

ORIGINAL ARTICLE

ERGONOMIC INCLUSIVE DESIGN OF INNOVATIVE TOILET FOR DISABLED USER

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ABSTRACT

Currently, the existing toilet design sold in the market has not satisfied criteria of the disabled people. Disabled includes the physical impairment, the hearing impairment, the visual impairment, and the cognitive impairment. This people prefer use a specific toilet to the public toilet. However, a specific toilet was not available in any place. This condition becomes a problem for them. As for the existing public toilet does not provide easiness in use and even has potential risk to lead accidents for them. The toilet was designed to serves only the normal people. Therefore, it needs to design a public toilet which can be used universally. So normal and disable people can use it easily and conveniently. Objective of this research are to develop design parameters of toilet based on the inclusive design concept to satisfy customer criteria. Axiomatic design was implemented in this study to identify the design parameters by means of mapping process from customer attributes and functional requirements. Anthropometric data was used and non parametric statistical analysis was conducted to validate the proposed design. Result of this study showed that design parameters identified was valid to satisfy customer criteria at 5% of significant level. The design parameters encompassed material used, dimensions and position of toilet attributes as well as additional environmental appliances.

Keywords: Toilet design, inclusive design, axiomatic design, disabled people

INTRODUCTION

Currently, a lot of toilet bowls are designed and sold in the market. These designs only considered criteria of normal people such that easy to use for them in public area. Unfortunately, this condition will cause little problem for disabled people scilicet the people who have physical impairment, the hearing impairment, the visual impairment and the cognitive impairment^{1,2}. It is because the existing toilet bowls do not provide easiness in use and even have potential risk to lead them into accidents such as contusions or abrasions, fracture, internal injury, scald and another kind of injuries³. Therefore, they prefer to use a specifically designed toilet bowls rather than using present public toilet.

However, specific toilets are rarely found in any place. To avoid such the above incidents, public toilet should be ergonomically designed. The goals of ergonomics are to enhance safety and satisfaction to users^{2,4}. Therefore, the product designers should include ergonomic criteria in their product design specifications, rather than only consider on the ordinary persons, which are normal and care less on the specific requirements for disabled⁵. Thus, this research will propose a design of toilet for satisfying all kind of people by using Inclusive Design concept.

METHODS

Inclusive design is a concept of design that meets as many customers as possible by combining diverse user requirements^{6,7}. This concept applied as basis to design an innovative toilet. Axiomatic design method is used to determine the design parameter (DPs) of toilet by mapping process from customer

attributes (CAs) and functional requirements (FRs) of the design. Survey was conducted to disabled respondents (46 males and 36 females) to identify CAs that costumer looking for design of toilet. Anthropometric data were gathered of the 40 females and 60 males of disabled respondents. All respondents were aged between 4 to 93 years old. Nonparametric Statistical test conducted to test the hypothesis.

RESULTS

Analysis of Survey

Result of survey showed that customer attributes identified were CA1: convenient in use and CA2: satisfying product. It means that the design should create easy, comfort, and safety in use for disabled customer. Moreover, the design also must be aesthetic, flexible, and provide clear information for satisfying the CA2. Thus, the functional requirement developed of a toilet design should be able to meet customers' characteristics (FR1) for satisfying CA1 and provide a good value of product (FR2) for satisfying CA2.

Analysis of Design Parameter (DP) of Toilet

Design Parameter that satisfying FR1 was DP1: ergonomic toilet design. This encompasses DP1.1.2: the cross sectional area of seat, which it was suited with the anthropometric data of thigh width for adult and child. The child dimensions engaged P5 (5 percentile) in order to use by child. Often the buttock of child almost duck into the hole due to the width of cavity was too large for them. In order to fit the big size adult, the dimensions engaged are at P95 (95 percentile) so that the big size adult can still feel comfortable when they are sitting on

the toilet bowl. The cross sectional area is shown in Figure 1.

Figure 1 - Virtual Design of seat area's material



On the other hand, DP1.1.1: the material used for portable seat, made from combination of acrylic and nylon to compose non rigid seat, make the seat warmer, and reduce the pain if the customer sit on for a long time. Therefore, to overcome these FR1.1 have taken these into consideration to minimize the pain when the user sitting on it.

The other points were FR1.2: to provide relax position. Therefore, DP1.2: two armrests will be provided to create the relax position. To satisfy the requirement, it was determined that the length of armrest was fitted with DP1.2.1: P50 of lower arm length for adult and DP1.2.2: height of the armrest was fitted with P50 of elbow height in sitting position. It was not only to create the relax position but also as the handle for the elderly when they move from sitting to stand. It was a kind of multifunctional part of toilet. The armrest was made from aluminum and covered by plastic⁸. FR1.3: Provide relax condition, was considered as well to create. DP1.3: comfort condition, intended when the customer doing activity inside of the room. Bad smell will be removed by DP1.3.1: adding fruit aroma perfume, installed inside of the room. In other giving perfume to the toilet area, FR1.3.2: air circulation, will be provided as the property to help the respiration when doing activities in rest room. Overall seat design can be seen on Figure 2.

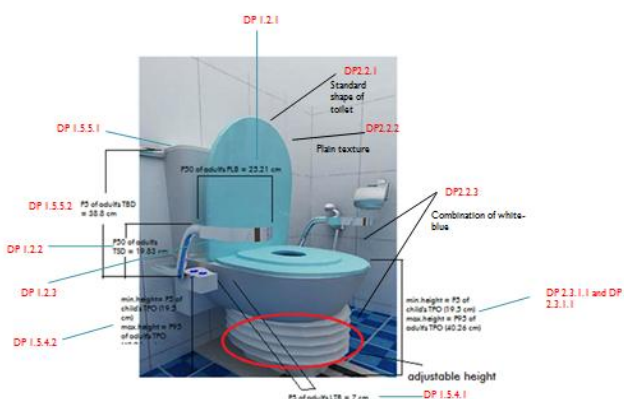


Figure 2 - Overall virtual design of toilet's seat

There were DP1.3.2: two units of window provided to the toilet. Based on this case, DP1.3.2.1: position of the window, was exactly in the middle of the inner sidewall of the bathroom, which the

upper side of the window was same with the door. For DP1.3.2.2: rectangular shape, generated according to the questionnaire, which spread to the customer. DP1.3.2.3: dimension of the window, was 50 cm x 70 cm with the width of the frame was 6 cm. DP1.3.2.4: material of frame was selected teak wood because of the durability. The other criteria to create relax condition were FR1.3.3: provide toiletries and FR1.3.4: washing hands. The toiletries will be provided were DP1.3.3: soap and tissue, while the washing will meet by DP1.3.4: providing sink. This description is as shown on Figure 3.



Figure 3 - Virtual design of toilet facility

The design considered FR1.4: accessible for wheelchair. To satisfy this requirement, it was needed large restroom, which adjusted with the wheelchair size. Based on observation, it was proved that range of wheelchair width was 50-85 cm. Therefore, the door width will be 100 cm. DP1.4: overall toilet dimension, will be designed in 1.8 m x 2.25 m purposed to give space for rotation inside the room. Dimension of toilet can be seen on

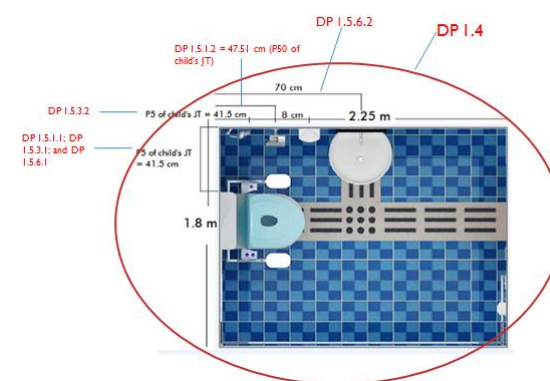


Figure 4.

Figure 4 - Virtual design of toilet from top view

Another aspect was providing FR1.5: easiness to reach the accessories of toilet. The accessories consist of toiletries (tissue and soap), lamp button, and shower, button of toilet height, flush button, and sink. To respond the requirement, the DP1.5: location of those properties provided. The horizontal location of toiletries was suited with DP1.5.1.1: P5 of hand reach for child as much

as 41.5 cm. This setting purposed to fit the people who have the small size because toiletries were important necessary in toilet. The vertical location actually will be suited with the elbow height in standing position, but there was no complete data in standing position due to the most of data came from the physically disabled people. To cover this condition, this substituted with DP1.5.1.2: which was the additional of popliteal height and elbow height in sitting position. The size was suited with the P50 of adult because it covers the average of people, include child. In addition, short position was not good also for the people in common. The z-axis of this position was suited with the P50 of hand reach of child for tissue and P95 for soap. There was difference size because to create the distance between the location of tissue and soap. DP1.5.6.2: vertical position of sink was suited with the P5 of shoulder height in sitting position on adult so this will not too short for the people who have big size. The position of sink is shown on the Figure 5.



Figure 5 -Virtual design of sink location

For DP1.5.2.1: horizontal location of reachable lamp button, was 25cm of the left door inside the room. This calculation based on the observation in several place of location of lamp button. While the DP1.5.2.2: vertical position, was suited with the P50 of hand grip in sitting position for adult because it covers the average size of adult and adult prefer tend to turn on-off the lamp than the child. DP1.5.3.1: horizontal position of shower and DP1.5.6.1: horizontal position of sink were same with the horizontal of toiletries, which was 41.5 cm suited with the P5 of child's hand reach. DP1.5.3.2: Vertical position was fitted with P50 of popliteal height for adult to cover the average of people with the z-axis was suited with P5 of hand reach for child to approach the reachable distance. DP1.5.3.3: right-left handed position, applied and DP1.5.3.4: automatic shower, this description can be seen on Figure 6.

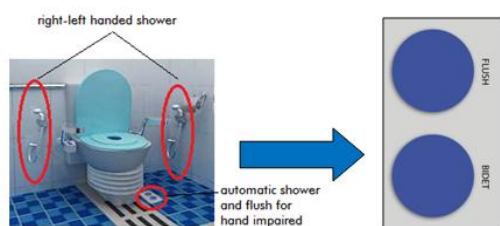


Figure 6 -Virtual design of automatic shower and flush button

For DP1.5.4.1: horizontal location of the adjustable button, was 7 cm from the center point with the

periphery of toilet cross sectional area. This size was suited with the P5 of metacarpal until thumb width for adult because it was the most possible size than the other. It was reachable size also for child. DP1.5.4.2: vertical location, was put depends on the height of toilet, which the range was 19.5-40.2 cm. DP1.5.5.1: horizontal location of flush button, was measured 0 cm because it will be located at the toilet, behind the back so there was no distant between the buttons to toilet. DP1.5.5.2: vertical position was suited with the P5 of shoulder height in sitting position on adult. It considered getting the middle size for the people. If the height of flush button was considered with the minimum size of child, it will be difficult for adult to reach the button that can be seen on



Figure 7.

Figure 7 -Virtual design for location lamp button and hand grip

The remaining was FR1.6: minimizing effort of control device. In addition to consider the design of toilet and the room, the control device considered as well. DP1.6: adjustable design, considering with ergonomic aspect. Based on the survey, the ergonomics aspect includes the simple mechanism controller of lamp button, shower, height of seat, flush, cavity, and sink faucet, which do not need more effort to use it. To provide FR 1.6.1: the lamp controller, it needs DP1.6.1: on-off button mechanism of the lamp button. DP 1.6.2: button was press head shower as the parameter for satisfying FR1.6.2: the mechanism of shower. Then, to provide FR 1.6.3: adjustable height controller, FR 1.6.4: simple mechanism of flush, and FR 1.6.6: voice controller then used DP1.6.3: press button mechanism of height controller, DP1.6.4: press button mechanism of flush, and DP 1.6.6: press button mechanism of voice button. To satisfy FR1.6.5: provide simple mechanism of cavity, it made DP1.6.5: open-close the cavity mechanism. The first layer was for child dimension and the second layer was for adult dimension. To satisfy FR1.6.7: simple and cheap mechanism, it made DP1.6.7: turning faucet. The control devices are shown on Figure 8.



Figure 8 - Virtual design of control devices on toilet

The last one was FR1.7: avoiding the accident that was involving FR1.7.1: providing safe material of the floor and FR1.7.2: railing at the wall. As FR1.7.2: safe design of toilet, it will made DP1.7.1: mosaic ceramics flooring that has good aesthetic and it made from no slippery material so that it will safe for the customer especially for elderly. Another aspect of safe point was the additional railing at the wall. DP1.7.2: horizontal handle, installed to fill the space efficiently. The length of railing will be depends on the area, and DP 1.7.2.2: diameter of railing will be 3 cm. The height was fitted with DP1.7.2.1: average of elbow height in standing position (tsb) of adult as much as 87.1 cm¹⁰. However, the dimension of elbow in standing position did not been obtained because most of the respondents were wheelchair and they could not take standing position. It was because the railing was a tool to help the elderly or physical impaired to walk inside of the room. Virtual design of material is shown on Figure 9.

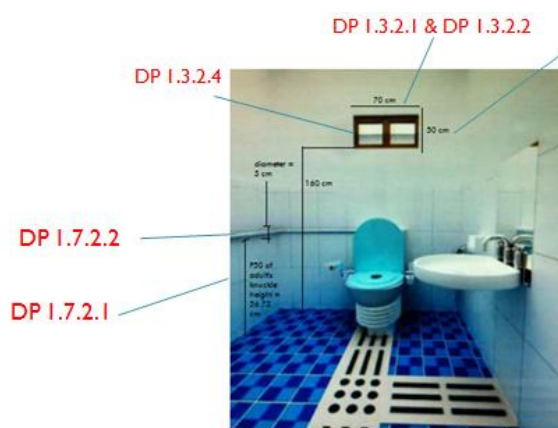


Figure 9 - Virtual design of floor and wall

DP2 for FR2: improving value product, was the aspects of product benefit that branched more specific into three points of FR, were FR2.1: provide information clarity, FR2.2: aesthetic value of the toilet, and FR2.3: flexibility in use. DP2.1 will satisfied FR2.1: display design. This display will provide for child and elderly. It was not only for the normal people with the particular needs but also for the disable people including all aspects, are hearing-speech impaired, visually impaired, wheel chaired, and hand-leg disabled.

The display designed with many considerations to provide FR2.1: clear information for all parties. The parameter of this requirement was DP2.1:

display design. FR2.1.1: information board, will be made clearly and simple. The design consists of DP2.1.1: text, symbol, and voice formation. FR2.1.1.1: information included toilet usage procedure in DP2.1.1.1: form of SOP. The SOP divided into two forms, which were FR2.1.1.1.1: provide information for visually unimpaired and FR2.1.1.1.2: visually impaired. The visually unimpaired consists of normal, hearing impaired, and mental impaired.

Hence, the information for visually unimpaired will be formed as DP2.1.1.1.1: text and for the visually impaired will be formed as DP2.1.1.1.2: audio. The other FR2.1.1.2: information were about the direction, FR2.1.1.3: inclusive toilet in the front of the door, and FR2.1.1.4: usage of button provided. The information about direction made in form of visually impaired floor as the direction for visually impaired to walk inside of the room to go to the closet based on the standard rule^{11,12}. The floor contains of stick out nodes to direct them whether they have to move straight or turn as shown on Figure 10.

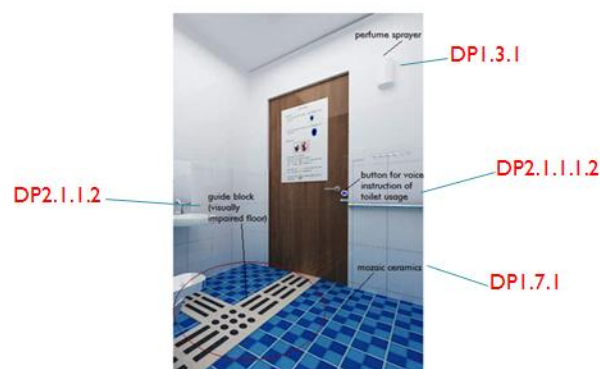


Figure 10 - Virtual design of toilet information

To provide FR2.1.1.3: information about the user and show that the toilet used for wider population, DP2.1.1.3: symbol given at the front of the door. This information divided into DP2.1.1.3.1: visual for FR 2.1.1.3.1: satisfying outside of visually impaired and DP2.1.1.3.2: voice information for satisfying FR2.1.1.3.2: visually impaired. The symbols of inclusive toilet design marked on the doorstep is shown on Figure 11.



Figure 11 - Information of manual toilet usage

Besides that, attractive visual appearance of toilet will provided to increase DP2.2: attractiveness customer to the toilet. DP2.2.1: The aesthetic aspects consist of shape of the toilet that was still standard based on the research. Other aspects were texture and color variation of the toilet. Based on survey that spread, DP2.2.2: texture chosen was plain because the most number of the respondents was adult and they prefer to choose plain texture than the others. Whilst DP2.2.3: color variation was combination of white and blue, as shown on Figure 12. Blue was the most preferred color by adult in general across the cultures which creates the calmness, comfort, peace, quiet, and relax for the user^{13,14,15,16}. White was considered the neutral color and pure. Thus, by combining blue and white, it will create the clean



impression¹⁶.

Figure 12 - Virtual design of seat design and colors

Adjustable seat design for DP2.3: adjustable of toilet height and two layers of cavity. DP 2.3.1.1: The adjustable height was fitted with P5 of child's popliteal height for the minimum height and DP 2.3.1.2: P95 of adult's popliteal height for the

maximum height. The cavity divided into two layers, which were for child and adult. By using anthropometric data, the dimension used in designing this part was popliteal buttock and thigh width. The child dimension was fitted with P5 of popliteal buttock and adult dimension was fitted with P95 of popliteal buttock. The purpose two cavities on toilet seat is shown on Figure 13.



Figure 13 - Virtual design of cavity size of the seat

VALIDITY TEST

Table 1 shows the result of Marginal Homogeneity test which it is to test the hypothesis of the data. This hypothesis is there is no different between customer criteria and design parameters. The result presents that the design is valid to satisfy customer criteria at 5% significance level. It means that the proposed toilet design may be used by the disabled user conveniently and satisfied.

Table 1 -Marginal Homogeneity Test Result

	Attributes	Asymp.Sig.(2-tailed)	Status
CA1	Easy	0.508	Accepted
	Comfort	0.327	Accepted
	Safety	0.651	Accepted
CA2	Aesthetic	0.077	Accepted
	Flexible	0.481	Accepted
	Clear information	0.695	Accepted

CONCLUSION

The design parameters developed divided into material, dimension, position, shape, colour, and types of voice and symbol. Mix of acrylic 85% and nylon 15 % for cross sectional area, teak wood for frame of window, aluminium covered by plastic for arm rest, fruit aroma perfume, on-off button of lamp, press head shower, press adjustable height button, press flush button, open close cavity, dimension of cross sectional area which was 9 cm and 20 cm, length of arm rest 25.21 cm, height of arm rest 19.83 cm, 30x50 cm of window's dimension, rest room area 1.8x2.25m, horizontal position of toiletries 41.5 cm, vertical position of toiletries was 52.79 cm, horizontal position of lamp

button 10 cm from the left door, vertical position of lamp button was 112.39 cm, horizontal and vertical position of shower were 41.5 cm and 40.2 cm respectively, horizontal and vertical position of adjustable height button were 7cm and 19.5-40.26 cm respectively, horizontal and vertical position of flush button were 0 cm and 38.8 cm, horizontal and vertical position of sink were 41.5 cm and 50.55 cm, press voice button turning faucet (90°), height of hand rail was 87.1 cm, and the diameter of hand rail was 3 cm, font of text SOP information was 60 point, dimension of visual display was 80 x 60 cm, height of adjustable height was 19.5 cm-40.26 cm, popliteal buttock of child was 18 cm, and adult size was 45.4 cm, two units of window, the position was exactly in the middle of the inner side wall of the

bathroom which the upper side of the window is same with the door, rectangular form of the window, standard shape of toilet, plain pattern, combination of white-blue. The types of voice and symbols such as: voice of SOP information, voice of inclusive information, visually impaired floor, visual inclusive symbol, adjustable height visual button symbol, adjustable height voice button symbol.

The proposed design was valid to satisfy the customer needs at 5% of significance level.

FUTURE RESEARCH

The future study needs to be improved by expanding the research scope into economic aspect, usability aspect, and others such as wider scope of respondents. Besides that, mechanical engineering, electrical engineering, and information system technology should be considered.

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