Design Project 2

A smart security device for bicycles

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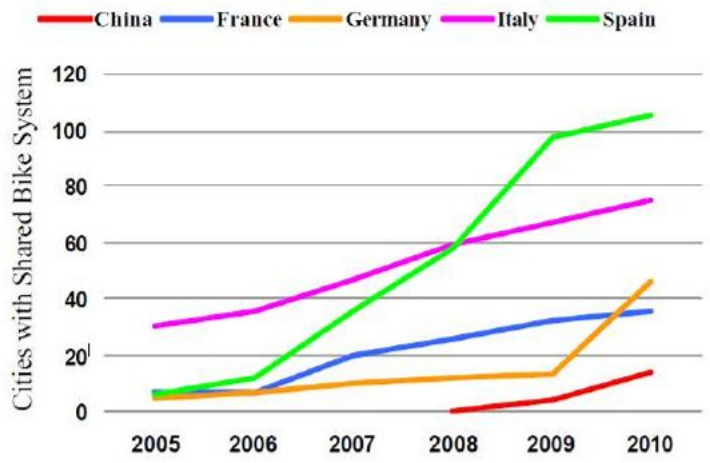
Literature Review

1. Research papers

Research papers on bicycle were mostly related to bicycle sharing systems and how they worked & maintained. These papers were from Europe and America. “Smart Bikes: Public Transportation for the 21st Century”[1] discuss about smart bikes, which is smart bicycle intended for share and use. Smart bike should be implemented in all places along with bicycle station, convenient parking facilities and separated bike lanes. It introduced smart cards for tracking and for check-out which encourage user to return bicycle so that the bicycle is parked not in other undefined location, which otherwise charges the user more for not obeying rules and replacement cost. The paper shows about the positives — non polluting, non traffic congestion, cheaper, low maintenance — of having smart bikes in the transportation system.

“Bicycle-sharing schemes: enhancing sustainable mobility in urban areas”[2] and “Bikesharing in Europe, the Americas, and Asia”[3], discuss about bicycle sharing schemes, the history of bicycle sharing systems, the growth of these systems, components, business, policies and how to make them effective. The paper is published in 2011, and the records from that year to past 10 years states that there were about 375 bicycle sharing schemes operated at 33 countries in almost every region of the world and was estimated around 236,000 bicycles. Comparing among selected countries —China, France, Germany, Italy, Spain — there was a rapid growth in bicycle sharing schemes in Italy

Growth in bicycle -sharing schemes in selected countries 2005 -2010

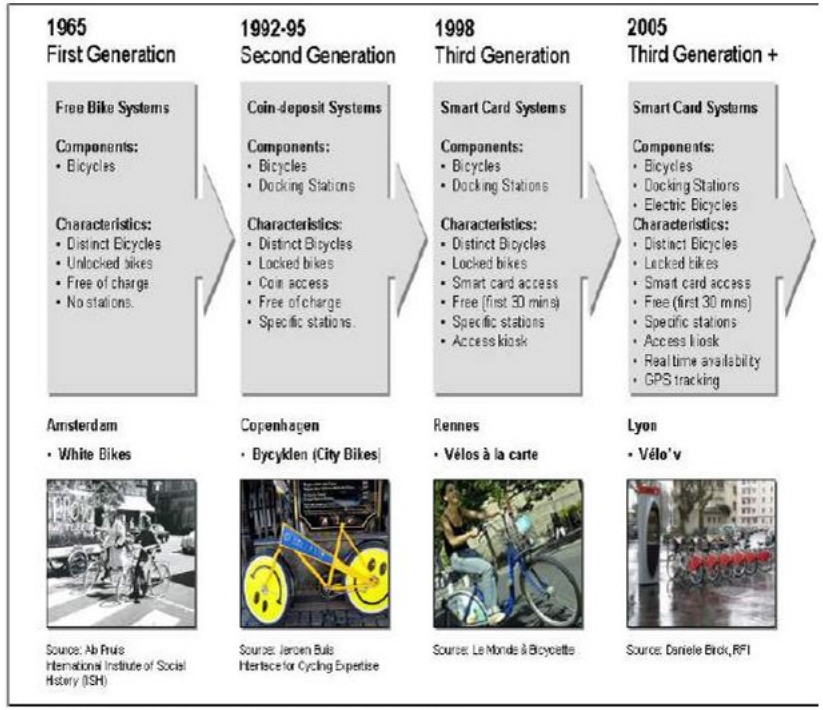


Source: Author’s estimates based on detailed research as of October 12, 2010.

and Spain. The rationale for introducing bicycle-sharing were to promote cycling, increasing mobility choices, improving air quality and reduce congestion. Bicycle sharing schemes fits in the urban transportation as they fall in 1km to 5km distance cycling. The paper discuss about the systems they operate - manual and automated. In the current generation bicycle sharing systems are operated automatically, thus removing the need of supervisors. The reasons of shifting to automated sharing systems were - users have to use credit-card, key card or mobile phones so that in case of theft or damage to the bicycles, the users could be held responsible and fined. The trade of these systems were they rely heavily on user interface, system control and monitoring. Their study shows that people dislike cycling uphill rather than an uphill, which shows topography is a factor affecting cycling. This causes low lying areas filling up with bicycles. So they implemented a credit for each bicycle returned to a higher elevation than a dedicated team with a vehicle. Another factor was climate, as there was less activity of cycling during winter months. They had faced theft and vandalism even though the bicycles were made of custom tools and parts. The main challenge faced by bicycle sharing systems was helmet laws in some regions that did not allow to initiate it. Other than that, it is safety of bicycle rider because drivers or pedestrians disregards the dedicated bicycle lanes.

The paper, “Smart Bicycles in an Urban Area : Evaluation of a Pilot Scheme in London”[4], discuss about the introduction of their bicycle sharing system, OYBike and the analysis of it. The parts for the bicycles were custom made to discourage theft and the bicycles carried advertisements on the frame, which was an additional source of their revenue. From their research it was found that people used their bicycle for leisure trips whereas the sponsored people used it more for

The evolution of bicycle -sharing programmes



Source: Adapted from Dhingra, Chhavi and S. Kodukula, 2010.

utilitarian purpose and was very effective. As a whole, public used it for recreational and leisure trips. The sponsored people used the bicycle on week days whereas the non-sponsored people used it for weekends. When the cycle was introduced, some people tried using for once to see the novelty. Sponsored usage on cycling declined during winter months and was unclear about the reason behind. Their suggestion were to engage sponsored users(may be giving offers or coupons)and reminding them benefits of cycling on regular basis. The analysis showed the cycle trends and found there was seasonal usage. Temperature and rainfall affects the usage of bicycle. The bicycle was left unattended during monsoon, which rendered maintenance problem. People used the bicycle when temperature was high and were used in non peak hours. One problem associated with this smart bicycle was locking system. User need a mobile phone to unlock the bicycle by confirming trip and locking the bicycle by confirming end of the trip. The research and system was successful. The paper shows the business potential of these bicycle sharing system, their franchising, rise in population of bicycles and people would prefer bicycle as a means of short distance transportation.

“Performance Analysis of Bicycle-to-Pedestrian Safety Application using Bluetooth Low Energy”[5] talks about the bicycle collision with pedestrians and the approach they took for solving & the causes of failure of the project. A person who is walking lonely would be using smartphone for chatting, browsing or listening to music. So they wear earphone to listen to music or call. Therefore the chances that the person could collide with a cycle is more. They used Bluetooth Low Energy (BLE) for communication and gives valid technological reason for choosing it. They made area of hazard into 4 levels, where the highest number shows

more possibility in colliding the bicycle with the pedestrian. The reception was the pedestrian's smartphone and the approaching bicycle carried BLE transmitter. Their success was given as when the pedestrian recognises the alarm produced by his phone, which is aware of the approaching bicycle, the pedestrian moves two steps before the bicycle reaches the location of the pedestrian. The project failed due to low speed of approaching bicycle,beacon loss and delays, error in GPS coordinates and channel synchronisation. Their success rate was lower when they conducted in non line of sight than the line of sight and no difference when number of cycles where less than 8. So the failure was mainly due to technical issues.

Though the above papers discuss about the history & dedicated components for bicycle sharing, advantages & challenges faced by bicycle sharing schemes, the paper "Cycling towards a more sustainable transport future"[6] also discuss about the future of cycling. It states the recent innovations — bicycle sharing and improvement in cycling safety through off-road and mixed-use paths (shared with pedestrians) and on-road cycling facilities by separated motor vehicles through physical barriers or buffer zones — had encouraged the usaged the usage of bicycles and would lead to increase in cycling activity. The rapid adoption of electric - assist bikes (E-bikes) in China and northern Europe was the another recent development in the history of bicycles. The number of E-bikes rose from 290,000 in 2000 to 35.3 million in 2016 (Campbell, Cherry, Ryerson & Yang, 2016). They are more competitive alternative to private car, as they are faster than mechanical bikes, thus facilitating over long distances. As they give more throttle, now it is easier to climb uphills and ride with heavy loads. Their research shows, the customers of E-bikes could be seniors and

long-distance work commuters. Studies also showed that E-bikes were far more energy-efficient and less polluting, so they contribute to transport sustainability. Improvement of real-time information technology for bicycles were improving leading to better guidance on optimal routes, parking & bike-sharing locations and their availability. Because of these improvements, the study also shows there was cultural shift in locational and travel preferences towards less reliance on the automobile and increased demand for living in mixed-use, compact developments in or near the city centre, which could further increase the growth in cycling.

Field Study

The research papers were mostly covering on bicycle sharing systems / smart bikes and less in normal cycles. To find out problems related to non-smart bicycles we went for field study inside IIT Bombay. We soon found problems were faced by students everyday and the cause were the bicycles they were using i.e. sports bicycles. We recorded the problems as well as recommendations on adding smartness in bicycles. We saw disadvantages in cable locks for bicycles and the related trust issues. So we did a user study outside IIT Bombay, to see whether general/commute cyclists also face lock problems. Surprisingly they don't have issues related to their bicycle locks or bicycle and they were using cycles according to its usage. The interview questions were open ended semi-structural.

1. Study on bicycles inside IIT Bombay

A total of 36 user interviews were done. At first, the study was done inside the campus to find out the most and

common problems found during cycling and on the cycle itself. This study would give more insights that gives an opportunity for intervention.

Number of users interviewed inside the campus	:	26
Age group	:	18 - 36 years old
Profession	:	Student
Number of boys	:	21
Number of girls	:	5
Number of semi - pro cyclists	:	2
Number of cycle enthusiastic	:	2

Questions

About problems faced while they were cycling.
Eg : during traffic, long distance travelling, comfort, navigation.

The problems related to their cycle had experienced
Eg : maintenance & service, flattening of tyres, locking, parking, tracking cycle, theft, mudguard design

1.1 Bicycle Problems

The interview started from hostel 14. Hostel 12, 13 and 14 are in same compound and each hostel has 3 wings, named ‘A’, ‘B’ & ‘C’, and an additional 1 wing, ‘D’, for hostel 12. Students interviewed from hostel 14 said the parking space for cycle is small and the allocated parking lot is full. Compared to other hostels, the number of cycles in these hostels are more i.e. cycle population is bigger. Most of them has similar brand & color of bicycles and therefore it is difficult to find one’s bicycle among a group of cycles.

Figure 1: Bicycle parking problems at hostel 12, 13, 14

Everyone, except cycle enthusiasts and semi - pros, faces maintenance issues like oiling, nut loosening due to vibrations, gear system issue etc and tyre flattening. Cycle enthusiasts and semi - pros care about their bicycle, maintains and cleans them in the interval of 2 or 4 weeks. Those students we interviewed from hostels 1, 7, 8, 12, 13, 14, found difficulty to service their cycle as the bicycle repair shops were far from them and was wishing for mini - bicycle repair shops were there, near to their hostels.

Cycle enthusiasts and semi-pros found difficult to share their cycles as they consider their cycle's value and they put effort in maintaining it. They had tendency to check their cycles in an interval, if they happen to park the cycle in a lone or unattended place. All users who had semi - sport or sports cycle, parks their cycle in an attended place. Pedestrians, especially children and teenagers, would be eager to try these parked sports cycle or gear bicycles and chances were they may switch the gears, which affects their life. One of the users had used an alerting system for bicycle and stated that the alarm was too loud that annoyed the public. There is a high probability that, a well maintained — a new looking — cycle
(need not be good looking like sports cycle) will be stolen. The current cable - locks for bicycle that are cheap, can be opened by other keys of same size. 2 users had stated that a locker key or another bicycle lock key of same quality or company, could open this cheap cable lock. Even if the lock — number and key lock — is costly, they will be picked or cut by the thief. All the users used locks that doesn't alert any bicycle theft or movement activity. So there is low trust issue on bicycle locks faced by the users.

Users doesn't know where to put a cable lock for locking and

Figure 2: Bicycle parking lot at hostel 14

Figure 3: Bicycle service shop — located near to hostel 4

after unlocking bicycle. The locks of the cable locks could leave scratches on the bicycle paint, if not properly placed. Users having key lock will be wasting time in picking the lock from his bunch of keys or from his pocket. All had to bend and lock & unlock his bicycle. Users who had used classic bicycles haven't faces issues in placement of locks as these bicycles comes with mounted locks. A special feature of this lock was, when the bicycle was unlocked, the key remains in the lock and to take out the key, the bicycle had to be locked, which also confirm him that whether his cycle was locked. They had preference in using this type of lock, but it will render in less aesthetic bicycle. Current cable key locks quality is poor, as they tend to freeze the key rotation after a time, so need to be oiled. So users find difficulty in locking as well as unlocking the bicycle using cable lock keys.

Users who took bicycles outside the campus for buying or exploring, faced traffic issues. They found difficulty in knowing the presence of vehicle behind them and they have to look back to see whether the vehicle is present or how far it is. There was no indicators or stop light on the bicycles, which could create confusion to the bicycle rider and the driver, on which direction the bicycle rider was going to turn, was he going to stop etc. Users went for exploring and long ride, used smartphone for navigation. The problem is they had to stop at interval to memorise the location, landmarks, direction and routes to take. This reduces the fun in cycling (as stated by the users). To reduce this effect semi-pro cyclists memorised the whole route map. Everyone knows that It is dangerous to look at their phone down — if the phone was mounted on the handlebar — for navigation while cycling. Cycling through the pedestrians was another problem faced by bicycle riders as the bicycle bell was not audible. No one had gone for night riding outside the campus

Figure 4: Theft and vandalisms

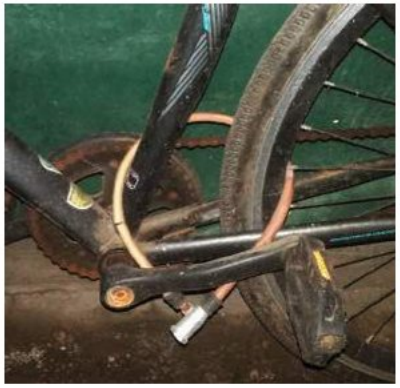


Figure 5

Figure 6

Figure 7

Figure 5, 6, 7: Lock placement problem

and even in the campus during night, users liked to have front light and reflectors positioned in a way that indicate presence of bicycle to approaching vehicles and pedestrians.

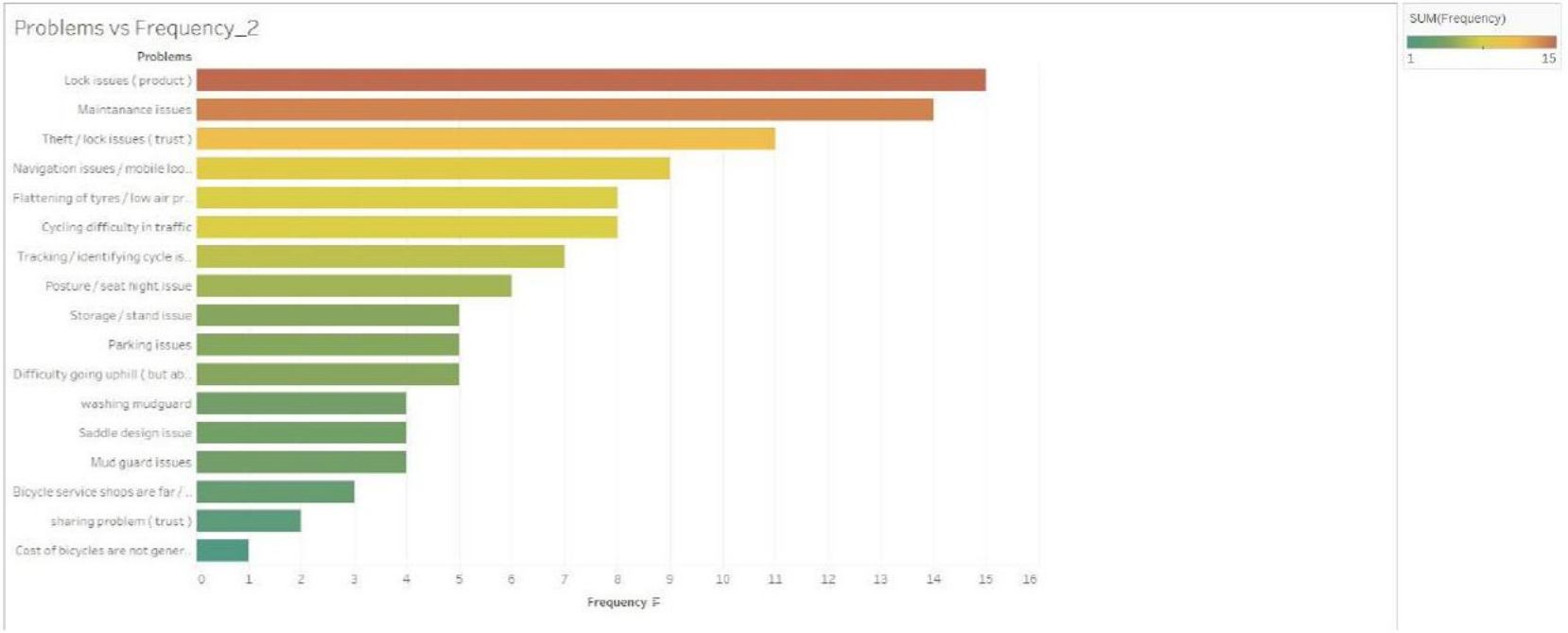
Cycle enthusiasts and semi-pros adjust their cycle seat height according to the standards as they travel long distance and therefore, they have to maintain a good posture ,i.e. on seat height, leaning angle and placement of foot on pedal. Ignoring this will result in back and knee pain, muscle fatigue etc. A good posture also give good turning maneuverability and comfort in riding uphill. The general users doesn't care about that. They ride their cycles in sitting posture and after 5 -10 minutes of ride, they feel temporary thigh pain, especially if they ride an uphill. So semi-pros recommends us to have a system that could tell the exact seat height and leaning angle according to user's height (and other biometric factors).

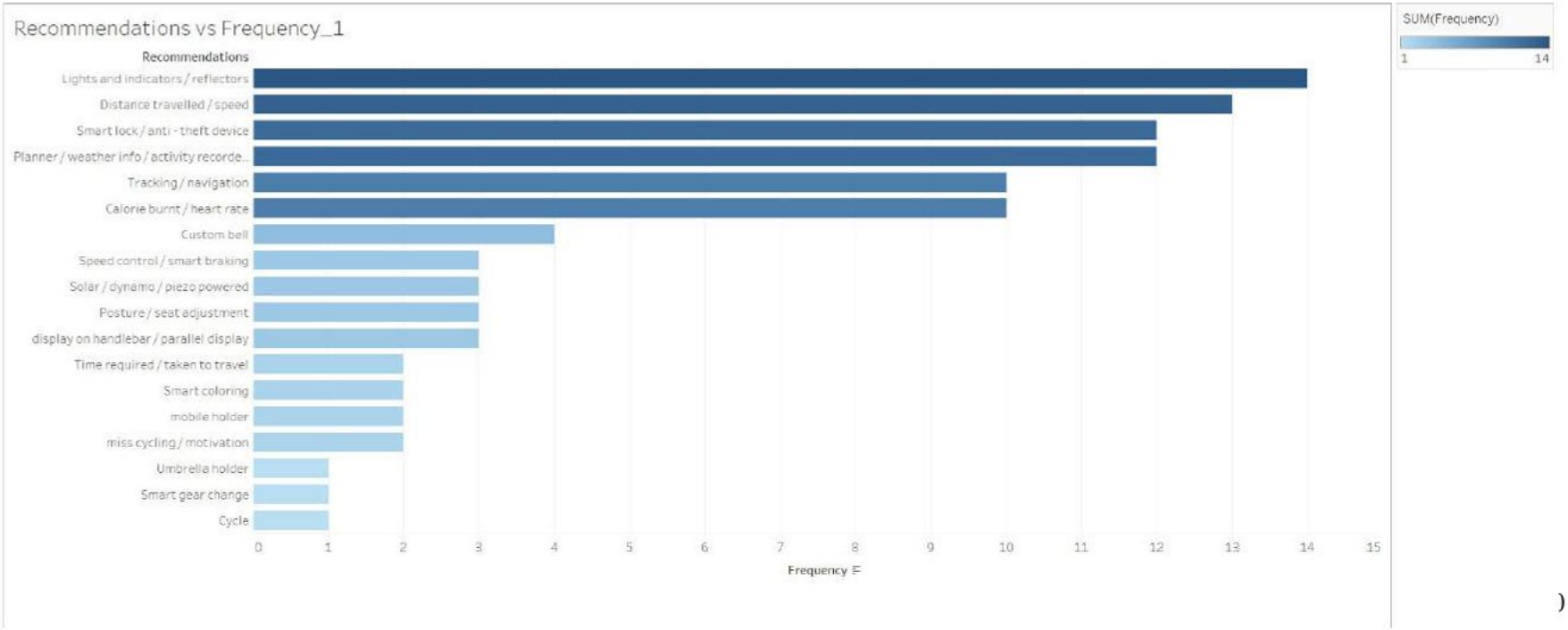
Sports cycle doesn't come with carrier for storage as the cycle was made not for general purpose, but it was still a problem faced by 5 users. 1 user stated there was no provision on bicycle to hold umbrella, for protection under sun and rain. 4 users stated rear mudguard of sports cycles were badly designed and many of the cyclists know about this. The reason behind was, these rear mudguard doesn't cover the half of the rear wheel and during rain, the water & dirt particles were thrown by the rear wheel parabolically that it falls on the bag or backside of the shirt worn by the bicycle rider. We had seen few cyclists and one user already changed the rear sports mudguard to general mudguard which covers half of the rear wheel.

Figure 8: Mudguard problems

1.2 Recommendations on bicycles

When we asked users about features and information that


Problems vs Frequency_2
Problems
Lock issues (product)
Maintanance issues
Theft / lock issues (trust)
Navigation issues / mobile loo..
Flattening of tyres / low air pr..
Cycling difficulty in traffic
Tracking / identifying cycle is..
Posture / seat right issue
Storage / stand issue
Parking issues
Difficulty going uphill (but ab..
washing mudguard
Saddle design issue
Mud guard issues
Bicycle service shops are far / ..
sharing problem (trust)
Cost of bicycles are not gener..
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Frequency
SUM(Frequency)
1
15


Recommendations vs Frequency_1
Recommendations
Lights and indicators / reflectors
Distance travelled / speed
Smart lock / anti - theft device
Planner / weather info / activity recorde..
Tracking / navigation
Calorie burnt / heart rate
Custom bell
Speed control / smart braking
Solar / dynamo / piezo powered
Posture / seat adjustment
display on handlebar / parallel display
Time required / taken to travel
Smart coloring
mobile holder
miss cycling / motivation
Umbrella holder
Smart gear change
Cycle
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Frequency
SUM(Frequency)
1
14

)

a smart device should have for bicycles were they would like to know about distance travelled and speed. 2 users didn't consider on showing calorie burned while cycling in the device. If the feature was present then should not show in the first screen. This brings about purpose of cycling. Number of users who regards cycling as fun or adventure and exercise are same. Less than 5 users consider gym for exercise. As we said earlier about the problem in tracking & navigation and locking bicycles, users want to have upgraded navigation system that don't lose their fun in cycling and smart locks which alerts, notify, records activity and improves user convenience for locking and unlocking bicycles.

Majority of the users had raised for adding features of lights and indicators for bicycles. 12 users, who were into adventure and exercise, liked to have planner, weather forecast, activity recorder and maintenance notifier. 1 user liked to have auto mudguard feature that covers the wheel during monsoon. 3 users recommended to have smart braking or speed control while going downhill and for sudden braking.
Surprisingly, 2 users wished the color of the cycle and changes according to season, which also improve visibility and reduces the boredom of seeing same color of the bicycle. Users also suggested for solar, dynamo or piezo powered device for the bicycles because they don't want to take it off from the bicycle just for charging. 4 users would try or go for e-bike or pedelec bicycles, bicycles that give additional trust while pedaling.

1.3 Conclusion

From the first user studies, we found maintenance, tyre pressure,navigation, locking and mud guard issues were

common. We decided to redesign the bicycle locks. The study was then done focusing on the problem faced during locking and unlocking of cycles. The collected data also shows it is time to electrify bicycles.

2. Study on bicycle locks outside the campus

We did user study at Hiranandani at Powai, R-city mall at Ghatkopar and Nahar at Chandivali in Maharashtra. A total of 10 users were interviewed outside the campus & their age ranges from 18 to 56 years and were men.

Number of users interviewed outside the campus	:	10
Age group	:	18 - 56 years old
Profession	:	Professor, Student, Mechanic, Delivery Man, Flower Seller.

Questions

The lock they had for your bicycle.
How much do they trust your bicycle lock.
Preference of the current lock.
About problems faced during locking and unlocking their bicycle.
The usual places they put their lock on the bicycle.
Convenience of their bicycle lock.
Opinion towards digitalizing the bicycle lock or making the lock smart.
Features that a bicycle lock should have.

Users having the sports cycle were using cable locks. They were facing issues of where to place the lock after unlocking and locking the cycle, scratches on paint of the bicycle, rotation of the lock getting frozen. One of the users also mentioned about the classic bicycle that came with mounted locks, which brought out no worries in placement of the lock and the key. He also mentioned that as these locks could create scratches on the bicycle's paint, people place them on the handle bar, which is very dangerous as it can catch on to other and create steering problem. The mechanic stated that these mounted locks rusted by ageing and under rain. He was comfortable with the cable locks and said it won't create scratches, which means he knows the placement of these locks after unlocking and locking the bicycle. These users told us that in a metro city, chances of bicycle theft were less as there are security cameras & guards at places and with the help of cameras, the thief could be caught. They told theft happens in rural parts. But 3 users, living in apartment, had faced bicycle theft.

Deliver men and flower seller, used classic bicycles having mounted locks. They were using these cycles for more than 7 years and haven't faced any problems related to mounted locks. Once in an year they had to service the bicycles. They were not at all worried about theft and these bicycles locks were open most of the time when parked outside shops during day time and kept inside the compound of the shop during night. Flower seller told us that no one will pick his bicycle as it was covered by mud and dirt.

If a user lost his bicycle lock or the lock was found not functioning, the user would make a homemade chain lock, as the basic shackle lock was readily available from his home and the chain if not present would buy from a nearby local

hardware shop.

It was a surprise to us that people had started delivering things other than goods to customers. Delivery men were from hotel, restaurant, medical shops & supermarket in Nahar and Hiranandani. They delivered respective items to customers living within 2km radius from their shop. The reason for choosing bicycles were they were cheap, no need of fuel, less maintenance required, reliable and environment friendly.

We conclude that commuters/local people were happy with their bicycles and the lock (mounted lock) they were using. From the findings it was obvious that Mumbai would experience a boost in bicycle usage, demand and development in the coming future. Problem of locks were faced by those users who had sports bicycles and locks of type cable lock.

Secondary Research

1. Heuristic Evaluation on bicycle locks

Bicycle locks are used to secure a bicycle to a fixed stationary object or to itself to prevent from falling and from theft. Usually the locks are fasten through the bicycle spokes to the frame. The locks are of different mechanism, shape and sizes giving differences in security. The most promising locks are bigger, heavier and costly.

There are test standards carried out in Thatcham and Sold Secure in the United Kingdom, ART in netherlands, SSF in Sweden and VDS in germany which rates their effectiveness in security. Tests carried out by Cyclists' Touring Club showed

most of the locks can be broken in less than 42 seconds.

We did a heuristic evaluation on 9 types of bicycle and rated them out of 5 (1- worst to 5- best) according to their toughness, bulkiness, weight, flexibility and reliability. I did not rate them on the cost, because it varies from place to place.

2.1 U - locks and D - locks

U-lock is preferred to lock a bicycle to a rack or fixed stationary object. It would discourage a thief but still he could manage to steal the bicycle leaving the rim behind. The main disadvantage of U-lock were bulkiness and heavy. So it's difficult to carry around and makes the bicycle more heavier.

Figure 9: U-lock[17]

Figure 10: Chain lock[17]

2.2 Chain lock

Chain lock is basically a chain with a lock, which can be a key type or a combination lock. Anyone can make this type of lock because it is simple & easy to make from household, provided the shackle lock and the chain were present. It is flexible as the chain can be passed through the spokes and the frame in different ways. A lengthy chain allow us to lock entire bicycle, but it could make it heavier.

2.3 Cable lock

Cable lock is similar to chain lock, where the difference between the two are : instead of chain it is an entwined thin cables making it stronger, lighter & flexible and the lock is permanently fixed to one end of the cable. This lock is widely used in India.

Figure 11: Cable lock[17]

The challenge faced by this lock (cheap version) is theft because it is easy to break by wire cutter, hand saw and picked up. The costlier ones are more secure compared to

cheaper variant as they would have overlapping steel jackets threaded over the cable. The combination lock that comes with cheap low quality cable lock fails as the gap between the disk can be seen and therefore its easier to decipher & unlock.

2.4 Wheel lock

The wheel lock is the most popular bicycle locks that are found in India, China, Japan, Netherlands and Scandinavia. A wheel lock is also known as O - lock, ring - lock or frame lock and commonly found in city bikes or classic bikes.
This type of lock is directly mounted on the bicycle seat stay. So the user is not worried about placement of the lock after unlocking and for locking the bicycle. Heaviness could be similar to cable lock, but considering security, it is better than cheap cable locks. Wheel lock provide low security. It can't secure a bicycle to a fixed stationary object. Apart from the disadvantages, this lock is convenient as user need not carry it and its lighter. It is effective against an opportunistic theft or for leaving the bike unattended for short duration, as it forces the thief to carry the bicycle. Commonly available wheel lock do not come with number lock

Figure 12: Wheel lock[17]

2.5 Locking skewers

The locking skewers replaces the existing quick release skewers in bicycles for additional security. It passes through the skewer hole, where one end of its stud is permanently attached to acorn nut and the other end fasten by double nylon inserting nuts and washers. This allows the entire assembly to freely rotate so an opportunistic thief will find difficult to open it by using aone wrench.

Figure 13: Locking skewers[17]

Their nuts also comes in unique customized version such that tool to open it is difficult to get in local hardware shops

and it is the company who manufactures them provides its unique tool to the customer. So it will be expensive for a user if he loses the tool as the manufacturer has to make its unique tool separately.

This lock is not flexible as it is fixed to one area, as a skewer, but it is lighter, custom made and no worries on placement.

2.6 Wheel tether

Wheels of a cycle can be secured by using wheel tether, which is a simple steel cable with a noose swaged on either end. It does not require a lock as it locks each part by knots and altogether they are secured by any lock. So the advantages and the disadvantages depends on the weight & toughness of the cable and the lock that is used.

Figure 14: Wheel teher[17]

Figure 15: Disc rotor lock[17]

2.7 Disc rotor lock

These locks can only be used in bicycles having disc brakes. These are small & compact and be carried easily. They sit around the edge of the disc rotor and locked by inserting the key. It consists of a metal pin that goes through the hole of the disc rotor between the seat stay and the chain stay. There is a possibility that the disc rotor will be directly damaged if the lock gets damaged. So this lock is not flexible enough as it only for bicycles having disc brakes.

2.8 Smart locks

These locks are commonly found in bicycle sharing systems. An example of a smart lock is shown here, LINKA, is the upgraded version of wheel or O-Ring lock. Smart locks has information technology features of tracking the bicycle, notifying the user of suspicious activities that happens on the lock and if it is tampered or breached it sends

Figure 16: Smart lock[17]

notification as well as alarms loudly with blinking lights. This lock as introduced one additional challenge to history of locks i.e hacking.

2.9 Forever lock

This was an interesting lock, because the user feeds the key into the key slot of an extendable drawer, pushes back to the normal position and rotate it, so that the rotation of the slot causes rotating the key in the lock, which is inside the casing (the lock is hidden and not visible from outside). It was like it had an additional mechanical hand for the key. It was an upgraded version of U-lock and claims unpickable, but it could be picked by using a bump key, a special key made for the lock and was picked by bumping the drawer when the key was inside the slot.

Figure 16: Forever lock[18]

We rated these basic bicycle locks according to toughness, bulk, weight, added value in usage & security and reliability. We found smart locks for bicycle were mostly used for security and their technology is fair in assist cyclists on cycling. So we decided to focus on improving added value cum reliability of a smart lock for bicycle.

Locks	Toughness	Bulky	Weight	Added value	Reliable
U - locks and D - locks	5	5	5	4	3
Chain lock	4	3	4	5	2
Cable lock	2	2	1	3	1
Wheel lock	3	3	2	2	2
Locking skewers	3	1	1	1	4
Wheel tether	4	1	1	5	3
Disc rotor lock	4	1	1	1	4
Smart locks	3.8	3	3	2	5
Forever lock	5	5	5	4	4

2. Smart locks

We explored the different smart locks available in the market, which were Lock8, Skylock, Bitlock, deeper lock, Linka, Noke U-Lock, I Lock It, Bisecu smart locks. Most of the locks comes with similar features like proximity locking and unlocking, tap button password, tracking, theft and motion sensing alert in the form of push notification and 110 dB alarm, self charging - induction and solar powered, usb charging, sharing, GPS, GSM and BLE connectivity. A table showing comparison of deeper lock with other existing locks present at the release of their lock is shown. We could see the placement and type variations through these smart locks - mounted lock : frame & fork type lock, mounted cable lock (Lock8) and U-Lock . Smart locks — deeper lock and Bisecu — had bicycle compatibility issue on area coverage, placement and type of bicycle.

Coming back to our users, that is IITB cyclists, majority are students. Most of the features the comes with these smart locks are not needed for the students and all the locks are expensive to afford. These locks doesn't assist on cycling — indicators or stop light, navigation, identify bicycle among others (excluding bisecu) etc. — during day or night. We liked self charging and color password unlocking (I Lock It) features of these smart locks.
From the secondary research we learnt that bicycle compatibility — type and placement of the smart lock that we are going to design and build — will be a main challenge and our smart lock should have cyclist assistance and should be affordable to our users.

From left to right starting from top to bottom : Lock8, Skylock, Bitlock, deeper lock, Linka, Noke U-Lock, ILockit, Bisecu smart locks [9-16].

Problem Statement

Technology has reduced the size of electronic devices, and there is a growth in number of bicycle usage every year, which leads to less traffic congestion, air & noise pollution. People prefers and will prefer bicycle as a means of short - distance transportation, which gives them health benefits of cycling.

The trend of the bicycles are going in such a way they look aesthetic, lighter and faster. The increase in cost of bicycles will change people to look after their cycle and the performance of existing locks are poor and not updated. Existing cable locks for bicycles are poorly designed, where the user has to adjust his posture for locking & unlocking the bicycle and these locks are vulnerable to vandalism causing bicycle theft.

So there is an opportunity to upgrade the cable lock which will make bicycles more secure and convenient to use.

Goals

- Suitable for all bicycles.
- Form and color match with bicycles.
- security.
- Convenient to use.
- Assisting features for cyclist.

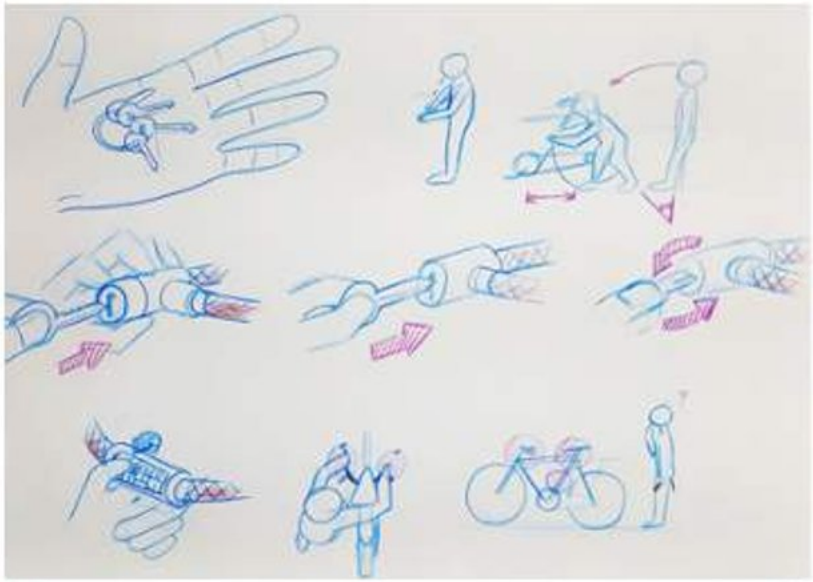
Scope

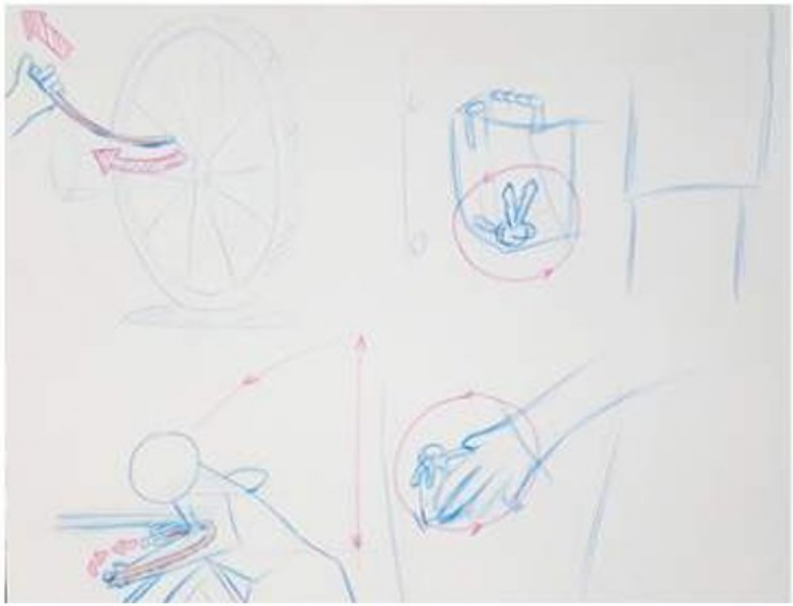
Users : IITB cyclists.

Problems and Gaps

Typical problems faced by cyclist before and after cycling on cable locks are :

Situation 1 - Approaching a locked bicycle
Cyclist searching and taking out his bunch of keys.
Choosing the key from the bunch of keys.
He has to bend to unlock the cable lock.
Correcting, inserting the key into the keyhole and rotating key.
Holding either end of the open the cable for preparing it to take out.
Pull out the cable through spokes.
Standing posture and may be on thinking on where to lock it on the bicycle.
Bending posture, if he plans to lock the cable under the seat post height.
Keeping keys in pocket or storage.





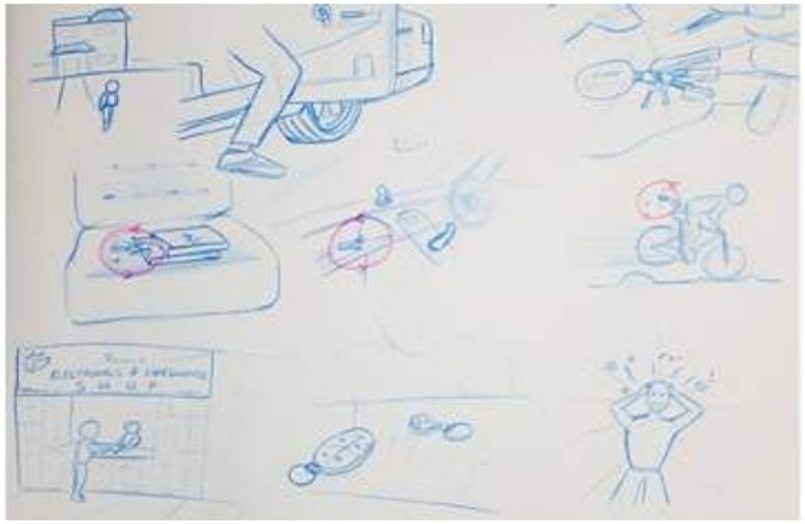
Situation 2 - Finding the key for the lock

The cyclist may have placed the key on a seat of a car or a couch.

He comes out the car or home and forget to take out the key & searches for it.

To avoid the above problem, he buys a key tracker from online or local hardware shop and integrates into his key.

On cycling, he might loose the tracker on the path due to thrown off from pocket at road bumps or loose friction of the tracker while pedaling.



Concepts

We did a mind map on cycle, bicycle locks and came up with ideas, which we later narrowed down to concepts. These concepts were mainly on redesigning the existing bicycle locks and focusing on convenience in using the bicycle lock. The concepts were categorised into :

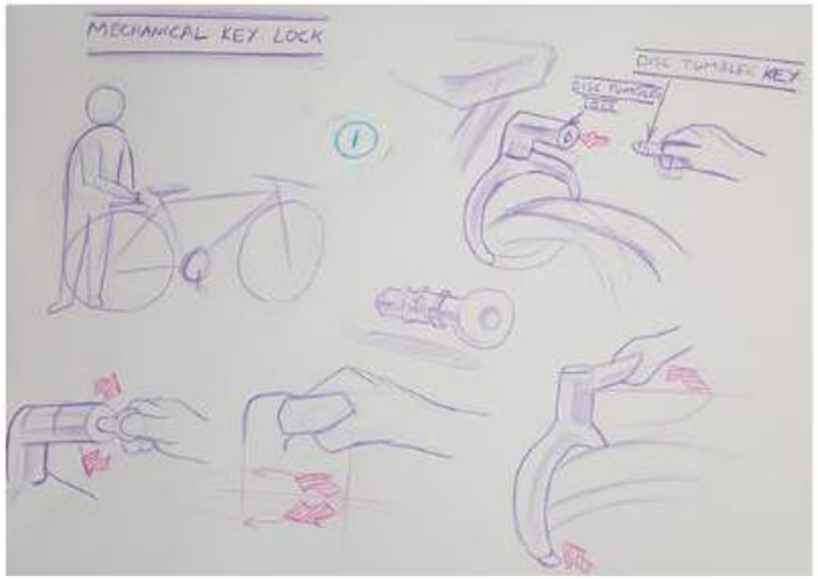
1. Mechanical Lock
2. Electrical Lock
    a. Automatic system
    b. Manual system

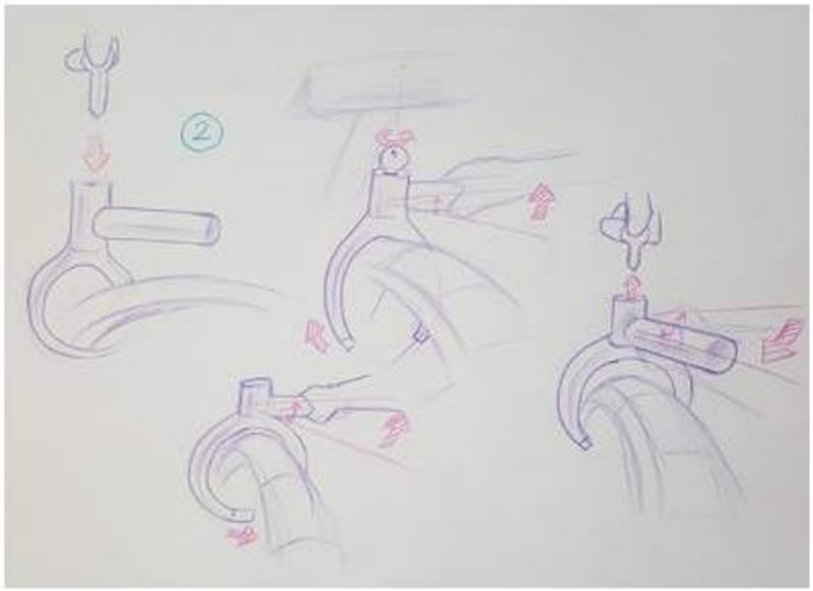
1. Mechanical

The proposed mechanical lock is an improved version in unlocking a mounted frame lock. Idea is based on door knob as it is placed on the convenient height to push / pull and open & closing a door. Similarly the a knob is placed above the frame lock, just below and behind the seat post.

1.1 Manual Locking system v 1.0
Here, the cyclist inserts the key into the keyhole, which on the axis of the handle, rotates the key and push the handle on either side to unlock the lock.

1.2 Manual Locking system v 2.0
Here, the cyclist inserts the key into the keyhole placed above the handle, pushes the handle to right side to unlock the lock.





2. Electrical

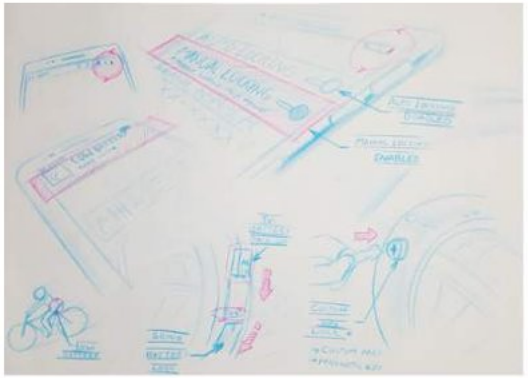
Electrical locks are the smart locks for the bicycle.

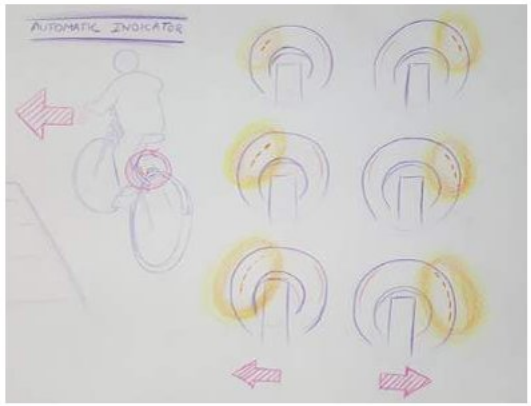
2.1 Mounted Frame Lock

To start using the lock, the user switch ON the lock and downloads the mobile app either scanning from the QR code that comes with the package or from the app store. He enters the serial number in the app. The app request the user for permission to turn ON the bluetooth of his smartphone to link the device and for locking & unlocking it. The lock works on Bluetooth Low Energy (BLE) connectivity, so it long last for year (depends on usage of the lock).

If he enables the proximity locking and unlocking feature of the lock and the device comes with default distance in identifying the user then, if he is inside the vicinity and comes towards the bicycle, the lock unlocks for him and if he goes away i.e. outside the vicinity, then lock locks the bicycle. If the cyclist's smartphone is at low battery power, then the app will disable the proximity or auto unlock & locking feature. If the lock's battery power is low or the lock turns off due to no charge, then the user can charge the lock using an external 9V battery or he could use the custom key that comes with the lock to unlock it.

The lock comes with auto indicators, i.e. when the cyclist turns towards left or right, the lock automatically recognises the cycle is turning and according to the direction, it flashes the indicator lights in an animated sequence.

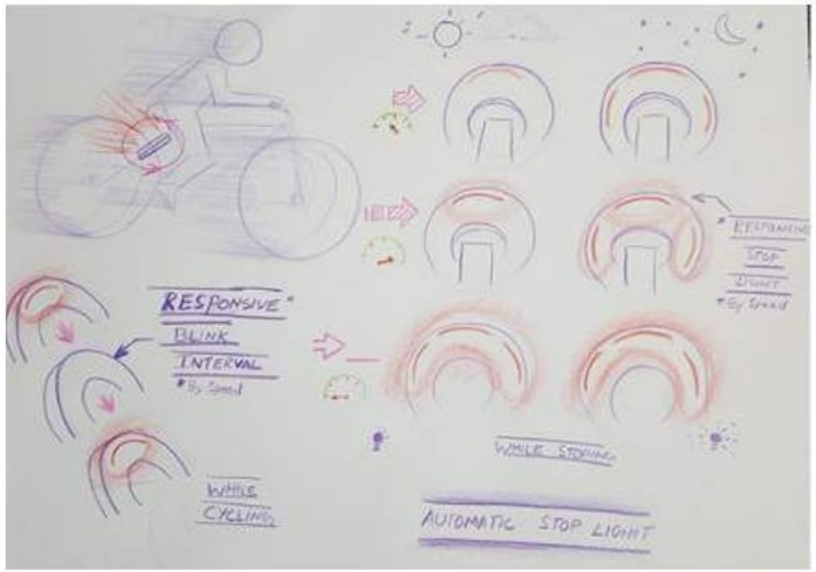


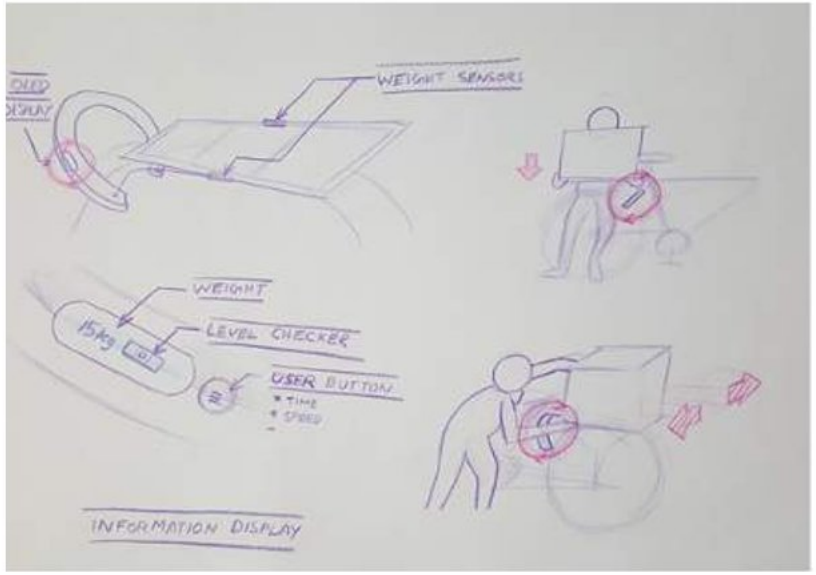


The lock has auto stop lights. When the lock is unlocked, the stop lights are turned on and flashes fast or slow according to the the speed of the bicycle. The brightness could be adjusted

by the user or adjusted automatically according to the time of the day.

Additional load sensors could be attached on the carrier of the bicycle to the load so that the user can check the weight and balance the load, that he puts on the bicycle, which is shown on the OLED display on the lock.

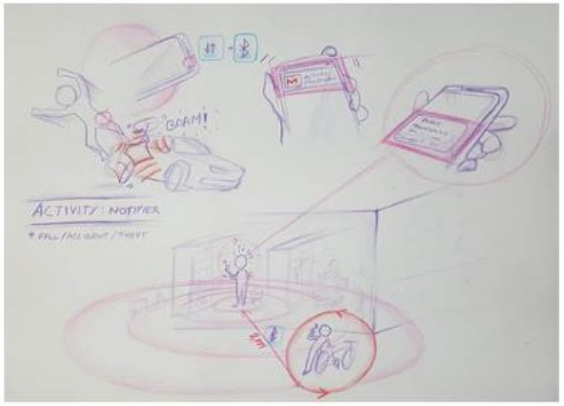


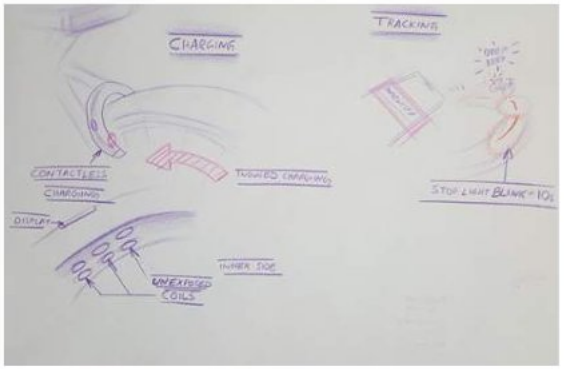


The lock also beeps to notify the user, when his smartphone receives message or call. An additional bell button can be connected to the lock where on pressing the button, the lock beeps audible to nearby pedestrians and drivers.

The lock senses accidental fall and alerts and request user to send message to his contact for help. The lock also senses tampering or hit on bicycle / lock and alerts the user by loud beep and notification message to his smartphone on the same.

The lock is powered by self induction by using magnets that was attached to the spoke for measuring speed. The lock could be used for tracking the user's cycle by means of flashing light and audible beep among bicycles in a parking lot. This could be done automatically or manually clicking a button in the app.





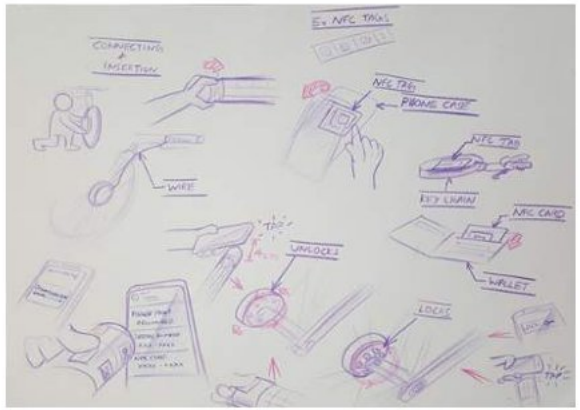
2.2 Spoke Locker

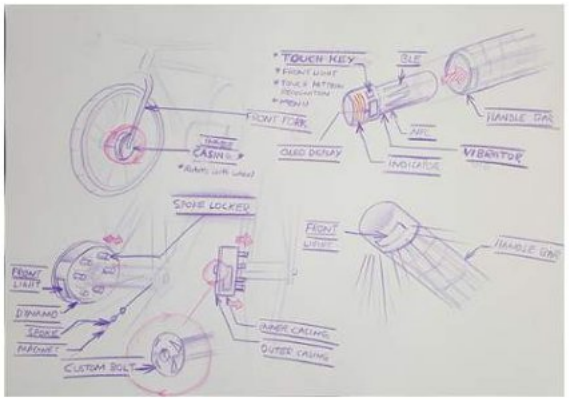
This type of smart lock is mounted on the front fork of a bicycle. It comes with a wired smart handlebars that are fitted into the hollow tube on either side of the handlebars of the bicycle. The handlebar comes with led indicators on front & back side and a fingerprint and NFC scanner.

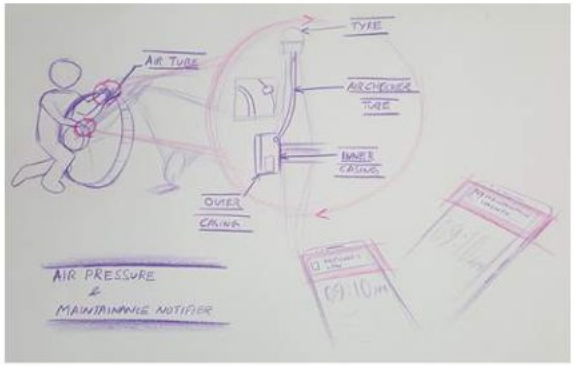
Here, the user downloads the app from scanning the provided QR code or downloading from the app store. The user registers the lock linked by BLE through the smartphone by fingerprint on the handlebar. He can either lock and unlock the lock by NFC of his smartphone or the 5 NFC tags that comes with the package or by his fingerprint placing on the scanning area of the handlebar.

The locking part has outer and inner casing. The outer case is fixed to the fork and inner case rotates along with the rim. The outer case comes with custom skewer to fix it to the fork and it discourages a opportunistic thief. The inner case has magnets and outer case has coils inside them, so when bicycle moves, inner case rotates and this causes self induced electrical energy and charges the system as well as records the speed of the bicycle. Locking mechanism works by passing rods through free areas between the spokes.

The inner casing comes with a valve to measure the air pressure in the front tube and alerts the user by lights and beep for warning about low air pressure in the front tube.



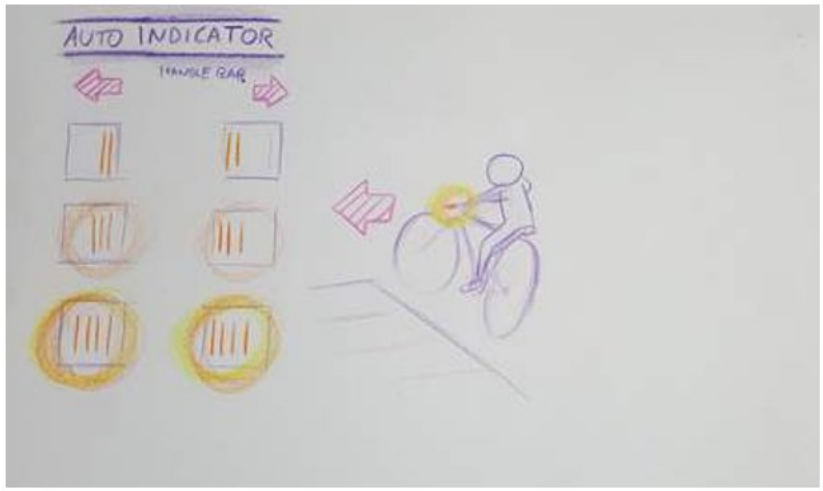


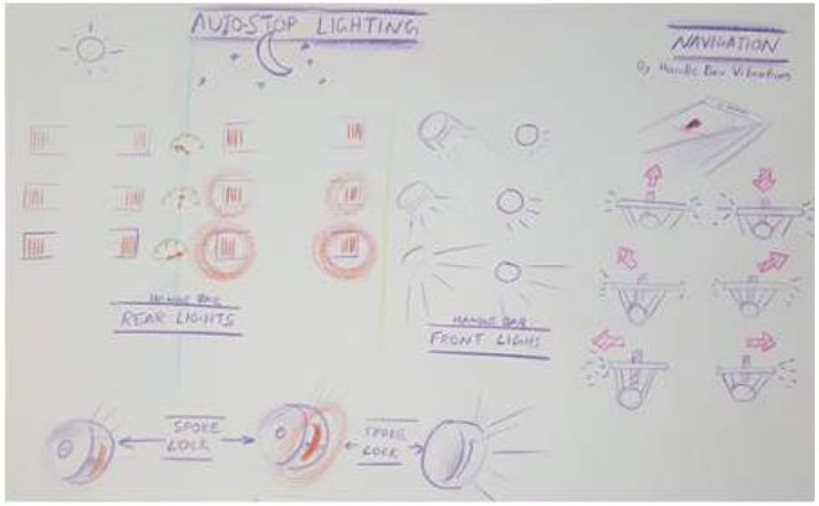


The lock will automatically determine whether the bicycle is turning and according to the direction, the handlebar flashes light in animated fashion.

The lock knows when the bicycle is still & moving and according to that, the handle bar flashes to the speed of the bicycle. During night, the front side of the handlebar and lock illuminates white light for a better visibility for the cyclist.
The user can link the navigation from his smartphone to the lock through the app and the handlebars give vibrations to the direction the user has to go.

- For forward, both handlebars vibrates equally low.
- For backwards, both handlebars vibrates equally high.
- For upcoming left direction, the left handlebar vibrates medium level and right handlebar vibrates very low.
- For immediate left direction, the left handlebar vibrates high and right handlebar vibrates nill.
- For upcoming right direction, the right handlebar vibrates medium level and left handlebar vibrates very low.
- For immediate right direction, the right handlebar vibrates high and left handlebar vibrates nill.





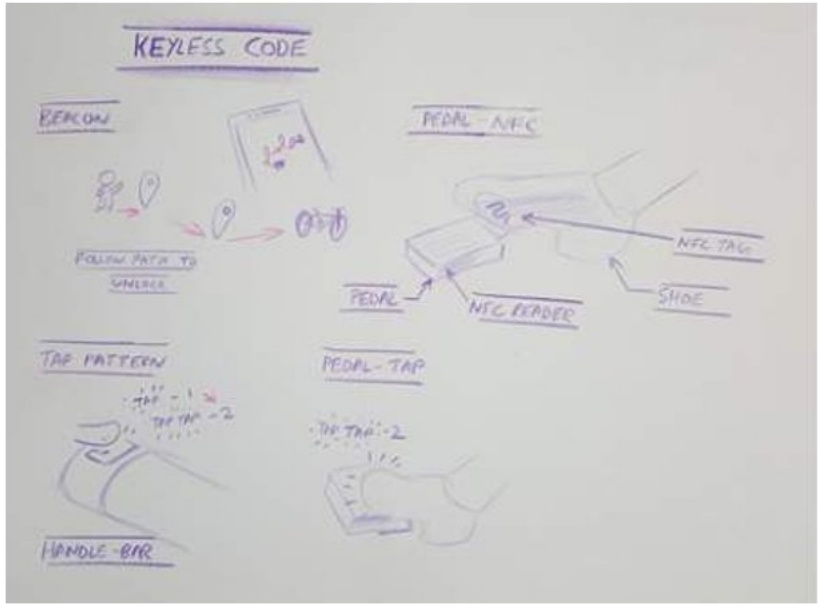
3. Explorations

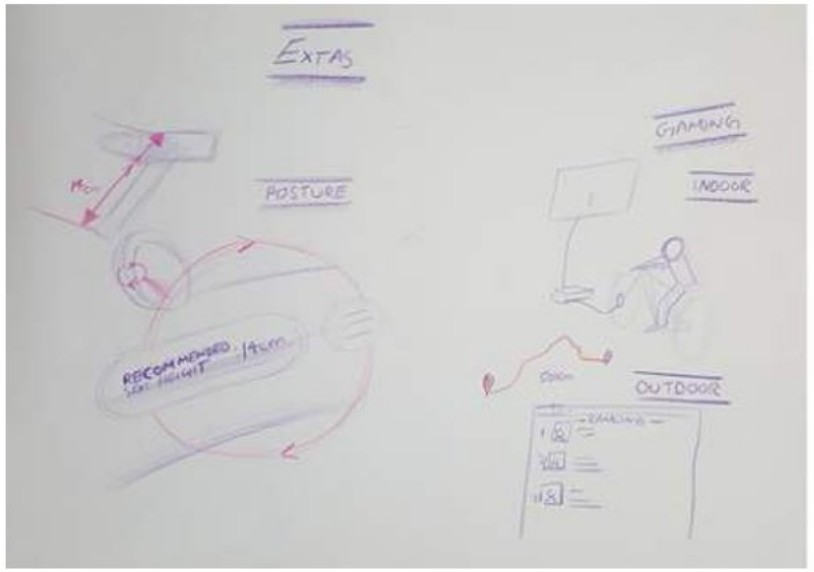
3.1. Keyless Codes

They were :
Tap pattern on handlebar.
Tap pattern on pedal.
Hidden NFC scanner in pedal and NFC tag inside the shoes of the cyclist.
The cyclist has to pass through position markers, fixed or random, set-up by the lock, near his bicycle, to unlock it.

3.2. Posture

Cyclist often faces the issue on posture while cycling. A long ride would render fatigue in legs, joint pains and back pain. These effects are caused due to improper setting of seating height & seat angle, cyclist's leaning body angle from seat to the handlebar and maximum leg angle to pedal. To rectify these effects, the cyclist's biometrics are needed to experience good cycling.





3.3. Indoor/Outdoor Gaming

The idea was to integrate gaming experience and through it promoting exercise in indoor as well as outdoor cycling. Games were based on online ranking in maximum speed attained, maximum distance covered, maximum map exploration - the game starts with blank or black map showing undiscovered and encouraging users to explore for bonus, fun riding & racing, maximum wheelie and stoppie time, minimum time taken or maximum speed attained between specific or marked locations in map.

3.4. Seat post feature device

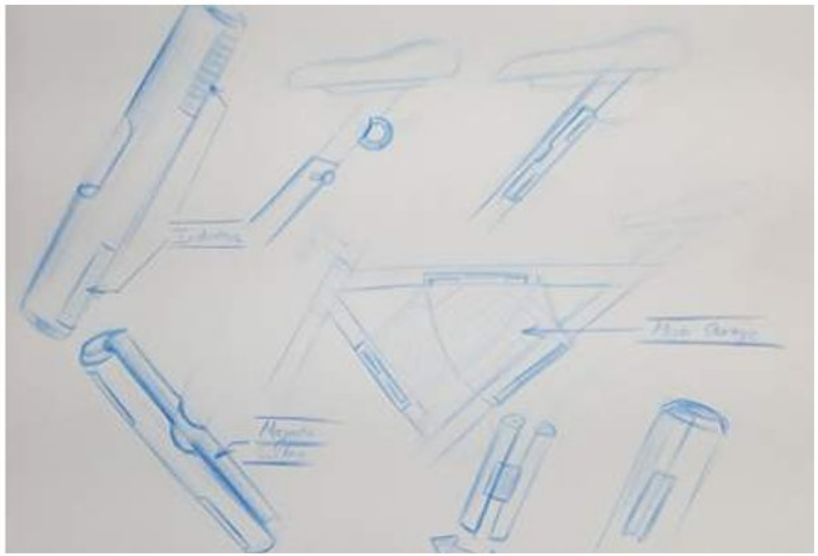
This a device that can be fixed horizontally or vertically on the seat post. It comes with mesh for storage when it is splitted and expanded. This becomes applicable when one piece is fixed to top tube an the other piece to down tube of the bicycle.
The device has indicators and stop lights, increasing the visibility and identity of a bicycle from far distance during night.

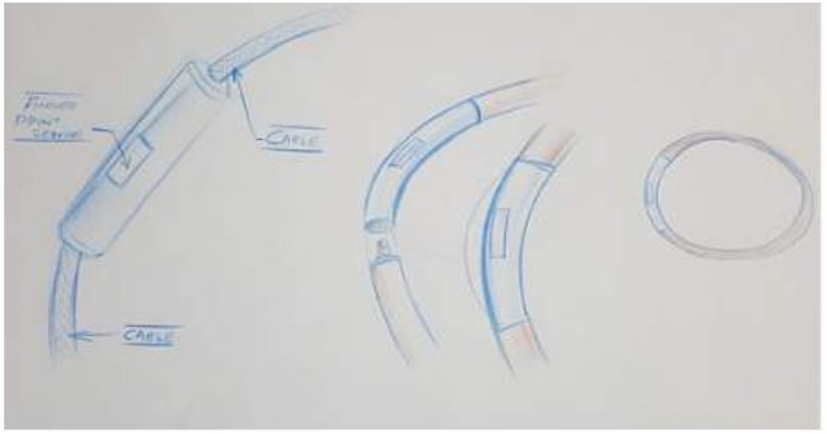
3.5. Cable lock

The idea was to improve the easiness in using the cable lock with fingerprint technology.

4. Conclusion

From the concepts and exploration, we decided to redesign frame lock in Concept 2.1 mounted frame lock, as it can do most of the proposed features in one device itself and could be easily setup on a bicycle, keeping in mind the constraints that would be faced on mounting it on different type of bicycle.



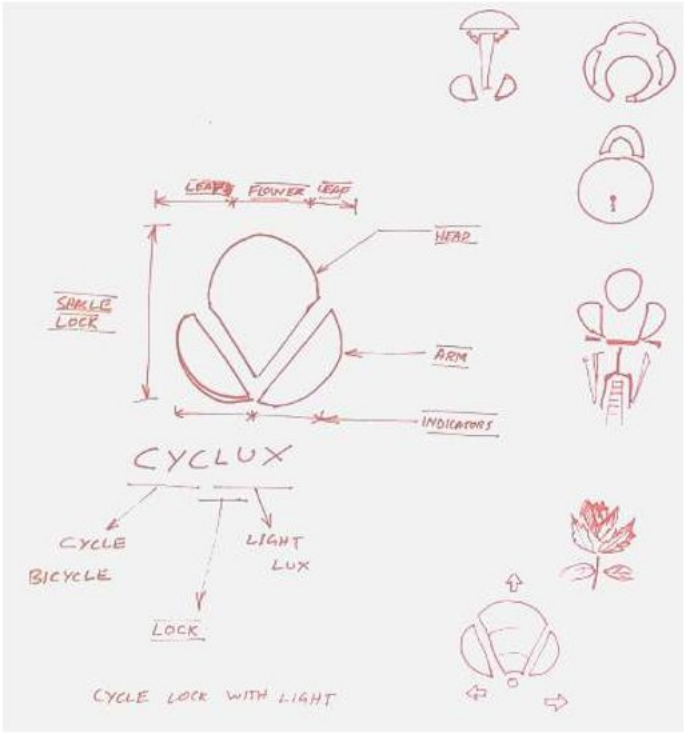


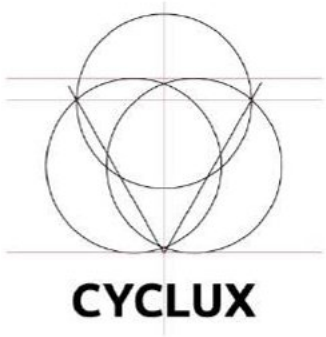
Branding - Name and Logo Design

After some iterations on words
— bicycle, locks, lights, assist — we came up with a name Cyclux. Expansion on Cyclux means, cycle lock with light as lux is the SI unit of luminous emittance. The logo is an abstract image depicting:

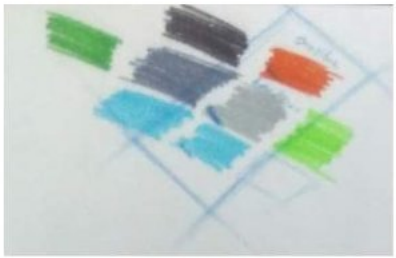
- Shape of a shackle lock.
- Head of a cyclist with arms
- on handlebar.
- Petal and sepals on either side symbolising a flower bud. This also represents green & eco-friendly.
- Form of the device with a stop light and indicators on either side, which comes below a saddle of the bicycle.
- Vision coverage of a person.
- The logo is made of perfect circles and lines.

The font chosen was Ubuntu, as it has dynamics and similarity of the frame design of bicycle' and letter 'l' has shape of a fork & letter 't' has side look of a handlebar with fork of a road bike or racing cycle. Shown image is a icon for the mobile app.





The colors — grey, red and light blue — are chosen such that they matches with bicycles.



Color - mood palette (source of color selection)

The image shown here is the intro screen for mobile app.

Cyclux logo ideation

Wireframes

1.1 Low fidelity wireframes

We started sketching out the low fidelity wireframes and then paper prototypes for the device before moving on to high fidelity wireframes.

The paper prototypes were grouped into 7, each having 4 screens for the app. The paper prototypes helped us in:

- Putting ideas faster
- Grouping the screens
- Ordering the screens

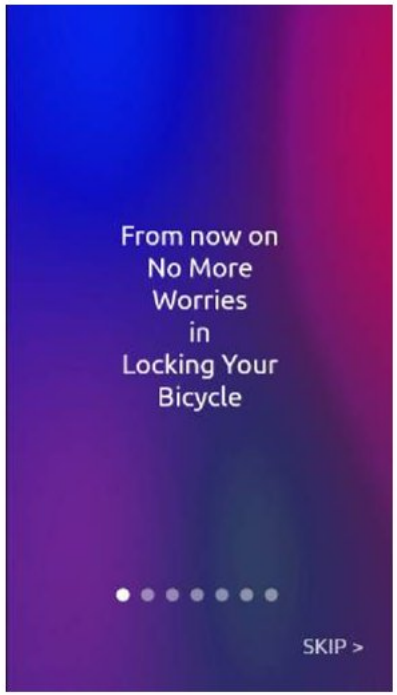
After finalising the screens, they were converted to high fidelity screens.

1.2 High fidelity wireframes

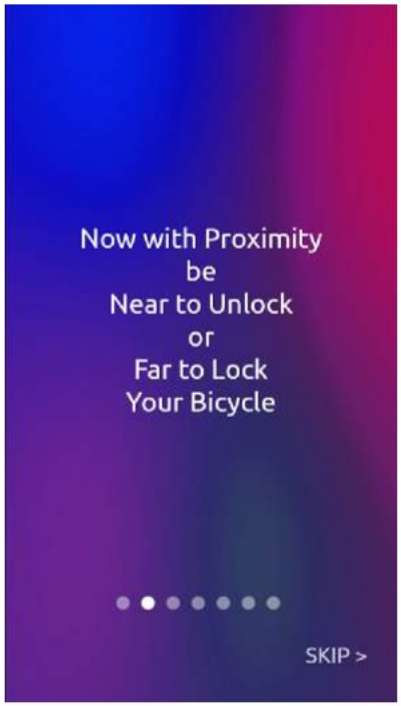
The high fidelity wireframes were done in Adobe XD and it was published online. The link to interactive app is : https://xd.adobe.com/view/29ad7c88-6ed0-4f9e-7ff2-6f83862ae8aa-5f9c/?fullscreen

Cyclux app icon in home screen

Loading screen



Welcome screen 1

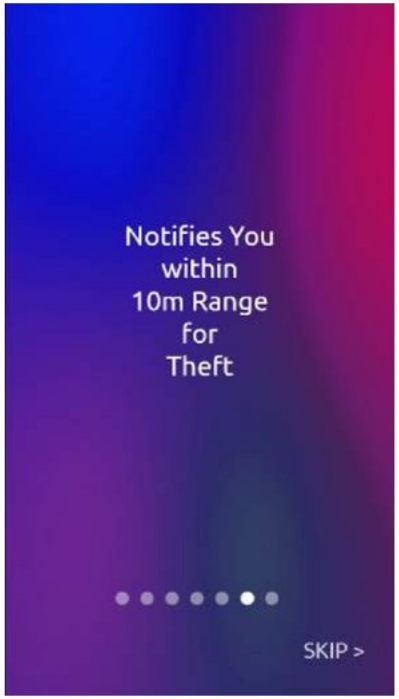


Welcome screen 2

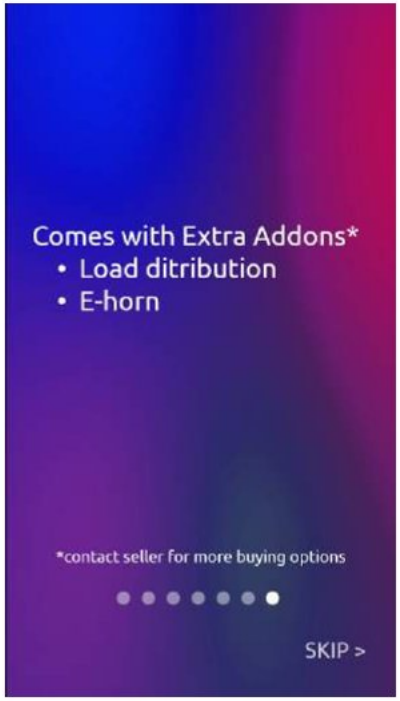
Welcome screen 3

Welcome screen 4

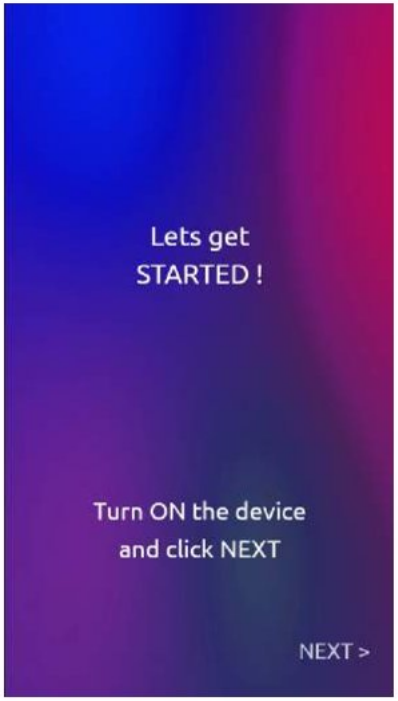
Welcome screen 5



Welcome screen 6

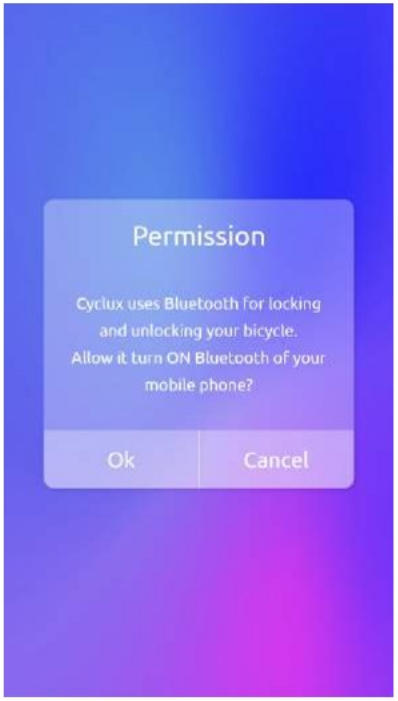


Welcome screen 7



Welcome screen 8

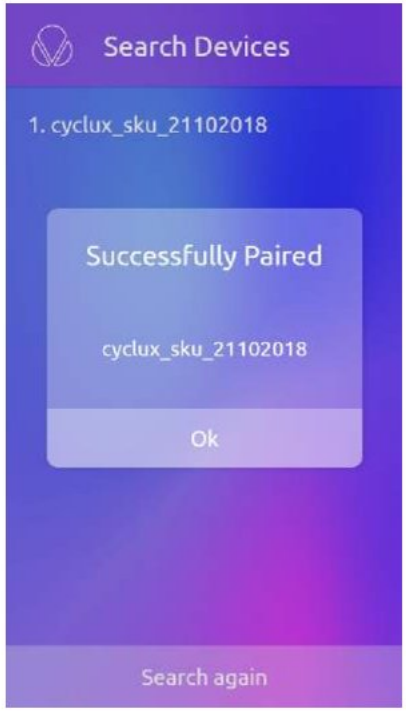
Login screen



Bluetooth permission

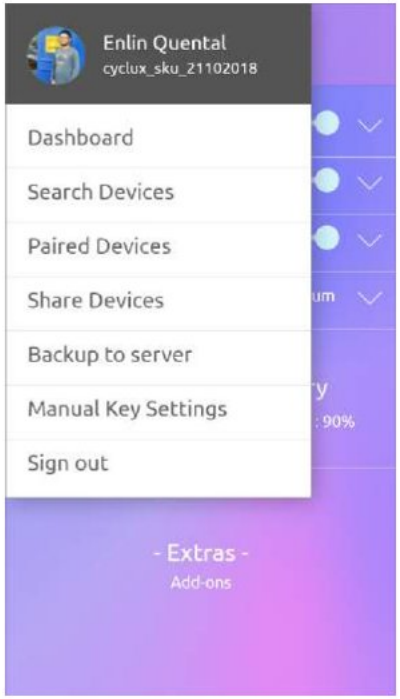
Searching devices

Search results



Pairing

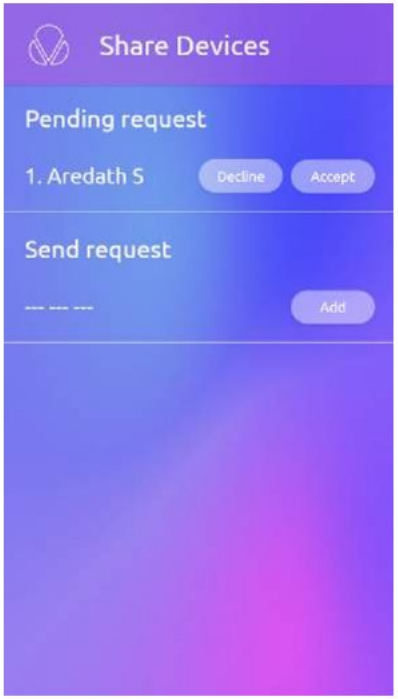
Dashboard



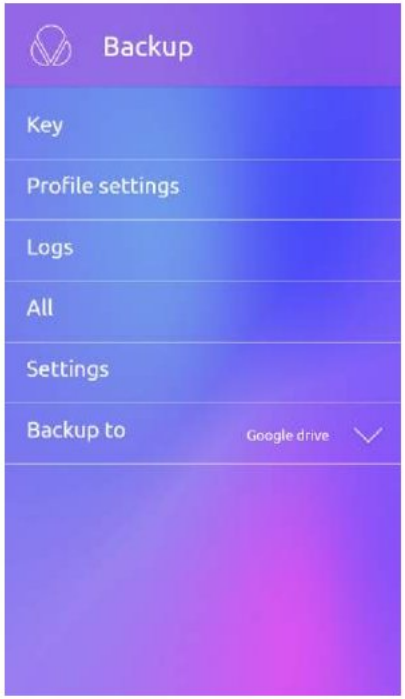
Menu screen

Paired devices

Options for paired devices

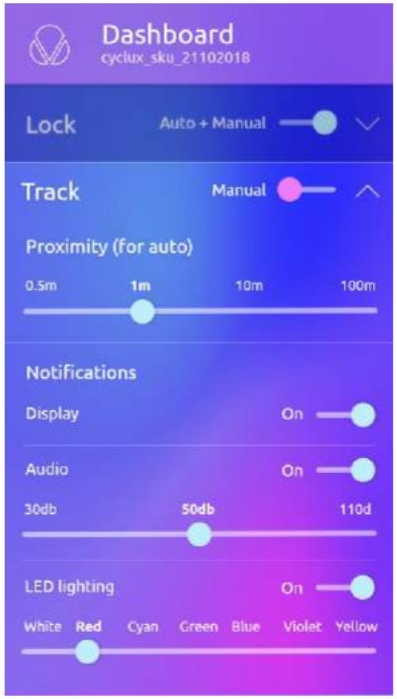


Share device screen



Backup screen

Locking option screen



Tracking option screen

Indicator and Stop light option screen

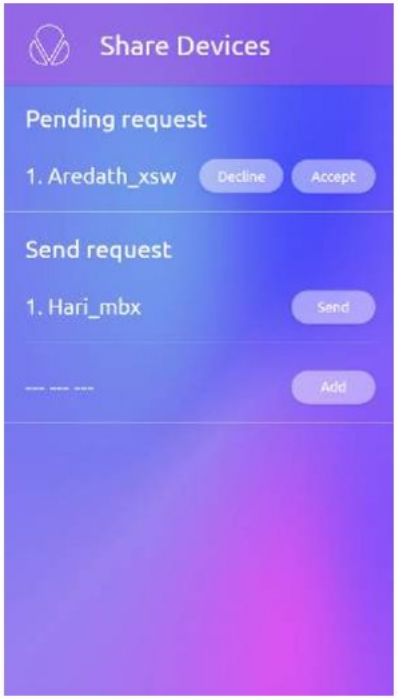
Indicator option screen

Stop light option screen

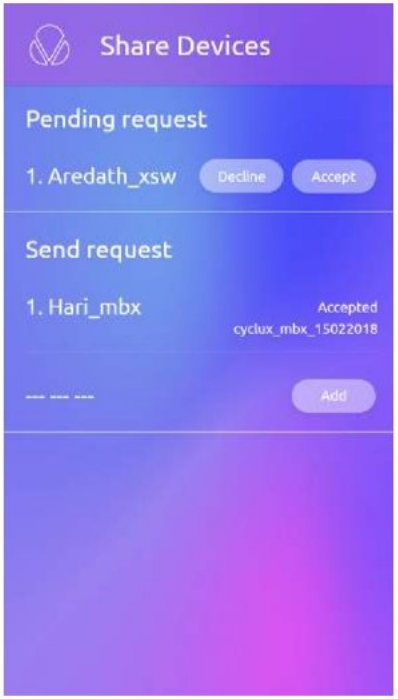
Informative screen

Battery status screen

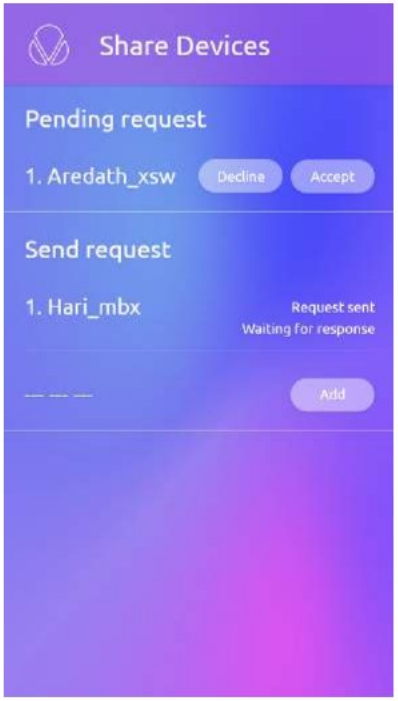
Manual key setting screen



Share request screen 1



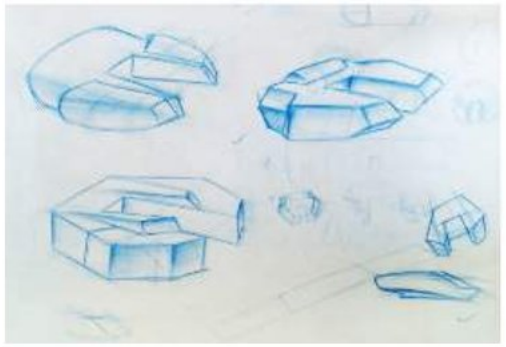
Share request screen 2

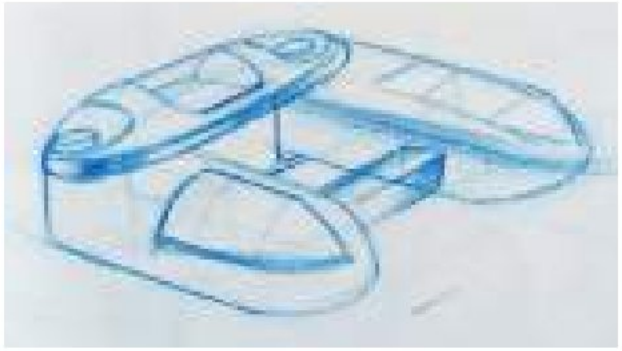


Share request screen 3

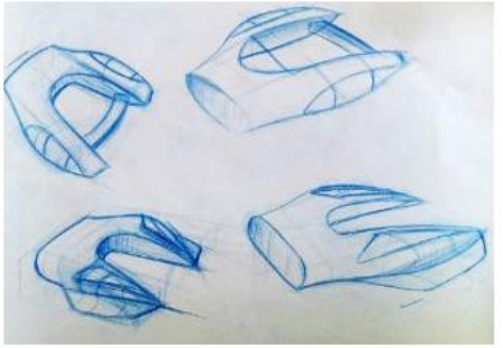
Prototyping

Form explorations

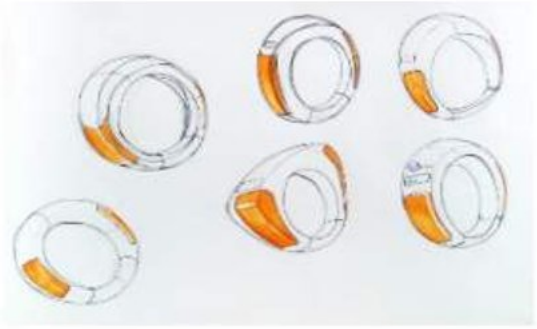




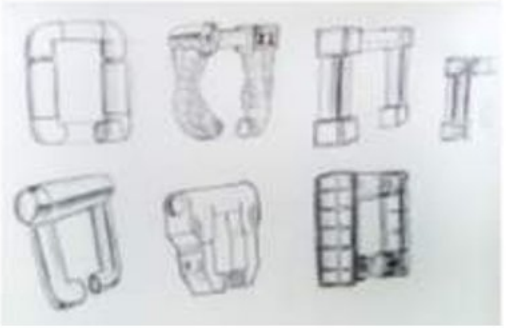
Idea behind the sketches were to explore on solid, muscular and withstanding damage forms.



Sketches were explored on semi-organic shapes.



Sketches were focused on simplicity - just circles and less/no bulk forms. Orange color denotes the indicators.



The form was inspired from the U-lock and adding textures variations on the basic form, which were inspired from PVC pipes, Roman pillars, classy-metallic finished U-Lock, robots and machines from the movie Star Wars, texture of grenade and all terrain military vehicles.

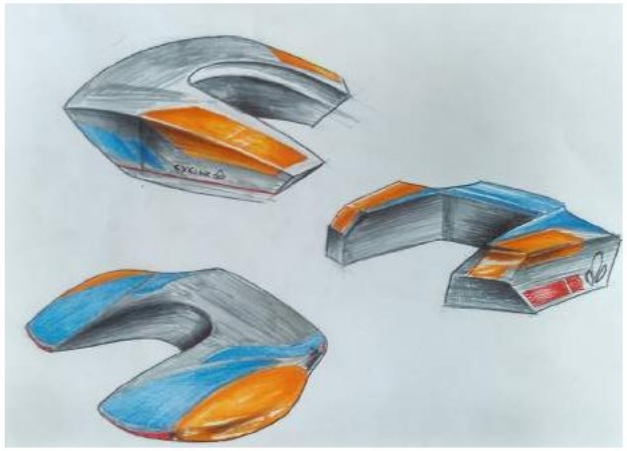
First sketches were drawn to get an idea of various shapes that were possible to go along with bicycle. Sketches were on families from organic, futuristic and muscle. We did a template (1:1 scale) for the device and made 3 form variations out of thermocol, each from one family. These forms were painted to see as near physical model appearance. A special form made out of MDF was made and vacuum formed it. This was to check whether the electronic components would accomodate inside it. It was found it is possible to accommodate them. So we finalised on a semi-organic form. We then further explored through sketches on the form and color schemes on them. We decided to 3-D print the final version of the form. So we started doing a 3-D model on the final version of form and added our color schemes to visualize, using Autodesk Fusion 360 and rendered them on Keyshot. While doing the 3-D modelling of the form, we came to know that the electronic components occupies majority of the space on the final form and there was no space to accommodate the unlocked position of the shackle inside the model. Therefore we discussed and decided that, the evaluation of the product will takes place into two parts :

1. Evaluation on the final form and color scheme
2. Evaluation on the working prototype

A basic 3-D geometric shaped form was made out of thermocol and shaped to fit through the seat-stay and seat-tube.
The thermocol marked with measurements became the template for forms. Three forms were made from the template, out of thermocol. Each form had a mixture of families from geometric, masculine: strong and bulk, organic and futuristic.

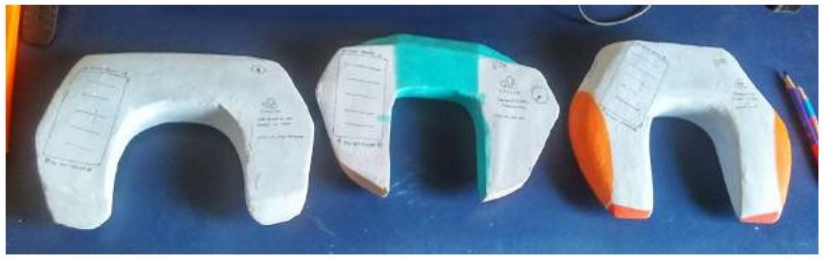
These forms given a layer of plaster of paris, for painting and then a layer of acrylic paint as a primer.

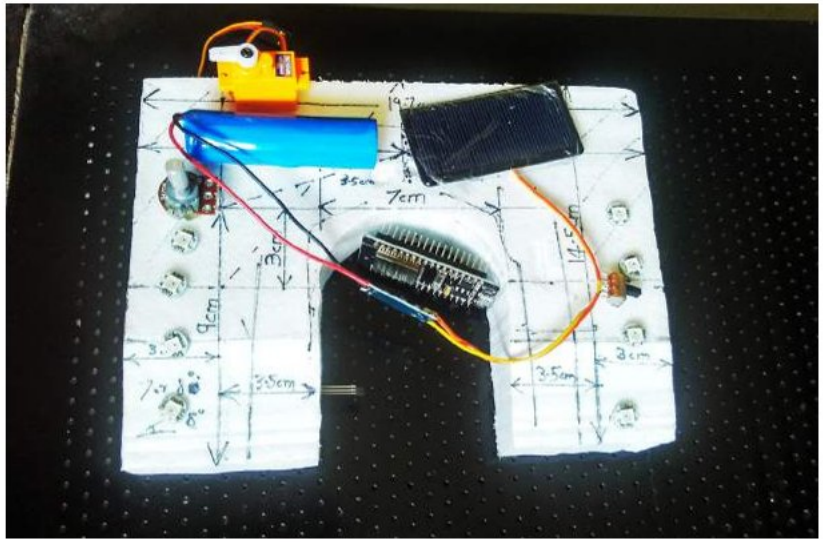
All the forms were acrylic painted, where the orange color denotes the indicator lights as well as stop lights. Light cool grey acrylic color is painted as the background color, whereas red, grey and cobalt teal color for graphics.



Placement of solar panel behind the form, represented as stripped rectangular box.

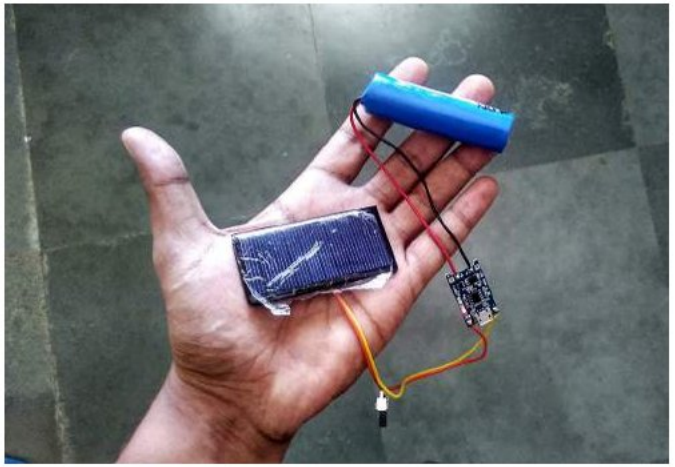
We then placed the electronic components on the thermocol template, to check their placement, before doing the 1st mockup model, which was vacuum formed.

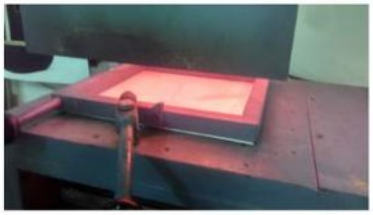




The working prototype of the device could be charged through solar and micro-usb port. So a test was done to check whether the battery could be charged under low sunlight and the result was positive. Similarly we tested the controller, addressable RGB led and servo for the prototype.

For the vacuum formed model, an MDF mould was sanded to the desired measurements on 1:1 scale, from the template. Using vacuum forming machine we developed the outer casing for the prototype, made out of 2mm thick styrene.

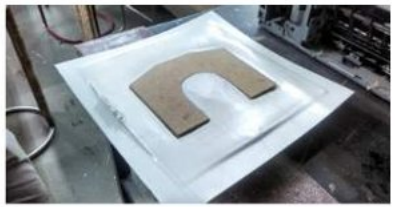


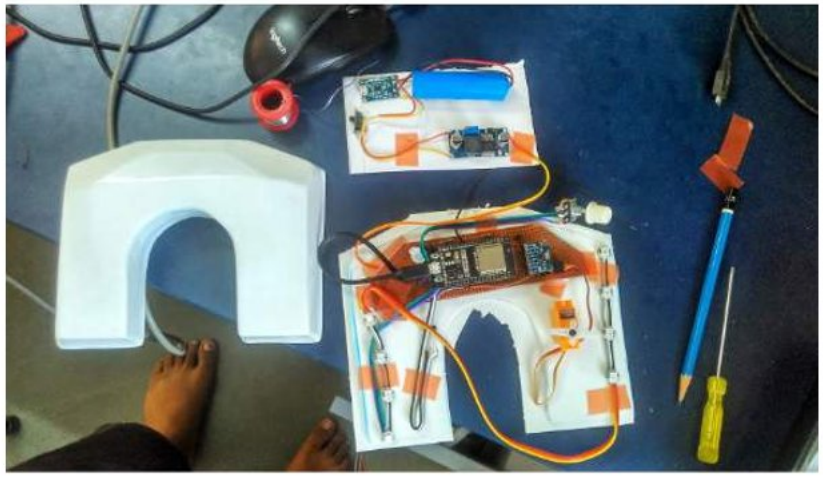


After vacuum forming, the components were kept to check whether the case could accomodate the electronic components.

We choose the semi-organic shape as the final form family for the product and sketched to further explore on this family with color schemes.

The final form and color scheme was finalised and started 3-D modelling it for 3-D print.





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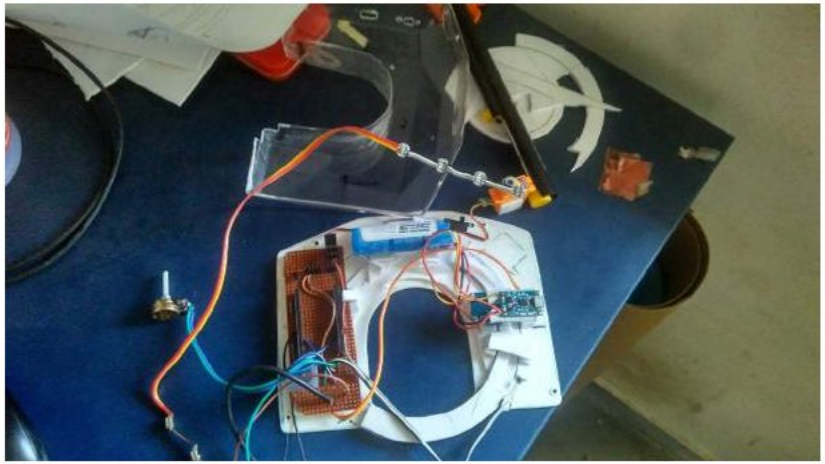
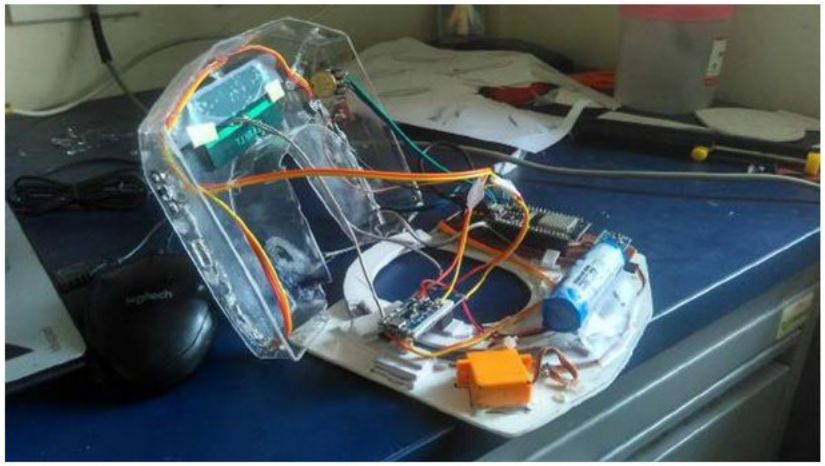
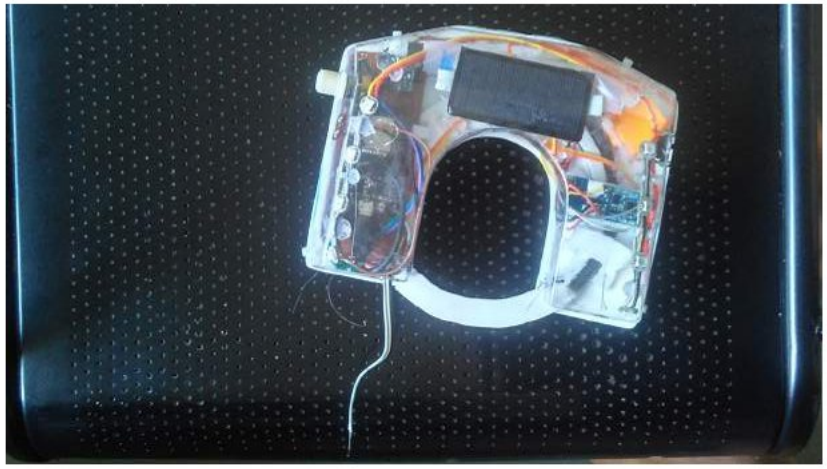
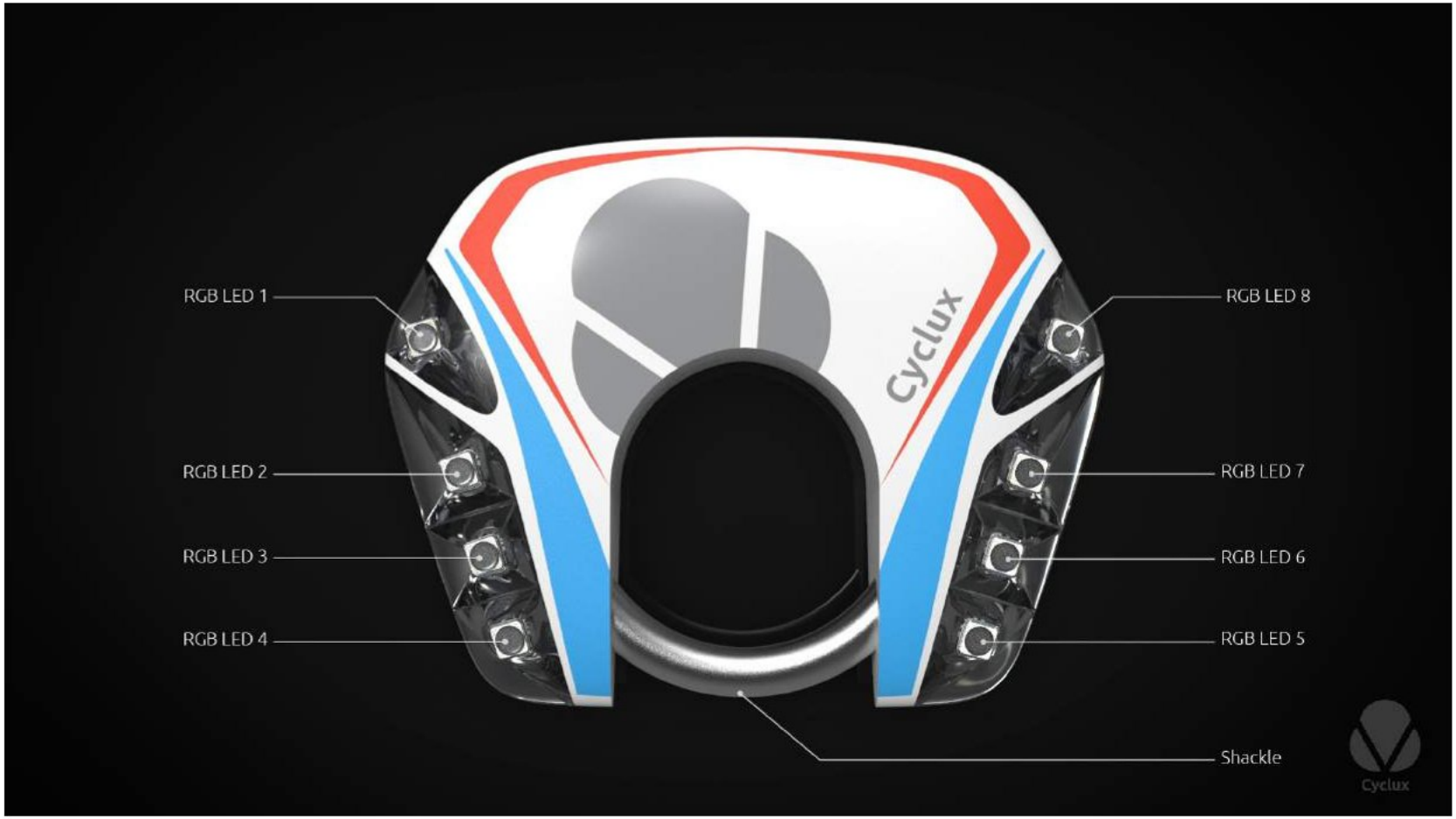
Working model — the making







Final Rendering



Top view


Knob for electronic rotary combination lock
Touch button
LED indication for charging
USB C port for charging
Solar panel 2
Solar panel 1
Cyclux

Bottom view


Knob for electronic rotary combination lock
Touch button
LED indication for charging
USB C port for charging
Cyclux

Back view

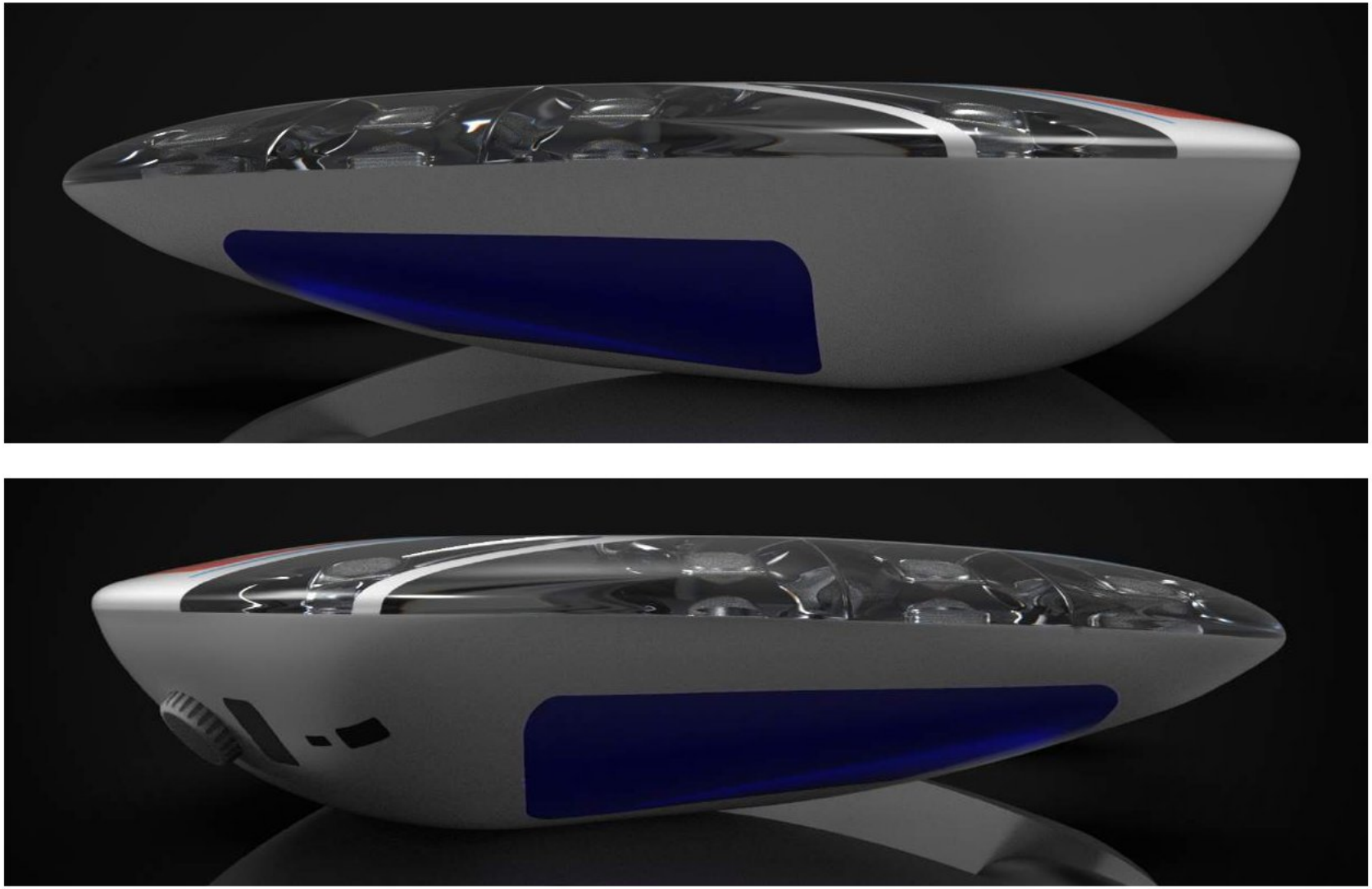
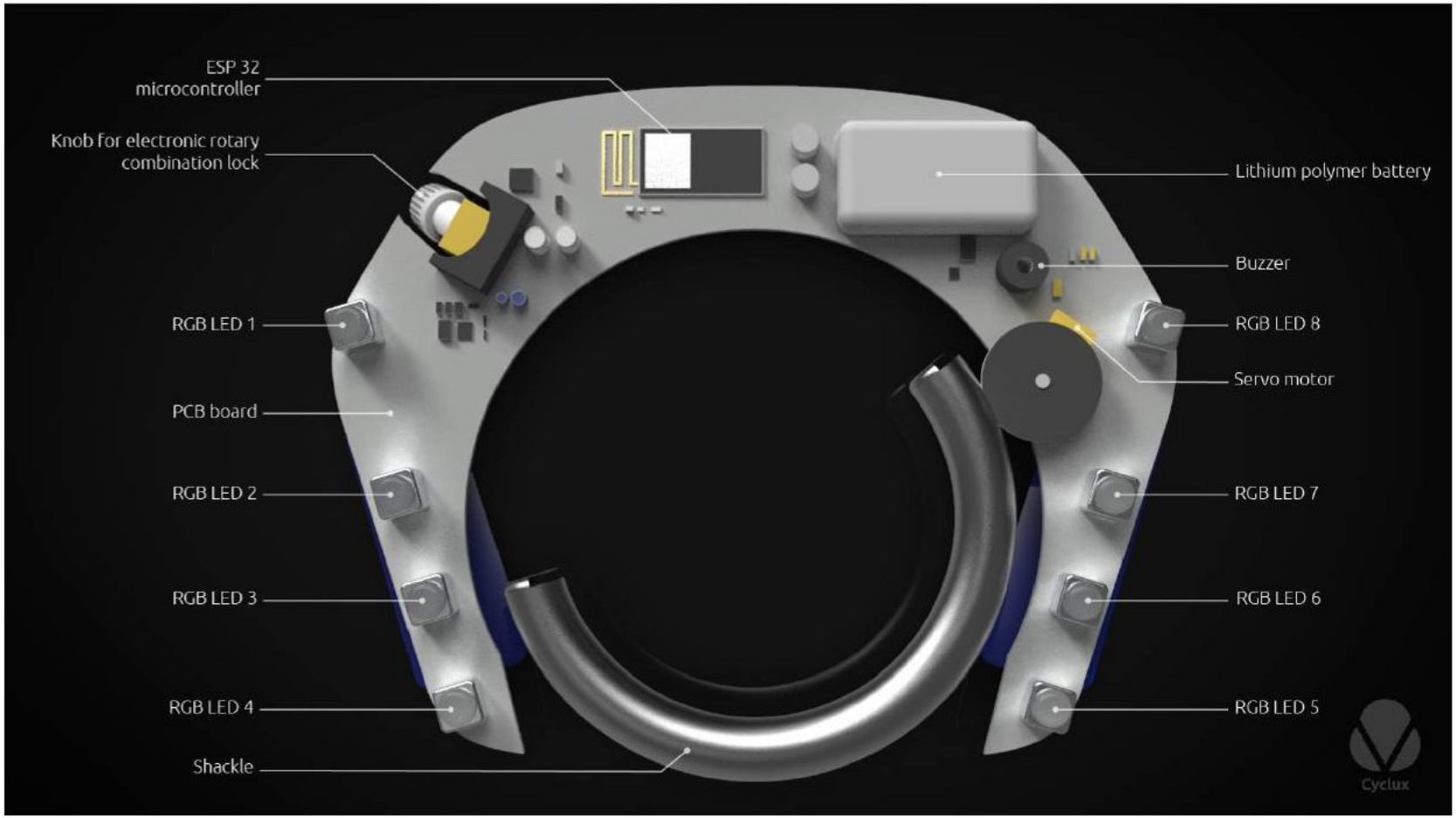
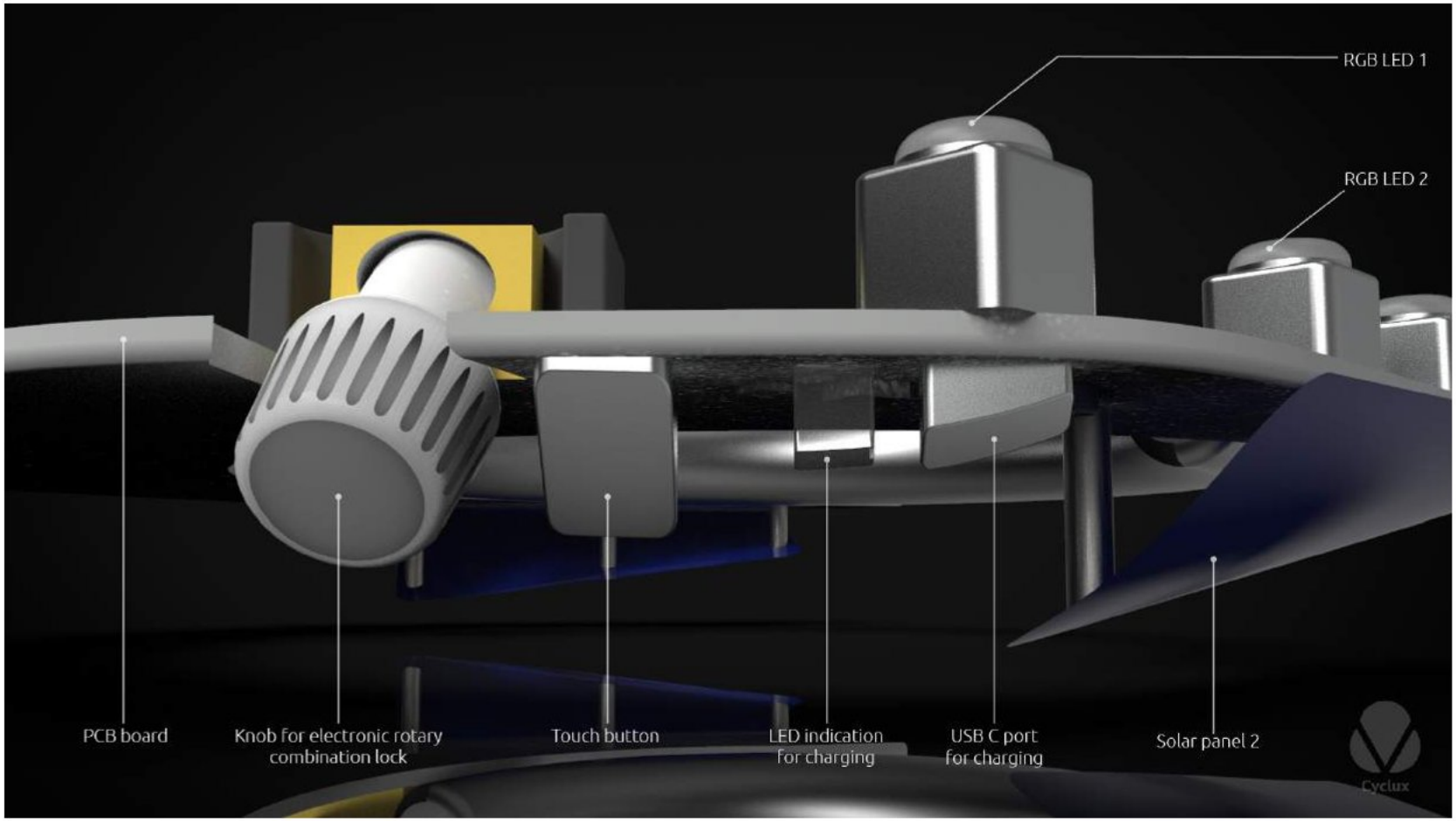


Image at the top: Right view, Image at the bottom: Left view



Innner components - Top view

Innner components - Bottom view



Innner components - Back view


Cyclux
Cyclux
Cyclux

Evaluation Protocol

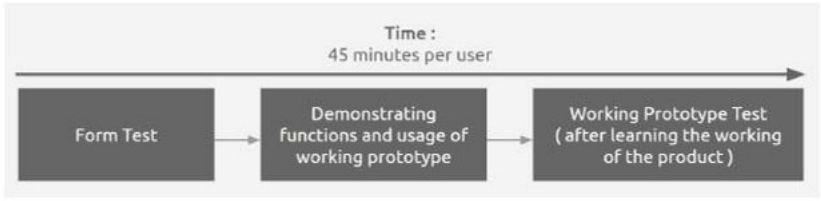
There were two evaluation: product form and working prototype. The reason behind two evaluations was that the product form, the actual form of the product 3-D printed in 1:1 scale, cannot accommodate the shackle inside the form as the main controller board occupies the desired storing space for the shackle. Therefore the working prototype, a vacuum formed body in 1:1 scale, would be performing the operation for shackle. In future, the main controller board will be manufactured in a pcb, which will reduce the size of the board and all the components will accomodate inside the actual form.

Protocol

Users
10 IITB cyclists

Session Duration
45 minutes per user

Method
A participant was chosen and he/she was presented with the 3D printed form and shown reference images of the rendering on the form from a laptop. The participant was also given a form having evaluation questions that he/she had to answer them parallelly.



The participant was then asked to explore the form in 5 minutes. After the given time, the participant was asked to evaluate on the form and color scheme used on it, from the given questions.

After answering the initial round of questions, the participant was shown the working prototype, which was fixed to a bicycle. Demonstration on the functions and usage of the working prototype was given.

After the demonstaration, the participant was given 5 – 10 minutes to use the working prototype by riding the bicycle.

Next, the participant was asked to evaluate on the working prototype from the given questions.

Questions

The questions were mainly focused on the following:

- Form matching with the bicycle
- Color matching with the bicycle
- The product suitablility for all bicycles
- Convenience
- How was assisting features for cyclist?
- How was the security features of the product?
- Overall feedback, pros, cons, upgrades, remove features, recommendations, wishlists.

Findings— form

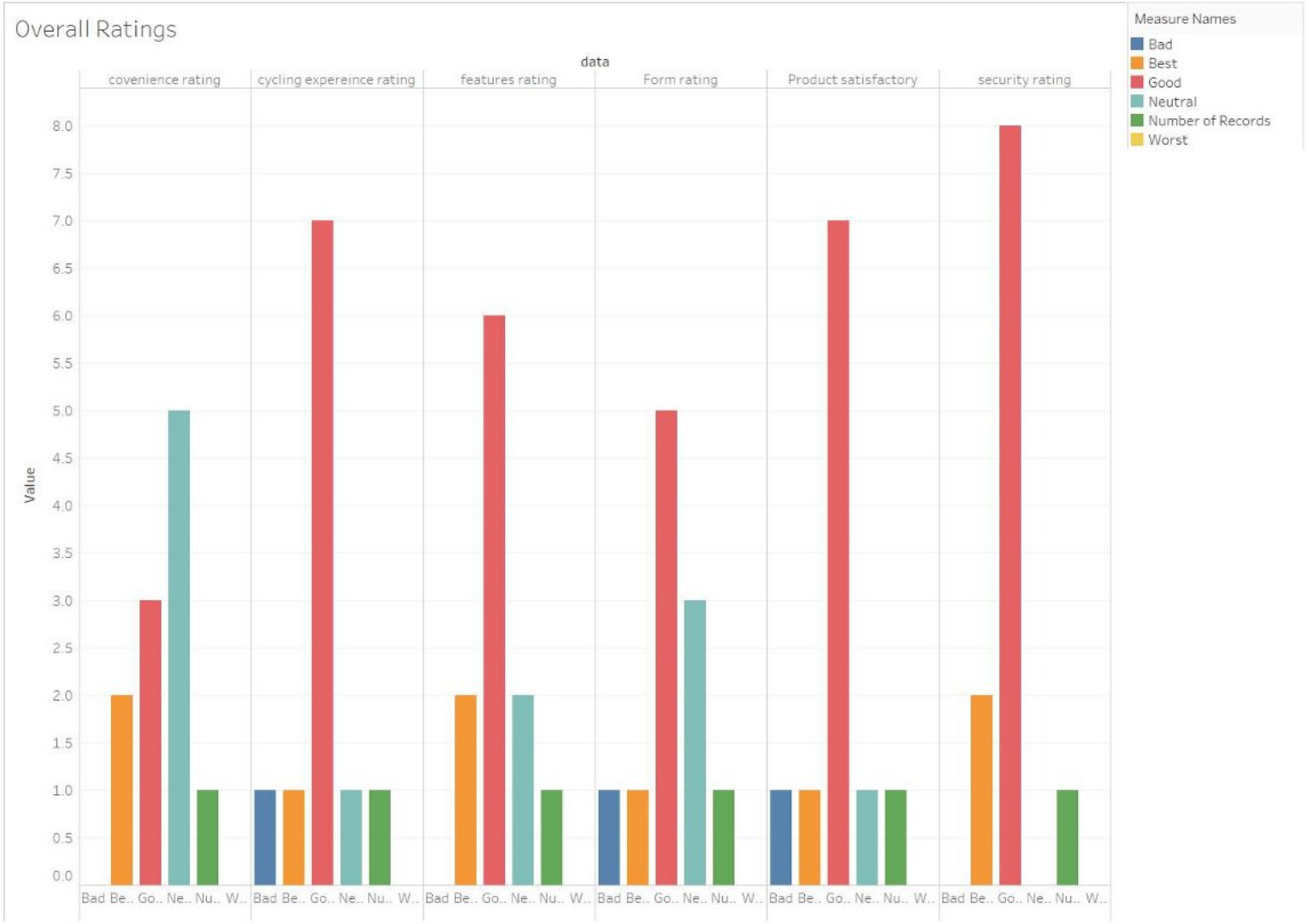
Participants found the product perceiving as spaceship, joystick, lock and remote control. They told us the product was for MTB cycles and was a smart security device. Colors were funky, edgy, sporty and it was targeted towards young audience. They said the colors does not go with all bicycles. Most of the participants informed us that the form does not fit in their bicycles.

Findings — working prototype

It was easy for the participants to lock and unlock bicycle, using the product. They informed us about false triggers for auto-indication, through out their cycle journey with the product. Informationsabout speed, distance travelled, calories burnt and weight loss were found useful by the participants.

Participants tested for false anti-theft alert detection by kicking the bicycle, which triggered the alarm, but also mentioning it as a false alarm, incase somebody wants to move the bicycle for parking space. Rotary dial lock process was effective but it was a complex process for the new users. Participants concluded that, it is an upgrade to the user's lock and improves security.

Overall Ratings



Future Scope

As per participants recommendations, we decided to build a compact form and better product placement for bicycles. Additional color variations for the product will be provided to match 95% of the bicycles available in the current market. Research on calibration for auto-indicators, and anti-theft alert triggering will be done more in the near future.
A USB-C type port for charging phones will be an additional feature of the product.

Conclusion

We succesfully developed a smart security device for the bicycles which distinguishes from existing smart locks for bicycles by the added unique features of auto-indicators and electronic rotary dial lock. Therefore this product does not exist in the current market. More research on callibration of auto-indicators and anti-theft alert has to be done. Users liked the product and the product had created a positive influence among users.

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