A functional ergonomic analysis of public toilets

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System

I shall present an analysis of the public toilet. I am concerned with the system surrounding the toilet seat; I am not primarily concerned with other parts of public restrooms, but I examine closely related parts of them, such as partitions between stalls.

Tasks

I have identified three primary tasks associated with toilets are defecation, urination and cleaning of the toilet. Both males and females generally defecate sitting down. Females also urinate sitting down, but males tend to urinate standing up. There are frequently dedicated urinals in male public restrooms, but males still frequently use traditional toilets to urinate in public restrooms. I've grouped defecation and urination into standing and seated tasks for my analysis. I've also separated the section on squatting to use the toilet.

Cleaning of the toilet is another important task to consider. Many public toilets in one building are generally cleaned by the same few janitorial staff every day. The janitorial staff are thus at a higher risk of injury associated with cleaning of toilets than people who clean their personal toilets in their own homes and can benefit from toilets designed to facilitate cleaning.

Other activities are associated with public toilets, such as vomiting, but these occur much less frequently, so I have not considered them in my analysis.

Most prior research on toilets has looked primarily at tasks performed sitting-down. My report thus focuses mostly on that task.

Task-based flaws of existing toilets

Seated use

McClelland & Ward (1982) found that toilets as they are currently designed are not the most comfortable. They chose to look at sitting toilets exclusively because preliminary trials had found that a squatting posture was uncomfortable. This study was conducted in Britain; in other cultures, however, the squatting posture may have been more bearable and may have warranted tests. They also did not look at standing. They studied user preferences of toilet seats for defecation. They looked at five toilet seats.

The first followed the current British standard for plastic toilet seats. The second was similar to the first except with an elongated aperture, the length of the void in the toilet seat from front to back, such that it was comparable with the next three experimental seats. The third provided increased buttock support. The fourth increased thigh support to encourage leaning forwards and included concave troughs in order to afford sitting in a particular orientation in the seat. The fifth was similar to the fourth but without the concave troughs, allowing more movement in the legs. (Figure 3)

Based on an anthropometric survey that they performed, McClelland & Ward (1982) chose apertures of approximately 36 cm for the last four of the seats, which was about four-thirds the aperture of the standard seat.

The preferred two seats were seats three and four, but men and women prefered different styles of toilet seats. Men preferred the fourth seat most and liked the third seat least. For women, this preference was almost completely reversed. The authors propose that the proximity of the opening to the genitals was related to this. This can also explain why the larger aperture was preferred.

McClelland & Ward (1982) also looked at seat angle and height. They built adjustable toilets and had users adjust toilets until they were most comfortable. They looked at slopes of six degrees sloping towards both the front and back and determined that angle was not an important factor within this range. They determined that a non-adjustable sitting toilet designed to accommodate both sexes should be 0.4 m tall. In their study, this was the mean preferred height for women wearing no shoes. (Table 1) They claim that it is easier for tall people to squat down to lower toilets than for short people to use taller toilets, so they recommend this number that is slightly below average. This number was slightly lower than the recommendation at the time.

This recommendation is still flawed, however, because it is suboptimal for anyone with height far from the mean. A better solution would be adjustability of some sort.

Cai & You (1998) studied user preference of sitting and squatting type toilets and developed a new design of squatting toilet. They found that people preferred sitting-type toilets at home because they were more comfortable and preferred squatting type toilets in public because they were more sanitary.

They found that people use many different strategies to cope with sitting-type public toilets; most of the participants would try to avoid using public toilets because of their unsanitary condition. When they do use sitting-type toilets, almost half of the participants would adopt postures other than sitting, such as “semi-squatting” on the toilet—bending the knees and hip but not contacting the toilet.

This study was conducted in Taiwan, and the results would likely be different in a culture where squatting toilets are less common, but we should still consider that sanitation is a concern as well as comfort and that people will not necessarily sit on the toilet as designed if such a posture does not seem sanitary.

Stalls often have too little space. If the doors often open inwards, there should be enough space for a user to close the door while standing in the stall in order close the door and to take off a jacket or backpack. (Figure 6) The 99th percentile for males of the largest distance between the stomach and back is 13.7". For pregnant women, the 99th percentile of this distancec is 16.6". The first percentile female measurement for this is 7.5". (Tilley et al., 2008) In order to accommodate most users, the distance between the stall and the door when it is fully open must thus be at least this large. It should actually be slightly larger, actually, because people cannot be expected to stand in exactly the correct spot.

Stalls are sometimes uncomfortably thin for wider people. The 99th percentile shoulder breadth for males is 20.6", and the first percentile shoulder breadth for females is 13.6" (Tilley et al., 2008). Stalls actually have to be wider than this, however, in order to allow for arm movement. Stalls should be wide enough to support this range of people.

Squatting use

Cai & You (1998) also designed a new squatting toilet and tested it on users. Their final design incorporates a 15-degree sloped area for placing the feet, improving squatting comfort.(Figure 5) They also collected anthropometric data of the squatting posture in order to size the toilet properly. (Table 2) These data can be used to determine how squatting toilets should be sized for different sizes of people and to determine whether adjustability is necessary.

Standing use

Little research is available on the standing use of public toilets. Cohen (2009, page 190) identifies one problem, however: Men who are peeing standing up often miss because the toilet is too small for them to aim well.

Another problem is the height of the stalls. A tall male whom I know can see over the stalls if he is standing up in a public restroom. This defeats the stalls' purpose to increase privacy. Stalls are sometimes not tall enough because the designer did not consider tall people.

Cleaning

Woods& Buckle (2005) looked at musculoskeletal risks in cleaning. They observed that cleaning staff adopted risky forward reaches of the arms when mopping small areas around toilet seats, such as those created by a toilet mounted on the floor (Figure 1).

There are also problems cleaning the toilet seat itself. Toilet seat height is generally determined for defecation and not for cleaning. It is thus not a surprise that toilet seats are uncomfortable to clean. They are generally lower than the knee height of short females, so one must bend down or sit on the floor in order to clean the seat. Tall cleaning staff need to bend down even when sitting on the floor. This is because the seat is not designed to be of ideal cleaning height.

Special populations

I've investigated concerns in public toilets related to the tall and elderly. These groups are often ignored by traditional toilet design. These are not the only special populations, of course. Work should go into looking at public toilets for other special populations.

Tall

I've already identified some of the problems that tall people have with public toilets. There are more. Because the toilet seat is too short for them, they must either sit in an uncomfortable way or lift themselves above the toilet seat and support themselves on the toilet paper despencer, which is not designed to support weight and thus sometimes breaks (Cohen, 2009, page 190). This whole situation occurs because of the lack of adjustability that I discussed earlier.

Stalls are often too thin or shallow for tall people as well (Cohen, 2009, page 190). Leg length is strongly associated with height, so tall people often do not have enough leg room in stalls.

Elderly

Dekker et al. (2007) studied how the elderly use supports to assist their use of the toilet. Many public restrooms do not have supports, but this study shows the necessity of supports. The study also identified the various ways that supports are used. Many public restrooms do not have supports that match these recommendations. For example, most restrooms around campus that have support bars have horizontally oriented bars (Figure 4) even though Dekker et al. determined that the elderly prefer vertically oriented bars.

Design suggestions

The fundamental choice of sitting toilets versus squatting toilets depends on the culture of the area where the bathroom is to be built. In arears like Britain, squatting is considered uncomfortable, making squatting toilets unacceptable. In Taiwan, sitting toilets are considered unsanitary and are thus unacceptable.

The conventional separation of men's and women's bathrooms gives us a unique opportunity to design different bathrooms suited to different users. For sitting-type toilets, men's bathrooms should have toilet seats closer to McClelland & Ward's (1982) fourth seat, and women's bathrooms should have seats closer to their third seat.

Within each bathroom, toilets should ideally be adjustable in height. McClelland & Ward (1982) found that preferred seat height was 0.430 meters with a standard deviation of 0.030 meters for men and 0.404 meters with a standard deviation of 0.033 for women. I recommend that seats cover at least the range from two standard deviations below the female mean (0.338 meters) to two standard deviations above the male mean (0.490 meters). Increased adjustability would also help cleaning staff.

If adjustability is not possible, the different toilet seats in each bathroom could each be of different height in order to cover that range, which would also allow them to be of different widths. (Figure 8) Squatting-type toilets could also be varied in width to support a range of users. Cai &

You (1998) found that the minimum distance between feet during squatting ranged from 6 cm to 35 cm and that the maximum distance between the feet ranged from 17 cm to 52 cm. (They used minimum and maximum distances because the feet were angled.) Graded widths of squatting toilets would support this range better.

Because concerns about sanitation cause often cause people tot use toilet seats as they not are intended to be used, an increase in the level of sanitation would encourage more correct use of the toilet. In order to accomplish this, toilets seats could be automatically cleaned after each use.

Stalls should be large enough to fit the widest of people. If space is an issue, a graded series of toilets and stalls would allow more efficient use of space. (Figure 8) It should allow people to enter the stall, close the door, sit down and use their arms without major restriction of movement. This would involve supporting dimensions like shoulder breadths ranging from 13.6” to 20.6” and distances between stomach and back ranging from 7.5” to 16.6” (Tilley et al., 2008).

We can solve the difficulty that tall males have aiming while urinating by making the toilet bowl larger and increasing the size of the seat on top. (Figure 7). This would keep the seat the same effective size for sitting. Stalls should also be tall enough to support the 99th percentile male height, 75.6” (Tilley et al., 2008).

To ease mopping, sitting toilets should be built into the wall instead of the floor (Figure 2). This avoids the creation of small pockets that cleaning staff have to adopt strange postures to clean. To ease their cleaning, toilets should ideally be adjustable in height. An alternative may be a chair (loosely interpreted) designed to position cleaning staff at the appropriate height.

To support elderly users, vertical supports should be positioned at a range of distances from the seat front, ranging from 175 to 515 mm. The height of the supports should range from850 to 1400 mm. These numbers are based on preferences recorded by Dekker et al. (2007).

References

Cai, D. and You, M. (1998). An ergonomic approach to public squatting-type toilet design. Applied Ergonomics 29(2), 147–153.

Cohen, A. (2009). The tall book : a celebration of life from on high. New York : Bloomsbury.

Dekker, D., Buzink, S.N., Molenbroek, J.F.M. and Bruin, R. (2007). Hand supports to assist toilet use among the elderly.

McClelland, I.L. and Ward, J.S. (1982). The Ergonomics of Toilet Seats. Human Factors 24(6), 713–725.

Tilley, A.R. and Henry Dreyfuss Associates. (2008) The Measure of Man & Woman: Human Factors in Design. Tianjin University Press.

Woods, V. and Buckle, P. (2005). An investigation into the design and use of workplace cleaning equipment. International Journal of Industrial Ergonomics 35(3), 247-266.

Appendix

Figure 1: A standard toilet seat

Figure 2: A toilet seat built into the wall to ease mopping

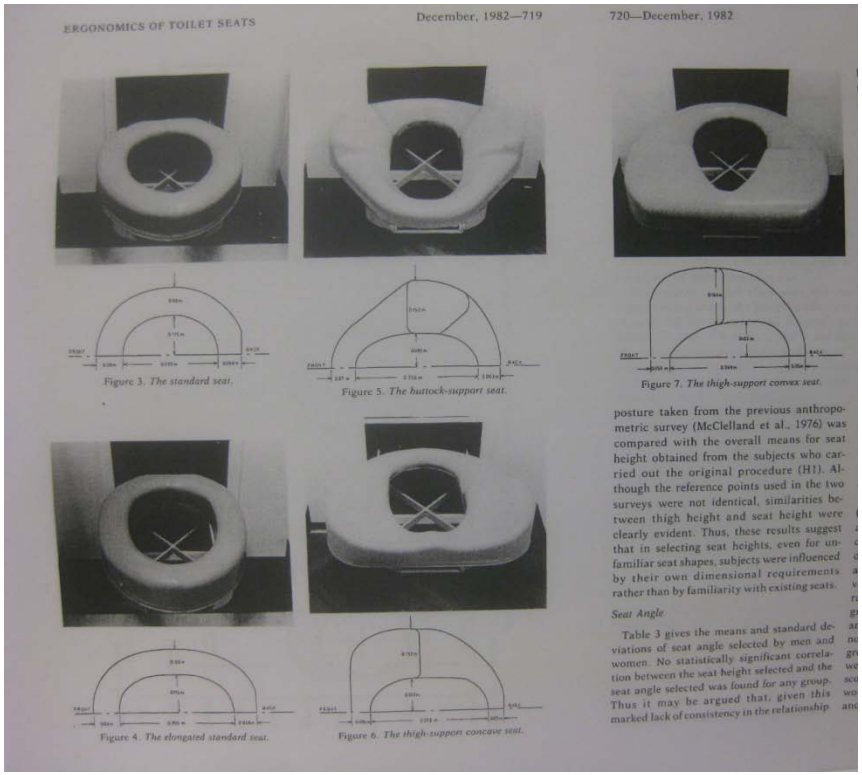

Figure 3: Toilet seats tested by McClelland & Ward (1982), from their paper

Figure 4: A toilet with horizontal supports

Means and Standard Deviations of Seat Height by Sex and Procedure (Dimensions in Meters)

		Men		Women		All	
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
All Seats	H1	0.430	0.030	0.404	0.033	0.413	0.032
All Ages	H2	0.391	0.048	0.355	0.037	0.309	0.042

Table 1: Preferred seat height, from McClelland & Ward (1982)

Table 4 Measured dimensions of the sample

Variable	*N*	Mean	SD	Min	Max
Foot length (cm)	79	25.25	1.40	22.00	29.02
Foot width (cm)	79	9.75	0.76	7.80	11.40
Max btw feet (cm)	77	32.30	7.40	17.70	52.40
Min btw feed (cm)	77	16.60	5.26	6.40	35.40
Angle btw feet (degrees)	77	36.83	13.06	14.50	70.00
Anus, *x* (cm)	77	0.61	1.50	−3.00	4.00
Anus, *y* (cm)	77	31.93	3.07	24.00	41.90
Anus, *z* (cm)	78	10.97	3.48	5.00	23.50

Table 2: Anthropometrics of squatting posture, from Cai & You (1998)

Comfort	30	5.63	0.85	5.03	1.27	4.97	1.27
Acceptability	30	5.13	1.36	4.87	1.31	4.77	1.28

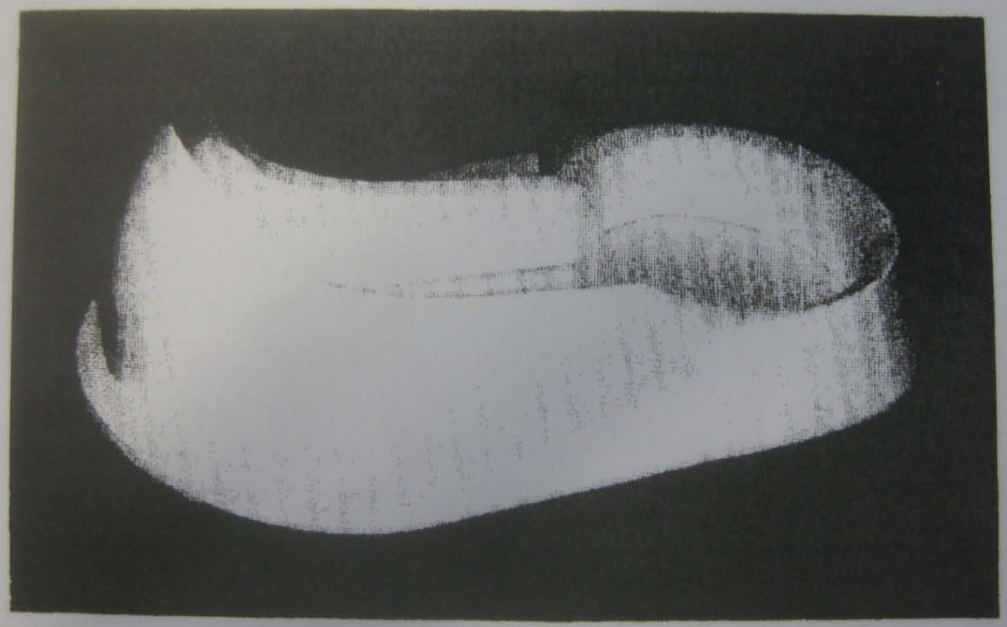

Figure 7 The final mockup

Table 8 Result of the evaluation of the final mockup

Figure 5: An improved squatting toilet, from Cai & You (1998)

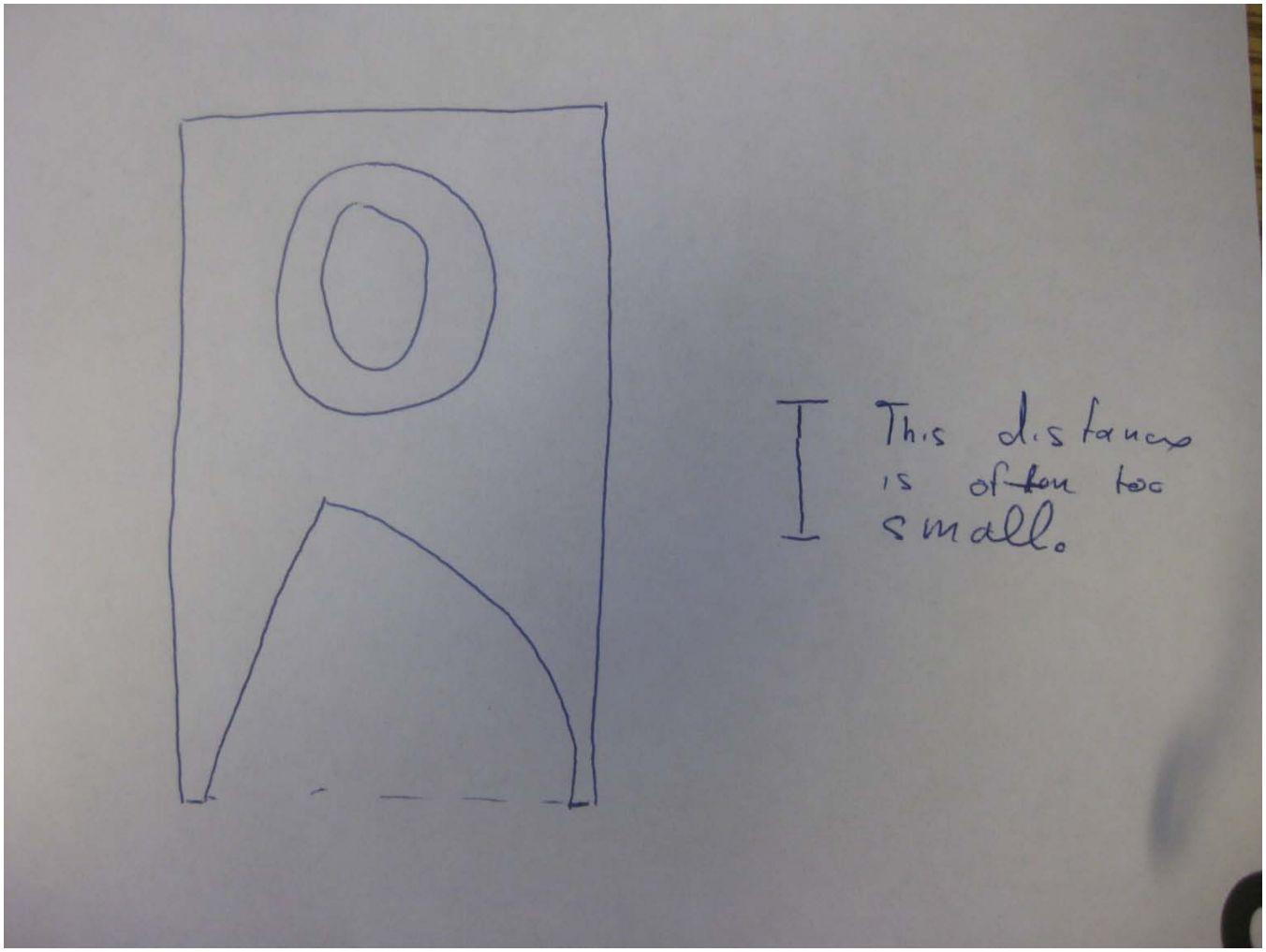

Figure 6: The lack of space in conventional stalls

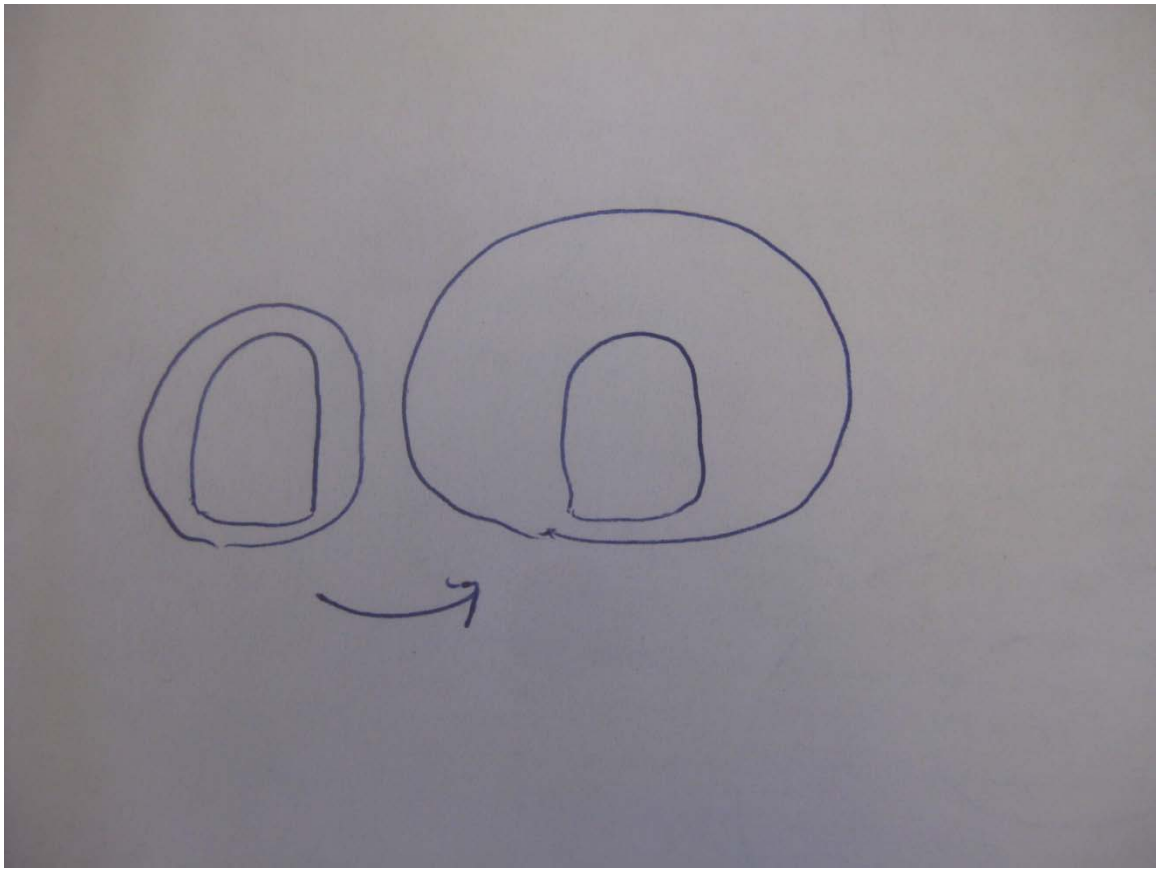

Figure 7: Large seat and bowls to allow urinating for tall men.

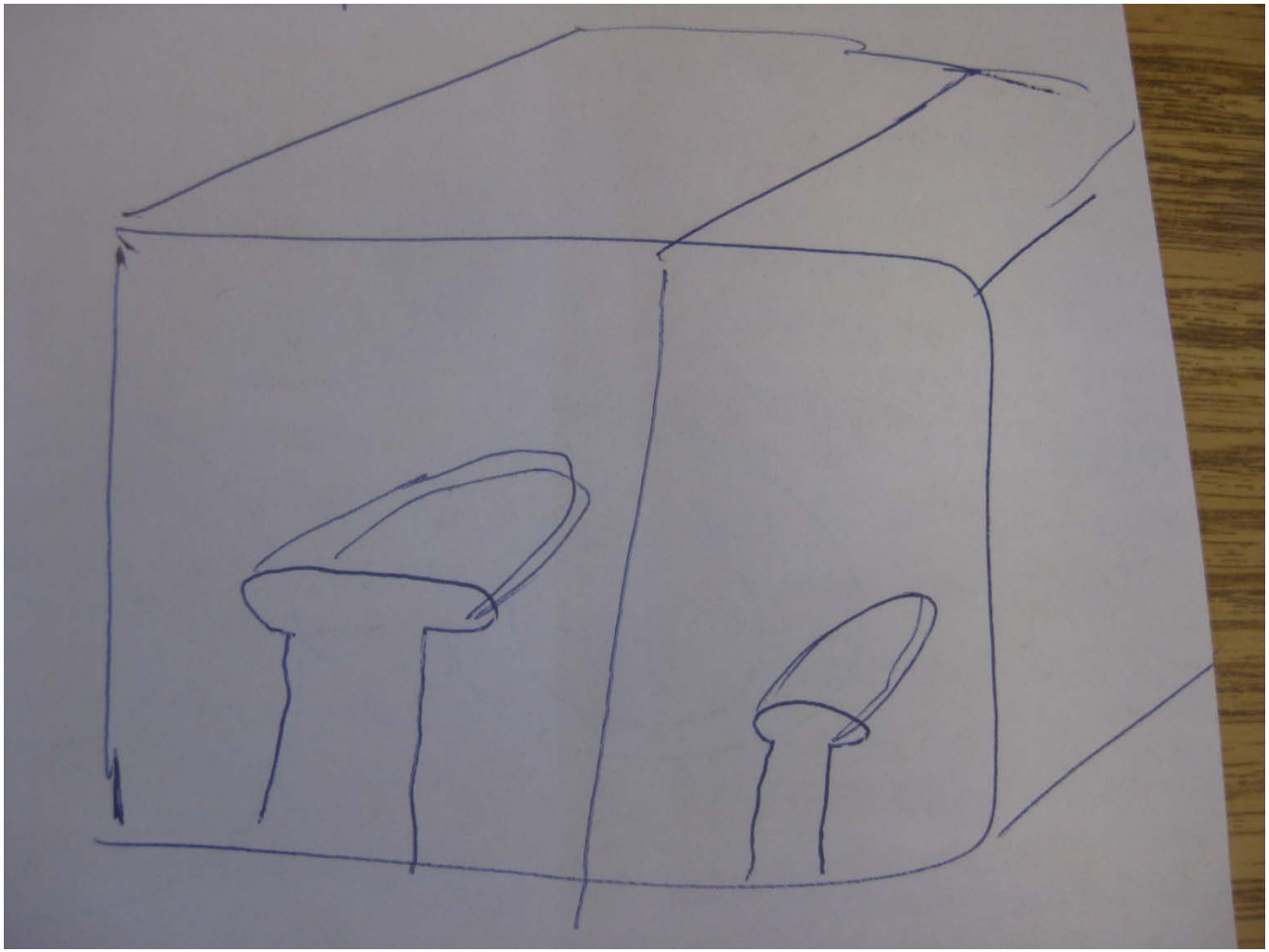

Figure 8: Stalls with graduated width and toilet size