. It is recommended that the 3D design model be used as an initial prototype and be shown to a subset of users in the pilot location prior to implementation. Ideally, the prototype should be printed or replicated into a physical model that users can interact more directly with. A physical stall matching the model's dimensions can be built in a room to have the users walkthrough. Users can validate the design features incorporated, and give feedback that can be used in the next iteration of the design. The final design should be agreed upon by the members in the

community before construction begins. Further steps that can be taken to follow the IDEO's design kit [18].

6.4. Alternative Design Features

There are a few design features that are suggested as alternatives by the design team but require additional verification and approval by Biopolus. The solution provided in this report is based primarily on the user feedback received in SantaCruz. Depending on the potential users and geographically location of facility, alternative designs can be investigated. Some of these designs include self-cleaning toilets (similar to the Eram Scientific design mentioned in section 2.1.4) or using a hose with a pressure handle (to prevent someone from leaving water running). These alternative designs can be found under Appendix C.

7.0 Conclusion

To conclude this project, the design team will provide Biopolus with a walkthrough of the 3D model to provide a full view of the design. This session can be used to answer any remaining Biopolus has about the design before the final handover to the Biopolus team. As the design is built using Google Sketchup, the original file will be sent and Biopolus can sign up for a free 30 day trial to work with model further. The University of Toronto Capstone team has thoroughly enjoyed working with Biopolus to create a design for the WaterHubs initiative, and hope that the design will be used in the pilot project.

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Appendix A: Observations Notes

Day 1, Dharavi

MCMG Meeting Notes

- 20 million people live in Mumbai
- 4 kL of water needed daily in Mumbai
    - Received from UDAN ~130km away
- 7 zones in Dharavi - each has pumping station
- After treatment, discharged into ocean 3ft inside
- Total approximately 34 wards
- Official population of Dharavi is 370000, actual population up to 1 million
- 280 community plots
    - 130 need to pay to use, operated/maintained by NGO - max is 2 rs for toilet, 3 rs for shower
    - 150 free for community - municipal responsible - 320000000 (32 crore) is the total budget, 40-50 million Rs. for the 150 plots
    - Average 10 seats per plot
- Not enough toilets in the morning
- Atleast 11-13 thousand toilets are needed to serve the population
- Government Clean India Mission to provide toilet to every house
- Individual toilets are subsidized 5000 Rs by the government, but toilets cost 20000
- Main problem for not building more are because they are lacking sewage connections and open land
- Design features are low priority for people living in these conditions
- Low wage words in construction, leather, taxi drivers
- Railway tracks and beach used for open defecation
- 5-7% defecate in the open
- Women don’t work, packing
- slaughterhouses in Dharavi, plotting food for the city
- Special only female toilets being built with CCTV cameras and implementing hotlines
- 1000:940 male female ratio
- Can’t construct on beach because it is a costal regulatory zone, but can build temporary units
- Target is to completely get rid of open defecation in 2 years time
- Extend sewer network to the slum in very difficult
- Mentality - enough to build a toilet at the home, why not build a shop instead?

Day 2, Santacruz

TPM- Open defecation is no longer a problem b/c of well maintained site

Showers

- 50-60 daily
- solar heating for hot water

Urinals

- Free to use
    - Trust that users will pay if they use water (for #2)
- All are separate
    - 1 for women - they come daily, use for free
    - 7 for men

Toilet

- Spring taps
- Water is from 3 ring wells
    - collect rain water

Gov't Funding

- exists for major repairs but is not very adequate

Caretaker

- Cleans 2-3 times a day
- From the community - so most of the users know them well and feel comfortable with them
- acts as an incentive to keep the toilet clean
- Can't check all the passes - caretaker usually knows who is a pass holder. They don't check outsider users
- 25-30% don't pay and they don't care about the facility as much
- Maintenance happens at night and major cleanup during the day is around 11 or 12.
- not enough water to flush - want users to use water to clean toilet seat.
    - thought about self cleaning heads but too expensive

Background

- TPM started off as a community based organization
- 1600-1800 people depend on TPM
- During repairs, other users will come to TPM
    - there are other facilities in the slum pocket, but TPM is cleaner and maintained better
- 1-2% of people will construct toilets in their own home - the problem is getting drainage into the sewage
- total slum population is 12 000
- dry waste and garbage is collect from entire slum pocket by TPM
- Wet waste is sent to municipal dumping ground
- Projects @ TPM are gov't initiatives that they took over.

2013 - Municipal corp

- Clean Mumbai initiative
- they give TPM a stipend $5400 for volunteers to come in and clean the waste

- Enrol into programs from municipal which gives funding and stipend to pay volunteers to help
- try to participate in many programs and employ many local volunteers as possible - college students, awareness programs
- gov't program available for NGO or organizations to enrol in
- 18-20 toilet blocks in slum pocket
- 120-150 families that enrolled in monthly pass
    - Money is used for maintenance, water, electricity, repairs, general expenses
- Some pass holder families can't pay, they don't enforce payments
- 3 rupees per flush, clean up, water usage, electricity usage
- Adjacent toilet block users, 38 families are also enrolled
- yearly audits for expenses

2 organization - for women TPM

- take care of woman initiatives, daycare

Expenses

- 2500 rupees for electricity of tpm - just for toilet block
    - primarily used for pumping water
    - toilet blocks are self sustaining
- 4500 rupees for water
- 40% lighting, 100% heating is from solar panel
- restrict municipal water for drinking - it only runs for 2 hours during the morning. Each tap has a meter connection
    - get 4-5000 L a day. Stored underground, pumped overhead
- 8000 L of ground water used daily from 3 wells
    - during summer peak (may-july), output from wells is not sufficient, tanker is used to subsidize
    - there a shortage of water during these months, water from municipal runs for less time 1.5 hours
    - recharge wells during monsoon
- Water from tanker is $1000 rupees a tank (not profitable)
- drinking water tanks are 2500-3000 rupees a tank
- pumps can not run longer than 1 hour continuously
- drinking water collected is 5000 L, some water is sent to the showers
- Usage has gone up and the ring well output deceased- need to collect more rain water
- Poverty line <$1 per day (very low)
    - more than $1 per household is not "poor"
- 26000 rupees for annum

Users problems

- No money to pay for the facility or change on hand to pay per use
- complaints on cleanliness is taken care of right away
- Western toilet for handicap, pregnant, child, seniors
    - most pp don’t know how to use them - many prefer squatting plates
- Strict guidelines for building of toilet blocks
    - gov’t deems necessary location, contractor's bid and build
- Problem starts once toilet is constructed - Maintenance

Appendix B: User Study

Day 3, Santacruz

Activity

In this activity different attributes about a toilet facility were drawn on sticky notes. Two groups of users were chosen, male and female. In both groups, a translator was used to help explain the activity due to the language barrier. The drawings on the sticky notes were also used to help the users understand the attributes better. Users were asked to rank the attributes from most important to least. They were asked to use the current facility as a benchmark and other facilities they have used to help make their decisions. The purpose of this activity was to see the train of thought and discussion from the users to understand what they find most important and why. Follow up questions were then asked based on the user answers.

Women User Interview

6 Women Users

- women feel comfortable with the joined complex with men but with the separate entrances.
    - Even if the entrances are close together, they feel safe in this facility, not others
    - They feel support from the men b/c they are good

- Shortage of water
- Want a dustbin for sanitary napkins
- Many users said TPM performed all of the below mentioned aspects well

1. Smell
    - Would still use the toilet if it smelled bad
        - Used actions to show they would cover their face with a scarf when using the bathroom
        - Smell is not as bad because of the caretakers and there is usually running water
2. Cleanliness
    - Caretaker cleans right away when they complain.
        - will wait for all women to leave or ask them to leave to clean the toilet that's dirty
    - Usually outsiders of the community make the facility dirty. Women will tell them to stop when they make it dirty
    - All wear their shoes when they go in
    - Kids that come in without their parents make it dirty
    - Much messier during Monsoon season because there is more mud
    - Messier in the hallway - passage has a lot of mud
    - Inside is usually clean because people pour water to make it go away

3. Light
    - It's on when they go to use it
    - Enough light

4. Vent

- They have proper/enough air - doesn't smell
- Do not want any big windows b/c of privacy and to deter people from looking in

5. Wait Time
   - Lunch time and after 5pm (5-7) are generally busy. There is a line up.
   - If the line is too long they go somewhere else. They don't have time to wait and will have to carry their own water to the sites

6. Gender Separation
   - Like the separate entrance

7. Privacy
   - Never experienced problems with men
   - there is a camera on the complex which probably stops people from peeping - but users don't know
   - They use the lock on the door
   - Comfortable with the open entrance since the actual toilets are covered

9. Price
   - Pooping needs water and they have to pay for that
   - Toilets are free to use
   - Monthly pass is 50 rupees for a family of 4

10. Toilet
   - All 6 prefer the squatting plate over the western toilets
     - they don't touch the seat and less bacteria
   - 3 like the bucket and 2 like using a hose
     - Problem with hose is that people run it the entire time they are in the bathroom, 5,10 or 15 min and wastewater.
     - During periods, more water is needed. one bucket is not usually enough
   - Would like to have a full mirror inside the bathroom
     - will not use if it was outside. should not be in front of the wash basin b/c women will block others from washing hands
   - Wash basin is needed

-Women will store water at homes in either drums (500 L) or buckets
-Water runs from the municipal only 2 hours a day

11. Laundry
   - All do laundry at home with water from the municipal

12. Shower
   - They use bucket water and refer buckets over the shower head to save water
     - shower heads waste more water than buckets

Extra notes from facility managers

Urinal

- They should have posters at the urinal to remind men to wash hands
    - good use of space to provide education and reminders to men to wash hands after using the bathroom
    - influencing children will help change the parent's habits as well

Caretaker

- Caretaker pays the electricity and water bill with the money they get from the monthly passes and individual payments.
- They get to keep whatever is left over. They are in charge of cleaning and hiring other caretakers.
- Solar panels help cover most of the water heating and light bill.
- Solar panels don't work during monsoon

Men User Interview

Note that men may have had a misunderstanding about the question, answers may be based on current best qualities at TPM

5 men users

- Many users said TPM performed all of the below mentioned aspects well

1. Clean
    a. People from outside make it dirty by throwing pan, cigarettes
    b. Caretaker keeps it clean
    c. Wears shoes and slippers
    d. They tell the caretaker when something is dirty
2. Water supply
    a. Currently exists
3. Light
    a. The amount of light there is now is good
4. Privacy
    a. safe
    b. They all use the lock
    c. Entrance is ok how it is
5. Wash basin
    a. Currently exists
6. Gender Separation
    a. Needed
7. Wait Time
    a. Wait time is around 8-10 am, but will stay in line instead of going somewhere else
8. Smell
    a. Caretaker maintains
9. Cost
    a. Current cost is fine

Bucket or showerhead?

- 3 prefer bucket

Seat or squat toilet:

- Seat toilet is better for people with feet or leg injuries, joint pain

Notes:

- Senior citizen should have priority in the line
- Caretakers should make them throw away things (cigarettes, etc) before entering the toilet
- Men look up when using the urinal, so place a different message at each urinal reminding men to wash hands (ie, you are paying this much so why not wash hands, x amount of bacteria on hand going back to your family, etc.)

Figure B1: Ranking of Design Attributes For Men

Appendix C: Additional Design Features

Self Cleaning Toilet System

Other ways to keep the toilets themselves clean is to implement an iteration of a self-cleaning system. Upon receiving an input from the user, the system will use the wastewater created from Biopolus' technology to push water through the base of the floor and clean it prior to the next use. This could either work though using a type of metal floor (for sanitary purposes) with holes to allow for drainage but designed to be smooth to not induce pain to users coming in barefoot, as most are. As it turns out, Eram Scientific has developed a free-standing, solar powered toilet that does just this [13].

A second design to the self-cleaning toilet would be one where the floor area surrounding the sides and back of the user is angled in towards the drain to automatically drain the spilt-over water that results from washing with a bucket after using the toilet. The biggest design flaw here is that it comprises a user's safety for any slight angles on a slippery floor can lead to a fall that results in serious injury.

Aside from the self-cleaning system, an automated flush initiated from a foot pump (i.e. one pump is enough for the flush) could be incorporated to control the level of water used for the toilet. Currently use buckets of tap filled water to use. The cultural consideration here is personal cleaning post usage. Women clean themselves using that bucket of water so if an auto flush were implemented, a hose must be located in each stall. This hose would be push-triggered to only allow water flow when a user applies force to prevent water wastage. A subject matter expert indicated that a problem at the facility is when women have personal taps, they often left them running freely.

Pit Latrine

Some alternative designs ideas to reduce the smell came from different types of technologies that would not necessarily work alongside the Biopolus technology schematic. This includes the separation of urine and solid waste as well as creating a ventilated improved pit latrine [25]. The later is a system that is intended for pit toilet structures but the concept of if there is no ventilation between the waste disposal area and the toilet stall, the smell will be forced back up into the stall if there isn't an alternative vent that the air can escape through.

Lastly, there is a plastic latrine pan intended to be used with squatting places that has been invented to block smell through a trap door design using a water seal. Details of this SaTo Pan are outlined in the next section [26].

SaTo Latrine

The SaTo latrine pan as seen in Figure 3 is designed with a simple counterweight trap door that opens when over 0.5 L of water is added to the pan [26]. A small amount of water is retained in

order to create a seal. This pan is made of plastic making it economically feasible, and it also is modeled to be a part of the squatting plate, thus users are not forced to alter their behaviours [26].

Figure 1: Sanitary Garbage Bin at TPM

Figure 2: Entrance to the Women's Washroom at TPM

Figure 3: SaTo Latrine [13]