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Anti-Theft Bike Rack

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Abstract: Bicycle rack typically consist of a base with supporting rails on the side to fit the tire of a bicycle. This rack act like a parking lot for bicycle, it is used to store and keep in the bicycle and make sure it will not fall. However, the rack available on the market today are very basic and not very secure. It is the same case for the public bicycle rack which in Malaysia, even a basic bicycle rack is hard to find as people prefer to ride a car or motorcycle. This public bicycle rack mostly can be found near public transportation stations. A bicycle rack with a built-in lock system was fabricated to enhance the security of the bicycle and will ease the user. The fabrication of an anti-theft bike rack consists of a stopper, pillar, housing, electronic box, and U-shape lock. The bicycle rack strength has been tested by forcefully pulling the U-shape lock using maximum human effort. The electronic locking system has been tested by attempting false trials to observe whether it will release the lock or not. The first experiment shows some deformation of the U-shaped lock, but the whole locking structure remains intact. The electronic locking system remain locking the U-shape lock when the PIN number is incorrect. The results from these experiments successfully testify to the objective which to enhance the security of the bicycle rack, when the U-shape lock remains locking after has been pulled out and the electronic locking system is fully capable to perform its duty with 0.01% of hacker ability. It can be concluded that the fabrication of this product fulfilled the study objectives. However, there are few improvements that can be considered such as adding more solenoid, hybrid power source, and add cover for the electronic box.

Keywords: Bicycle rack, Lock system for bicycle, PIN lock

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1. Introduction

A bicycle, often known as a bike or cycle, is a human-powered, pedal-driven, single-track vehicle having two wheels mounted to a frame, one in front of the other as shown in **Figure 1** [1]. Bicycles can transport us from one location to another, though not as quickly as a car or motorcycle, and they also provide health benefits. It is commonly used as the main transportation in several countries and as a hobby equipment for the people who love to cycle. There are no adequate bicycle racks in Malaysia, and even if there are, they are badly managed or handled. A public transit system, such as the LRT, does not have a bicycle rack, notably in Subang. Some of them even lock their bicycles to the fence, streetlamp, and any other feasible location [2].

Figure 1: Standard bicycle design [1]

A bicycle, like a car, has a lock mechanism for safety. Most of bicycle owners always go for a basic chain lock like in **Figure 2** [3]. Some of products on the market and in public places only include a steel frame and a chain lock. Therefore, the main objective of this project is to design and fabricate a bicycle rack with enhance with a lock system that increases the security of the bicycle. It can reduce the possibility of bicycles from been stolen. Other than that, it can make the bicycle parking look tidy. The bicycle rack comes with an anti-theft system that includes a four-pin numbering system and an alarm buzzer for further safety.

Figure 2: Common chain lock [3]

2. Literature Review

On the market, there are numerous bicycle racks to choose from the available stores and the internet. **Figure 3** depicts the products offered through the online application. The only available product on the market is a bicycle rack that does not include a lock system. It must pair with another locking system [4].

Figure 3: Bicycle rack on the market [4]

There are plenty of bicycle lock variations available in the market. The only difference is the price, material, how tough the lock was and the mechanism of the lock. **Figure 4(a)** is a traditional chain lock. The lock is easy to break and be lock picked [5]. Another lock is a combination lock consist of numbers as shown in **Figure 4(b)**. This lock can be opened via trial and error or just break the lock part [6]. The Head-on bicycle lock in **Figure 4(c)** is a new lock design which locks the tire with a helmet as its lock, but it can be overcome by removing the tire as it is the only lock placed on the tire [7]. This project concept is a bicycle rack with a PIN lock system by Arduino program. The bicycle is placed inside the rack with a lock that will hold the bicycle in place.

(a) (b) (c)

Figure 4: Type of chain lock (a) Traditional chain lock [5] (b) Combination lock [6] (c) Head-on bicycle lock [7]

3. Methodology

To make the anti-theft bike rack, the process must follow step by step procedures. It must start from the beginning in order to make the project happen.

3.1 Fabrication of anti-theft bike rack and Material of Component

Figure 5(a) shows the design of the anti-theft bike rack. **Figure 5(b)** shows a normal bicycle rack with a specific height and width. Two rectangular shapes with size 50cm × 2cm × 2cm as the stopper with 28 cm width between them and two pillars with 20 cm width and 30 cm length. A basic stopper will be welded to the pillar left and right to strengthen the bicycle rack from collapse. **Figure 5(c)** shows a number pad lock powered by Arduino and it requires a password to open the lock. If the user inserts the wrong password, the LCD display will be displaying wrong password. **Figure 5(d)** shows a U-shape lock that locked the bicycle by the Arduino. The U-shape design is used because the shape is the strongest compared to others. The size of the U-shape is 20 cm width and 1cm radius.

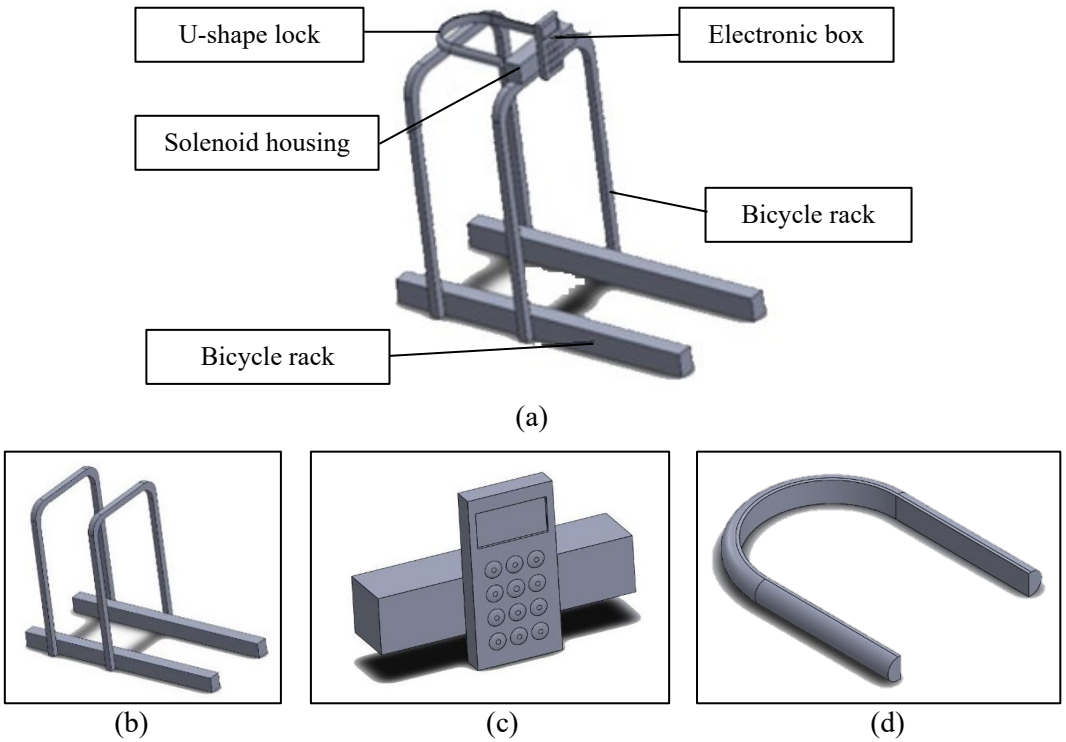

Figure 5: (a) anti-theft bike rack Solidworks drawing (b) Bicycle rack (c) Solenoid housing and electronic box (d) U-shape lock

Table 1: Characteristic and Mechanical Properties of Material for Each Component

Component	Material	Characteristic/ Mechanical properties of Material
Bicycle rack stopper	Aluminium	· Corrosion resistance · Strong · Ultimate tensile strength, 110 MPa · Tensile Modulus, 69 GPa
Bicycle rack pillar	Aluminium	· Corrosion resistance · Strong · Ultimate tensile strength, 110 MPa · Tensile Modulus, 69 GPa
Solenoid housing	Aluminium	· Corrosion resistance · Strong · Ultimate tensile strength, 110 MPa · Tensile Modulus, 69 GPa
Electronic box	Polyvinyl Chloride (PVC)	· Strong · Weatherproof
U-shape lock	Galvanized metal	· Does not rust · Strong · U-shape lock will prevent damage paint on bicycle · Ultimate tensile strength, 79.8 MPa

Table 1 stated all material that has been used for each component. Bicycle rack stopper, bicycle rack pillar and solenoid housing are using Aluminium metal material because these components will be exposed to weather conditions which are sun and rain. Aluminium metal has been chosen as it is non-ferrous metal, corrosion resistant, easily cast, welded and machined [8]. Aluminium is ideal for a bicycle rack because it does not contain iron, so it has higher resistance to rust and corrosion. Even the metal cannot rust, but it does oxidize. When the Aluminium is exposed to water, a film of Aluminium oxidizes quickly on the surface. To prevent Aluminium from oxidizing, the surface of the stopper, pillar and solenoid housing will be coated. The amount of ultimate tensile strength and tensile modulus for Aluminium is 110 MPa and 69 GPa. The material for the electronic box that has been choosen is Polyvinyl Chloride (PVC). PVC has many advantages such as being extremely hard and generally strong. PVC is an extremely durable, lightweight and high chlorine content makes the material fire-resistance [9]. PVC is very ideal for the electronic box since it is exposed to the sun and rain. Moreover, if inside the electronic box a short circuit and resulting in fire, PVC will reduce the amount of fire spread [10]. The galvanized metal has been chosen for the U-shape lock because the surface of the galvanized metal is more durable, and it will not be oxidized too quickly. Other than that, galvanized metal is not easy to freeze and crack even in cold weather and very suitable for locking the bicycle especially in the cold and freezing environment [11]. The ultimate tensile strength for galvanized metal is 58 MPa to 79.8 MPa [12].

3.2 Experimental Setup for Strength Analysis

The main purpose of the anti-theft bike rack product is to provide full security to the user's bicycle. In order to test the bicycle security, an experiment needs to be conducted to test the bicycle rack security strength. Four civilians that consist of two males and two females that have different heights, different weights, and different ages have been called to test the product security as shown in **Table 2**. They have been told to pull the U-shape lock with their maximum force in just a short time. A blue line has been marked as the starting point, 0 cm. After the civilians have pulled the U-shape lock, the distance from the housing and the blue line will be measured by measuring tape. After five times test, the average movement will be taken.

Table 2: Characteristic for each civilian

Civilians	Gender	Age	Height (cm)	Weight (kg)
A	Male	51	165	68
B	Female	44	156	79
C	Male	20	170	55
D	Female	21	156	70

3.3 Arduino setup for locking system

The anti-theft bike rack that has been fabricated is equipped with a security system that is powered by Arduino. The user that wants to unlock the lock must key in the correct four-digit PIN number. If the PIN number is correct, it will trigger the solenoid and it will retract and release the lock. To test the efficiency of the lock system, a few trials of a multiple PIN numbers will be typed in. The PIN number that will be tested on the locking system will be a combination of any four-digit number as shown in **Table 3**. The observation will be made after the attempts have been made whether the solenoid is retracted or not.

Table 3: The chosen PIN number combination

Trial	PIN number
1	1234
2	1235
3	8888

4. Result and Discussion

The anti-theft bike rack has been fabricated and tested in order to testify the objectives. To obtain the analysis result, two experiments have been conducted to test the product. For the first experiment, four civilians from multiple ages, weights, and heights have been called to test the product security. There are two men and two women, one man and one woman are from the middle-aged group and the other one man and one woman are from the adult age group. The civilians were asked to test the lock strength by pulling the U-shape lock by using their maximum force in just a short time. The second experiment is to test the Arduino locking system. A few attempts of multiple combinations of PIN number password will be typed in.

4.1 Working Principle of anti-theft bike rack

Figure 6 shows the fabricated product of the anti-theft bike rack. **Figure 6(a)** shows the base of this anti-theft bike rack product. In consists of two long Aluminium metal as a stopper at the bottom part. The distance of the two Aluminium stoppers at the bottom part is 28 cm. The function of the stopper is to hold the tire in place. The stopper will make the tire of the bicycle not move forwards nor backwards. **Figure 6(b)** shows two pillars that are perpendicular to the Aluminium stopper. The distance of the two pillars attached at the Aluminium stopper is 20 cm. The pillar on the other side is to maintain the bicycle upwards to the ground. This is to make the bicycle not fall to the ground. A Bicycle tyre will be held in between two pillars. It will hold and prevent the bicycle from falling to the ground. **Figure 6(c)** shows the electronic box. This is where the user will type in the PIN number to unlock the bicycle rack. Inside the box is where the Arduino and all the electronic components such as wiring, relay module, and buzzer are placed. The box is made from PVC material. The Arduino is set with one four-digit password. The password can be changed according to the user. The user that wants to unlock it will key in the PIN number and then the Arduino will power up the solenoid. If the password is correct, the Arduino will detect it and trigger the solenoid. The solenoid then will retract and release the lock. If it is incorrect, Arduino will detect it and display 'Wrong Password' on the LCD display and the solenoid will remain locked. The four digits must be all correct in order to unlock it. **Figure 6(d)** shows the housing that is used to attach the lock system of the bicycle rack. The housing has a dimension of (32.5 x 5.5 x 3.5) cm. The housing used is from Aluminium metal. It is where the electronic box will be attached to the bicycle rack. Inside the housing, there is also a solenoid placed. The solenoid is the one that will be the lock for the bicycle rack. **Figure 6(e)** shows the U-shape lock. The function of this U-shape lock is to lock the bicycle on the frame of the bicycle. The U-shape locks is made from galvanized steel. The U-shape lock will go through the frame of the bicycle and go inside the housing where the solenoid is placed. This will make the U-shape lock the bicycle from being stolen. To unlock the U-shape, the user must type in the correct PIN number. When the PIN number is correct, it will retract the solenoid. When the solenoid is retracted, it will release the u-shape lock and the user will pull out the u-shape lock to release their bicycle.

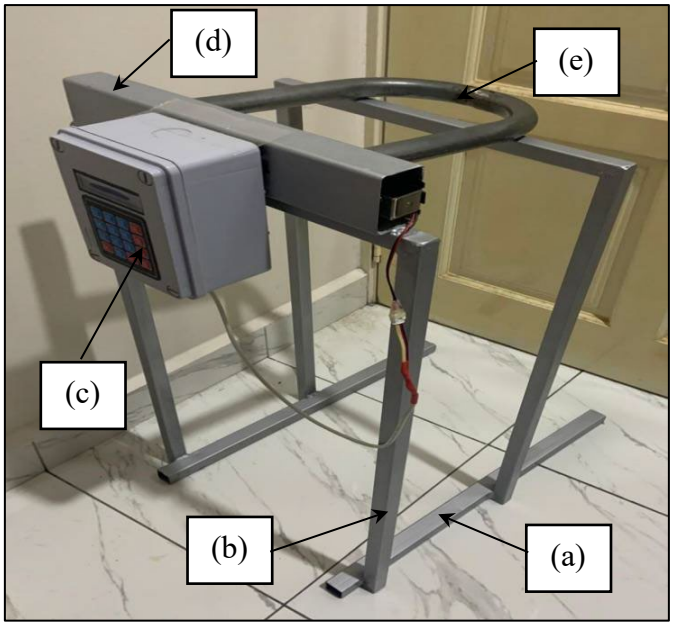

Figure 6: (a) Stopper (b) Pillar (c) Electronic box (d) Housing (e) U-shape lock

Figure 7 shows the anti-theft bike rack being used by one user. In the beginning, the bicycle rack is locked. **Figure 7(a)** shows that the user must unlock it first by pressing the correct four-digit PIN number. This will make the solenoid retract and release the lock. **Figure 7(b)** shows that the user will pull out the u-shape lock. **Figure 7(c)** shows that the user will put their bicycle inside with only the bicycle tire going inside the two pillars. **Figure 7(d)** shows that after the bicycle has been placed inside the bicycle rack, the user now will place the u-shape lock back into the housing. The solenoid will extend and lock the bicycle. The bicycle inside is now safe and secured.

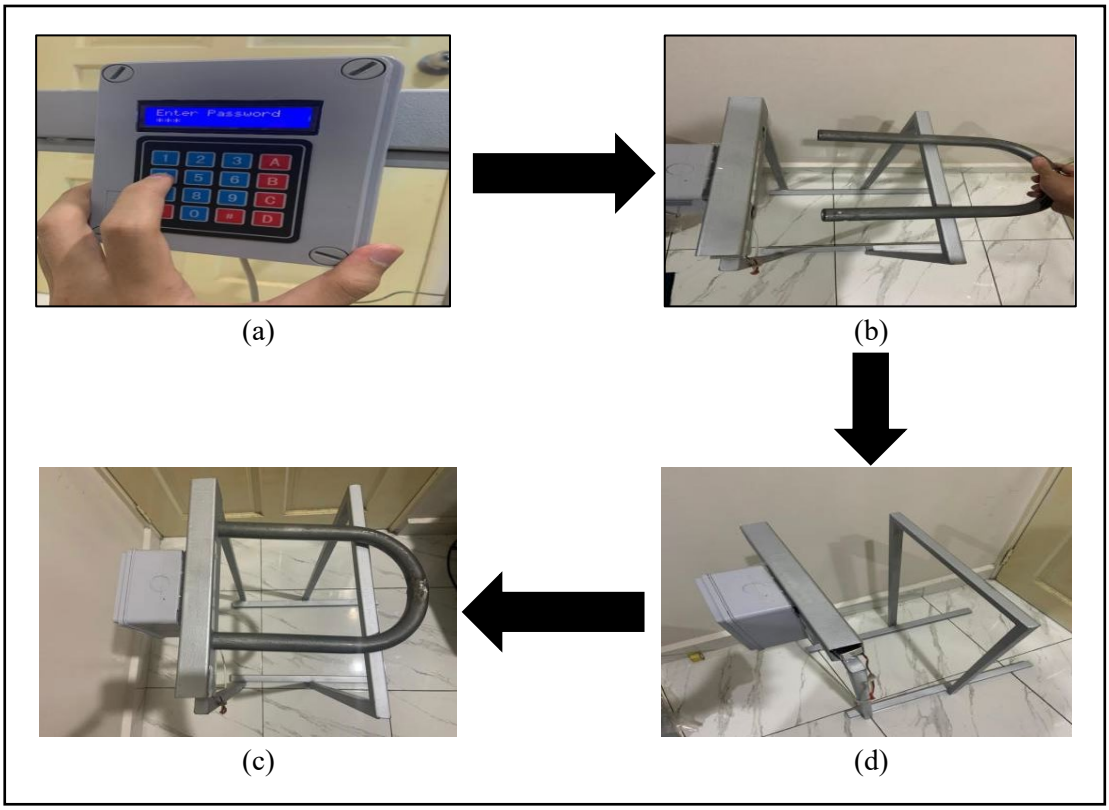

Figure 7: Working principle of anti-theft bike rack

4.2 Analysis on anti-theft bike rack Strength

The experiments that have been conducted is to obtain the result on the strength of the U-shape lock. The material chosen for the U-shape lock is galvanized steel. This is because galvanized steel has the most suitable material properties for the U-shape lock. The experiment conducted is where the four civilians were asked to pull the U-shape lock by using their maximum force in just one time. **Figure 8** shows the graph of movement distance from the blue line when four civilians pull the U-shape lock. In general, this result does not represent the actual data. It can be concluded that males with different ages, weights, and heights are most likely to have the same result of the U-shape lock movement distance which is 1.3 cm from the blue line. **Figure 9** shows a blue line that has been marked as the starting point, 0cm. Females with different ages, weights, and heights will have different results. However, even with the movement of the U-shape lock, the bicycle rack is still locked securely, this shows that the only way to unlock the bicycle rack is by entering the PIN number.

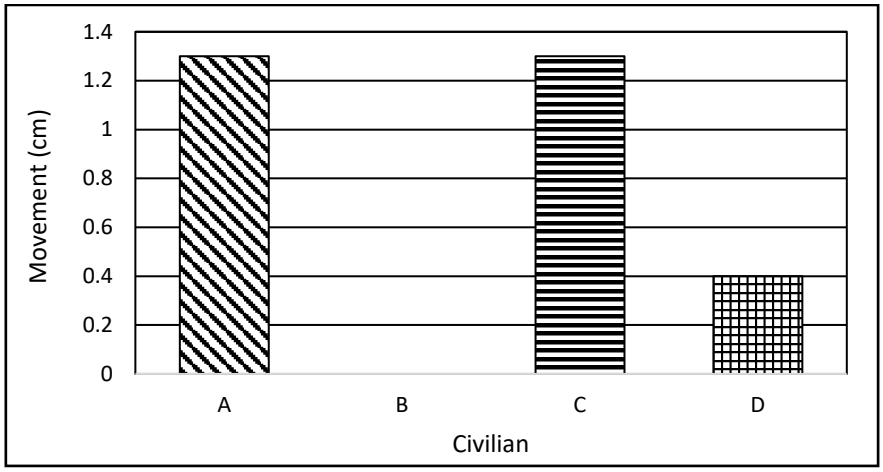

Figure 8: The result of the movement distance testing for four civilians

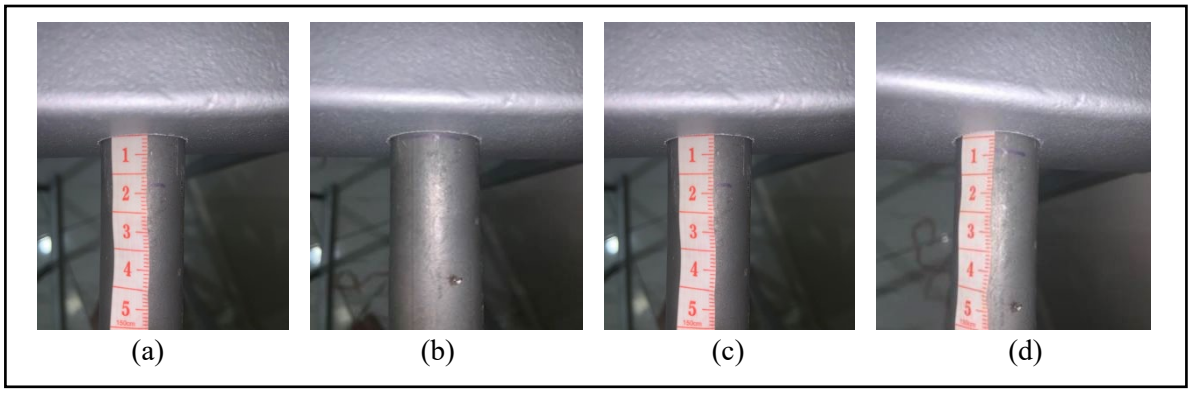

Figure 9: Movement distance from blue line for (a) Civilian A (b) Civilian B (c) Civilian C (d) Civilian D

4.3 Arduino operation system

The second experiment is to study how the Arduino will operate. The Arduino has been set with four-digit password. The password set for this experiment is 1234. If the user types in the correct password, it will trigger the solenoid and the solenoid will retract as shown in **Figure 10(a)**. This will make the solenoid release the U-shape lock. If the password is incorrect, it will not trigger the solenoid, but it will display 'Wrong Password' on the LCD screen. This will not make the solenoid release the U-shape lock as shown in **Figure 10(b)** and **Figure 10(c)**. The electronic locking system still have a limitation since from 10000 trials to open the password, there is 1 possibility (0.01%) to get the right password.

1. Trial 1
    - Password: 1234
    - Result: success
    - Solenoid: retract

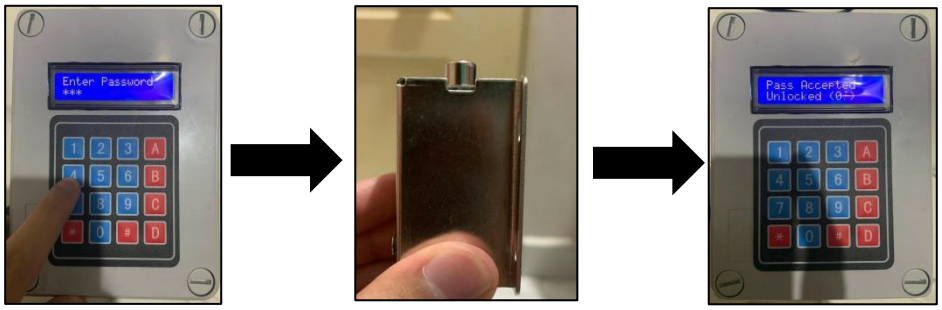

Figure 10(a): Result of Trial 1

2. Trial 2
    - Password: 1235
    - Result: fail
    - Solenoid: remain

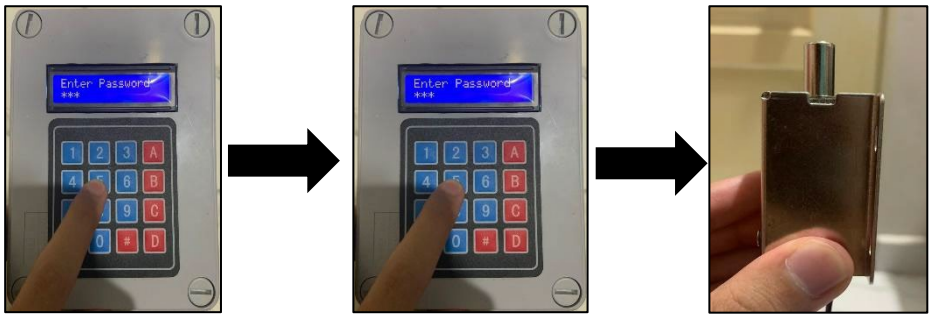

Figure 10(b): Result of Trial 2

3. Trial 3
    - Password: 8888
    - Result: fail
    - Solenoid: remain

Figure 10(c): Result of Trial 3

4.4 Cost Analysis

In fabricating this anti-theft bike rack, a few components have been bought in order to complete the fabrication. All the components have a different price depending on their functions and properties. **Table 4** below shows the list of components and the price.

Table 4: The list of components and the price

Component	Quantity (unit)	Price (RM)
Bicycle rack	1	60.00
Aluminium metal	1	10.00
Keypad	1	5.00
Arduino	1	35.00
Solenoid	1	20.00
LCD display	1	10.00
	Total (RM)	**140.00**

5.0 Conclusion and Recommendation

Anti-theft bike rack comes with an improvement in terms of safety compared to an existing product in the market. The password will be given to the owner of the bicycle so that the user can use the bicycle anytime by just inserting the password at the number pad. If the password is correct, the Arduino inside the number padlock will unlock and release the U-shape lock and users can use their bicycle normally. After using the bicycle, users can keep their bicycle on the anti-theft bike rack neatly and safely without worrying about losing their bicycle.

After completing this project, it was found that some areas of study could be improved for future study. With further study and understanding, the lock itself may be better and stronger to make it more secure than before. The U-shape lock material can be changed with harder and stronger metal. The rack may be redesigned with an adjustable height rack so it can fit all types of bicycles. The programming in the Arduino can be improved by using unique passwords (combination of letters, digits, or other symbols), to enhance the security, also with more and better interaction script that will ease the user. To counter the 0.01% possibility trial to open the password, the electronic locking system is supposed to be programmed with a trial threshold amount to open the password.

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