Developing Foot Lock for Public Toilet Facilities

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Abstract

The impact of the COVID-19 pandemic is detrimental to the community; therefore, it is necessary to take actions that can minimize the spread of COVID-19 so that business sustainability can be maintained. One way to minimize the spread of COVID-19 is to reduce physical contact using hands. However, based on observations, it is known that there are no available tools in Indonesia that are used to avoid hand contact with the toilet door lock. This of course can be a means of spreading the Covid-19 virus. Therefore, in this study, a foot-operated toilet door lock was designed and made so that it is expected to reduce the spread of the covid-19 virus. Foot lock product design was carried out using the Quality Function Deployment method. Customers' needs were identified by using interviews and questionnaires. Quantitative measurements were conducted to identify priorities, which consist of respondent satisfaction level, goals and sales points, improvement ratio, and row weight. The research continued with the development of technical responses (HOWs) to meet customers' needs and then the house of quality was developed. Alternative design concepts were developed using a morphological chart. The selected design was then made into a foot-operated door lock and tested for ease of use. The foot lock that has been made has an outer dimension of 308 x 126 x 121 mm.

Keywords
Foot lock, Public Toilet Facilities, Quality Function Deployment, Covid-19 pandemic

1. Introduction
The spread of the COVID-19 disease that continues to increase in Indonesia has a negative impact on the country's economic growth in the industrial, mining, development, trade, and other sectors. The continuous spread of Covid 19 and the increasing number of cases also make the performance of an organization or company decline. Based on the impact of the spread of the COVID-19 disease that is detrimental to the community, it is necessary to take actions that can minimize the spread of COVID-19 so that business sustainability can be maintained. One way to minimize the spread of COVID-19 is to reduce physical contact using hands. Prevention of physical contact with hands is very important because the hands are the body parts that generally touch the eyes, mouth, and nose, where these parts become a means of transmitting COVID-19. By preventing physical contact using hands and washing hands regularly, it is expected to minimize the spread of COVID-19. Touch-free handle and interface is one method to reduce Covid-19 transmission (Barnes and Sax 2020).

With the aim of minimizing the spread of COVID-19, many tools have been made to avoid physical contact with hands. These tools can be in the form of sensors on parking ticket machines or foot-operated hand soap dispensers. Based on observations, in Indonesia, there is currently no foot-operated toilet door lock. The problem is that the lock handle on the toilet door can be a source of spread of disease because it is generally used and touched by hand so that the hands can be contaminated by viruses and bacteria. According to Pan et al. (2021), although SARS-CoV-2 is transmitted mostly by respiratory droplets and direct contact, but it turns out that viral RNA fragments have also been detected in the faecal waste of Covid-19 patients. Therefore, the cleanliness and effective sanitation of public toilets must be a high priority concern.

1.1 Objectives

This research was conducted with the aim of developing a foot-operated toilet door lock so that physical contact using hands in the public toilets is minimal thus the spread of Covid-19 can be reduced. Hopefully, the economic activities could be recovered, and business sustainability could be maintained.

2. Literature Review

According to Ulrich and Eppinger (2012), there are six phases in developing a product, namely:
• Phase 0: Product Planning
At this phase, the target market for the product, the targets to be achieved by the company, all assumptions made, and the various limitations that exist are determined. This is also known as a mission statement.
• Phase 1: Concept Development
In this phase, the identification of existing market needs that have been determined in the previous phase is carried out. From the identified needs, various product concepts can be developed which will later be evaluated for each product. The product concept with the best evaluation results will be realized into a real product.
• Phase 2: System-Level Design
The system-level design consists of product architecture, subsystems, and components of the product, as well as the final assembly process.
• Phase 3: Detailed Design
In this phase, a complete specification of the geometry as specified in the technical drawings, material specifications, and the tolerance level are determined. The identification of all standard parts to be purchased from suppliers is identified as well.
• Phase 4: Testing and Refinement.
At this phase, the prototype is made according to the design concept that has been determined. Testing is carried out on the prototype and if it does not function as desired or does not meet consumer needs, then refinements are made until it reaches the predetermined expectations.
• Phase 5: Production ramp-up
In this phase, the product can be produced by using the intended production system. The purpose of this phase is to familiarize workers with the new production method and to quickly identify its shortcomings of the new production method.
According to Ficalora and Cohen (2010), Quality Function Deployment (QFD) is a quality planning and management process to drive the best possible product and service solutions based on customer needs. Four phase model of QFD proposed by Hausser and Clausing (Maritan 2015) consists of four matrices, namely, House of Quality (HoQ), Part Deployment Matrix, Process Planning matrix, and Production Planning Matrix. To develop HoQ, there are several steps including identifying the Voice of Customers or customer needs (WHATs), determining the importance of customer needs, developing technical responses (HOWs), identifying relationships between customer needs and technical responses, developing technical correlations matrix, and determining desirable technical attributes (Ficalora and Cohen 2010).
Several previous studies related to the door opening tool using a foot pedal can be seen in figure 1-figure 5. In figure 1, a device for opening the door by using a foot was installed inside the door leaf. A pedal located at the bottom of the door leaf was integrated into the device. To open the door, this pedal was pulled out from the inside of the device by using the foot. After the pedal is completely pulled out, the door can be pushed or pulled to open while keeping light pressure on the pedal with the foot (Preiss and Kramer 2011). The second design (figure 2) was an invention that relates generally to a foot-operated door opening device particularly suited for opening doors of walk-in type refrigerators (McBain 1993). This device could be readily retrofitted into the existing door, and it included a lever system that could be adjusted to accommodate different handle sizes. A foot pedal was used to activate the device. The third design (figure 3) related to a foot-operated door opener suited for use in public facilities such as restrooms (Stuart 2007). This device included an elongate housing that has openings at the upper and lower ends. There was an elongate actuator that extended through the housing. An upper end of the actuator was engaged with the door handle and the lower end of the actuator carried a foot pedal. To pull the actuator downwardly, the foot pedal had to be depressed. This mechanism would rotate the door handle to open the door. The fourth design (figure 4) is related to a foot-operated door opener, comprising a foot-operated actuator mechanism (1) with at least one foot surface element

(3) and a door-opening mechanism (2) to open the door (Klein 2016). The fifth design (figure 5) was a foot-operated door lock for bathrooms, comprised of a door plate, a door frame, a lock rod and pedals (Xia 2009).

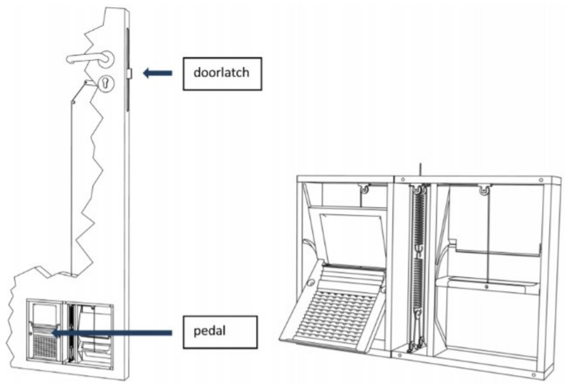


Figure 1. Door opener with optional hand or foot operation (Preiss and Kramer 2011)

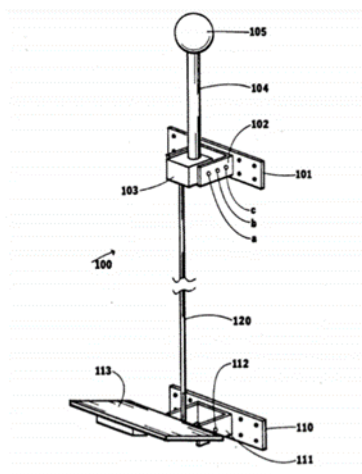


Figure 2. Foot activated door opener (McBain 1993)

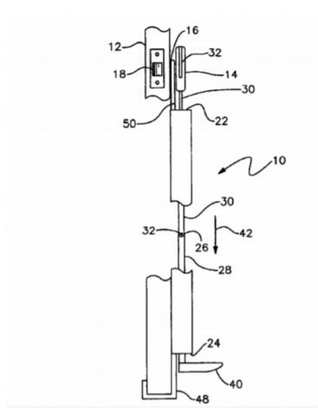


Figure 3. Foot-operated door opener (Stuart 2007)

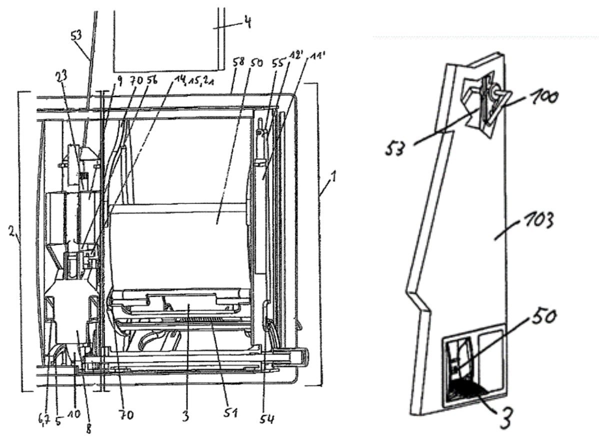


Figure 4 Foot-operated door opener and door (Klein 2016)

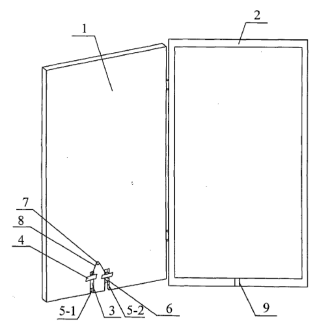


Figure 5. Washroom foot-propelled door lock (Xia 2009)

There was also one study (Maranha et al. 2021) regarding the development of a dynamic hands-free door opener (figure 6). The door opener was designed to be operated by arm.

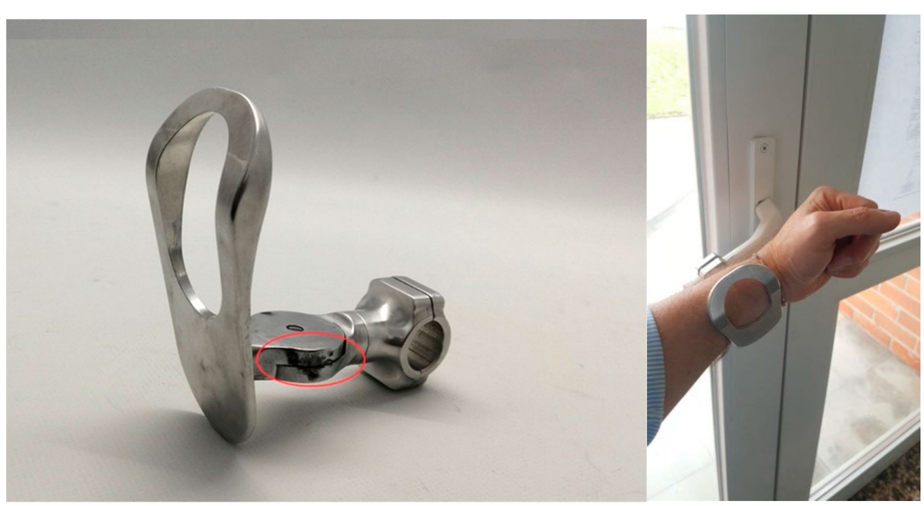


Figure 6. A dynamic hands-free door opener (Maranha et al. 2021)

3. Methods

The research method consisted of 10 phases as follows:

1. Preliminary research included searching for information regarding problems with the spread of COVID-19 that may occur in public places through literature studies and observations in public places.
2. Formulation of problems. Based on the results of preliminary research conducted on public toilet facilities, it was found that there was a problem with the toilet door lock that could cause hands to be contaminated with the COVID-19 virus. Therefore, it is necessary to consider another alternative which is a foot-operated door lock.
3. Determination of research objectives. The purpose of this study was to make a foot lock, which was a foot-operated door lock used in public toilets. The foot lock would be expected to minimize the transmission of COVID-19 by changing physical contact from hand to foot in opening, closing, and locking the toilet door.
4. Literature study was conducted to obtain theories that will be the basis for this research including the product design process, Quality Function Deployment (QFD), and previous research.
5. Data collection consisted of primary data and secondary data. Primary data included customer statements regarding the need for a more hygienic toilet door lock, as well as the level of importance of these needs. Customer statements were collected by interviewing several business owners. In addition, alternative materials that can be used were also needed, as well as anthropometric data needed for the design of the foot lock. Secondary data needed were consumer profile data, and existing door lock products for comparison.
6. Identification of consumer needs. In this phase, the customer statement data that has been obtained from the interviews will be transformed into a questionnaire that will be distributed to public toilet users to get the level of importance of the customer statement.

7 Quantitative measurements were conducted to identify priorities, which consist of respondent satisfaction level (collected by using questionnaires), goals and sales points (determined by the design teams), improvement ratio (calculated as a ratio of goals and satisfaction level), and row weight. After the data on quantitative measurements were obtained, the research continued with the development of technical responses (HOWs) to meet the needs of consumers. Then the row weight and column weight were calculated which will eventually be combined in the form of a house of quality.

8. Development and assessment of alternative concepts. Based on the values obtained in the House of Quality, several foot lock designs can be made. Concepts were made using a morphological chart. After that, the design concept was selected based on the highest criteria value which will be continued in the tool-making phase.
9. Making foot lock. At this phase, a rough sketch of the product was made, which was further detailed into a sketch of each component making up the product and refined into a technical drawing. The research continued with the purchase of materials and components needed to make foot lock. The process of making components was carried out according to the technical drawings so that they were ready to be assembled into a foot lock.
10. Testing foot lock was conducted to test the performance of foot-operated door lock. If any faults were found in the trial of the foot lock, repairs would be carried out immediately. The improved tool then should be tested again.

4. Data Collections

Based on the results of interviews with a restaurant owner, a factory owner, and a mall worker in charge of mall facilities, 11 customers' needs for the toilet door lock were obtained as seen in table 1.

Table 1. Customer needs

No	*Customer's Statements*	*Need Statements*
1	Lock is durable	Durable lock
2	Affordable price	Affordable price
3	lock is easy to use	Ease of use
4	lock is comfortable to use	Ergonomic lock
5	lock can be used by children and elderly people	A broad range of use
6	lock can be installed on any door type	Flexible to use
7	lock can be cleaned easily	Ease of cleaning
8	lock can protect users' hygiene	Hygienic foot lock

9	lock can be used smoothly	Smooth key slot
10	Safety feature is available	Safety feature
11	lock has an aesthetic aspect	Good design

The level of importance of customers' needs (table 2) and the level of satisfaction with the currently existing toilet door lock (table 3) were determined, through questionnaires distributed to 34 toilet users.

Table 2 The level of importance of customers' needs

No	Need Statements	Importance rating					average
		1	*2*	*3*	*4*	*5*	
1	Durable lock	0	1	0	8	25	4.68
2	Affordable price	0	2	5	10	17	4.24
3	Ease of use	0	0	0	5	29	4.85
4	Ergonomic lock	0	0	1	7	26	4.74
5	A broad range of use	1	1	2	9	21	4.41
6	Flexible to use	1	1	6	4	22	4.32
7	Ease of cleaning	2	0	4	7	21	4.32
8	Hygienic lock	0	0	3	9	22	4.56
9	Smooth key slot	0	0	1	3	30	4.85
10	Safety feature	1	0	1	7	25	4.62
11	Good design	2	2	12	10	8	3.59

Table 3. The satisfaction level of the currently existing toilet door lock

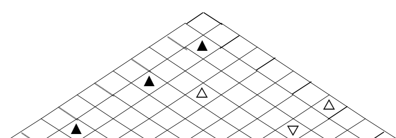
No	Need Statements	Satisfaction level					average
		1	*2*	*3*	*4*	*5*	
1	Durable lock	0	1	5	13	15	4.24
2	Affordable price	0	0	7	12	15	4.24
3	Ease of use	0	2	3	8	21	4.41
4	Ergonomic lock	1	1	7	11	14	4.06
5	A broad range of use	0	3	2	8	21	4.38
6	Flexible to use	0	0	2	12	20	4.53
7	Ease of cleaning	1	2	7	11	13	3.97
8	Hygienic lock	6	6	1	8	13	3.47
9	Smooth key slot	0	6	7	8	13	3.82
10	Safety feature	4	8	4	7	11	3.38
11	Good design	2	2	10	14	6	3.59

Then the goals and sales points were determined, while the improvement ratio was obtained by dividing the goal by satisfaction level. The goal, sales point, and improvement ratio for each customer need can be seen in table 4.

Table 4. Goal, Sales Point and Improvement Ratio

No	Need Statements	Goal	Sales Point	Improvement ratio
1	Durable foot lock	5	1.5	1.18
2	Affordable price	4	1.5	0.94
3	Ease of use	5	1.5	1.13
4	Ergonomic foot lock	5	1.2	1.23
5	A broad range of use	5	1.2	1.14
6	Flexible to use	5	1.2	1.10
7	Ease of cleaning	5	1.5	1.26
8	Hygienic foot lock	5	1.5	1.44
9	Smooth key slot	5	1.5	1.31
10	Safety feature	4	1.5	1.18
11	Good design	3	1.5	0.84

Furthermore, the row weight was calculated as the product of the level of importance, sales point, and improvement ratio. There were 11 technical responses determined based on the previously obtained consumer needs. Then the relationships between each customer's need with technical responses, the direction of development of technical responses, and the relationship among technical responses were determined. Further, the target value was determined for each technical response and the column weight was calculated. After all the data were complete, a House of Quality (HoQ) was made which can be seen in Figure 7.



Technical Responses	materials used	ease of manufacture	foot lock dimension	foot lock stability	foot lock position	label on foot lock	component variation	shape of foot lock frame	foot lock operation	dimension accuracy	mechanical system	importance level	satisfaction level	Goals	Sales Point	Improvement Ratio	Row Weight
Direction of Improvement	●	●	▼	▲	●	●	▲	▼	▼	●	●						
customers' needs																	
durable foot lock	9											4.68	4.24	5	1.5	1.18	8.28
affordable price	9	9										4.24	4.24	4	1.5	0.94	6.00
ease of use			3	9								4.85	4.41	5	1.5	1.13	8.25
ergonomic foot lock			9		3							4.74	4.06	5	1.2	1.23	7.00
broad range of use						3						4.41	4.38	5	1.2	1.14	6.04
flexible to use							9					4.32	4.53	5	1.2	1.10	5.72
ease of cleaning	1		3					9				4.32	3.97	5	1.5	1.26	8.16
hygienic foot lock									9			4.56	3.47	5	1.5	1.44	9.86
smooth key slot										9		4.85	3.82	5	1.5	1.31	9.52
safety feature								3			9	4.62	3.38	4	1.5	1.18	8.20
good design								9				3.59	3.59	3	1.5	0.84	4.50
	85	38	70	44	14	13	39	85	41	44	42						
	16	7	14	8	3	3	8	17	8	8	8						

Figure 7. House of Quality of foot lock.

5. Results and Discussion

Based on the relationship between the technical response and critical parts that have been carried out, the strength of each existing relationship was determined. The relationship that was classified as weak will be given a value of 1. If the relationship was classified as moderate it will be given a score of 3. The relationship that was classified as strong will be given a value of 9. The strength of the relationship between the technical response and critical parts was described in table 5. Based on the HoQ that has been created, there were three consumer needs categorized as important, namely: hygienic foot lock, smooth key slot, and durable foot lock. In addition to the HoQ, there were also three technical responses that have significant value, namely the shape of the foot lock frame, the material used, and foot lock dimension.

A morphological chart was created based on the three most important technical responses and consumer needs. The morphological chart was made to develop several alternative concepts. Then one alternative was chosen to be made into a real product. On the morphological chart, there were six criteria, and each of them has three to four choices. The morphological chart that has been made can be seen in table 6. Based on table 6, there were many combinations that can be made, but in this study, only 3 alternative concepts of foot lock design were made. The first design concept used iron as the main and frame material, silicone pedal, sliding as the operational method, and screw as the connector of the assembly and frame. This first design alternative can be seen in Figure 8 (a). The second design concept used stainless steel as the material of the main body and frame, PVC as pedal material, pressing as the operational method, assembly connectors used bolts and nuts while the frame connectors used welding. The second alternative design can be seen in Figure 8 (b).

Table 5. Part Deployment Matrix

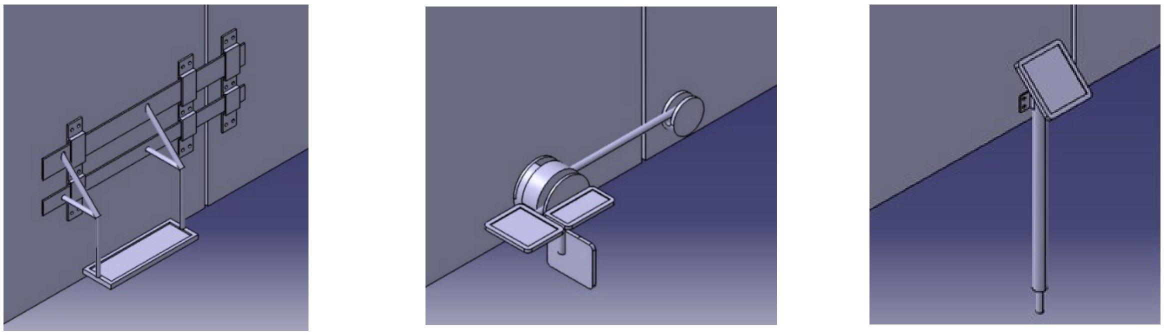
.

No	**Technical response**	main frame	slot handle	bolt and nut	lock bar	foot step	**Row Weight**
1	materials used	9	3		3	3	16
2	ease of manufacture	9	1			3	7
3	foot lock dimension	9	1		3	9	14
4	foot lock stability		3	9	3	9	8
5	foot lock positioning	9	3			3	3
6	label on foot lock					3	3
7	component variation			9			8
8	shape of foot lock frame	9	3		3	9	17
9	foot lock operation	9					8
10	dimension accuracy	9	3		3	3	8
11	mechanical system	9					8
Column Weight		729	177	144	189	462	
Percentage		43%	10%	8%	11%	27%	

Table 6. Morphological Chart.

Criteria	**option 1**	**option 2**	**option 3**	**option 4**
main material	*Stainless Steel*	iron	*PVC*	-
frame material	*Stainless Steel*	iron	*PVC*	-

pedal	rubber	silicon	*PVC*	iron with thread
operational method	slide	press (rotation)	press (spring)	
assembly connector	welded	bolt and nut	screw	
frame connector	welded	bolt and nut	thread	screw



(a) **b)** **(c)**

Figure 8. Alternative design concept 1 (a), concept 2 (b) and concept 3 (c).

The third design concept used PVC as the material for main body, frame, and pedal, pressing (using spring mechanism) as the operational method and screws to connect the assemblies and thread for frames assembly. The third alternative design concept can be seen in Figure 8(c). Of the three alternatives, an assessment was carried out to select a concept to be made into a finished product. The summary of the assessment can be seen in table 7.

Table 7. Design concept selection

No	**Criteria**	**weight (%)**	**average score**			**weighted score**		
			Alt 1	*Alt 2*	*Alt 3*	*Alt 1*	*Alt 2*	*Alt 3*
1	functionality	31%	4.67	4.67	4.00	1.43	1.43	1.22
2	ease of use	22%	3.33	5.00	4.33	0.75	1.12	0.97
3	ease of manufacture	24%	4.00	3.67	4.33	0.98	0.90	1.06
4	price	22%	3.67	4.33	4.67	0.82	0.97	1.05
					Total	3.98	4.42	4.31

According to table 7, alternative design 2 was chosen to be made as a prototype. Before the prototype was made, the detailed size of the foot lock was determined. Based on the average foot width of Indonesian women (Tan, Hartono, and Kumar 2010), the pedal width was determined to be 9 cm. The pedal length was determined at 5 cm. The length of the lock bar was 20 cm with a diameter of 8 mm. The mainframe size was determined with a diameter of 5 cm and a total thickness of 8 cm. The slot to be made was 2 cm wide, 2 cm long, and 3 cm high. The size of the bolts and nuts was selected with diameters ranging from 4 to 6 mm. Then a technical drawing was made, and a 3D foot lock design can be seen in figure 9.

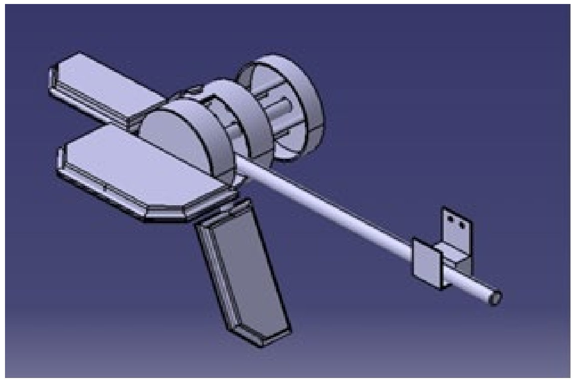


Figure 9. 3D foot lock design

The process of making the prototype was carried out in a workshop. The prototype that has been completed can be seen in Figure 10. After the prototype has been assembled, the function of the prototype was tested, and some shortcomings were found. When the open pedal was pressed to open the lock, the lock bar rose but immediately it fell to the locking position even though the closing pedal was not pressed. The second drawback was the inclined pedal at the open position. After the problems were identified, several improvements were made by making the second prototype. In this second version of the prototype, there was additional support on the mainframe that kept the lock bar open when the user pressed the open pedal, and the bar would not fall into the lock position unless the close pedal was pressed. In addition, the angle between the open and closed pedal bar was changed to 115 degrees. The two bars were level with the pedals both in open and close positions. Figure 11 showed the second prototype that has been made.

Figure 10. The first prototype

Figure 11. The second prototype

After the second prototype was completed, an analysis was carried out to compare the time to open the latch model of the public toilet door (figure 12) with the time to open the toilet door using a foot lock. The test results were shown on table 8.

Figure 12. A typical door-latch

Table 8. Time comparison of opening toilet door

Time to open door using foot lock (s)					Time to open door using door-latch (s)				
6.29	5.04	4.37	4.75	5.83	4.66	4.76	4.69	5.11	4.74
5.64	5.69	5.31	5.53	5.45	4.43	4.85	3.92	4.56	5.12
4.40	4.72	5.82	5.21	4.84	4.87	5.07	4.86	5.32	5.49
4.35	4.24	4.63	4.98	4.65	4.82	4.55	4.67	4.18	4.10
4.58	5.62	5.27	4.61	5.41	5.14	4.40	4.07	5.56	4.61
5.63	4.99	4.46	6.21	5.56	4.94	4.37	5.10	4.33	5.18

Based on table 8, it was known that the average time to open the toilet door using a foot lock was 5.14 seconds, while the average time to open the door latch was 4.75 seconds. In other words, the time to open the toilet door using a foot lock was 8.21% longer than using a latch. The total cost of materials used to make the second prototype of the foot lock is Rp. 60,946.30. Currently, there is a similar product called Merino foot latch, manufactured by Merino company in India which can be seen in figure 13. Its dimension is 131 x 118 x 49 mm (length x width x height). The material used is stainless steel (SS304). The mechanism to open and close the latch is by sliding it to the left and to the right.

Figure 13. Merino foot latch

6. Conclusion

This research has produced a foot lock, which was a foot-operated toilet door lock so that it can maintain the cleanliness of public toilet users and hopefully can reduce the spread of the Covid-19 virus. The foot lock outer dimension was 308 x 126 x 121 mm. To further ensure the stability of the toilet door in a locked condition, it is recommended to improve the foot lock design with a locking mechanism in the center of the door.

Acknowledgements

The research team would like to thank LPPM Universitas Pelita Harapan for funding research no: P-07-S/FaST/V/2021.

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Biographies

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