



Product: DeliverED Home

Team: DeliverED



Abstract

Our product aims to eliminate the need for waiting at home for a delivery – we will provide a secure and convenient personal mailbox for contactless deliveries, controlled by an Android app. In this demo, the goal was to get everything to a level of a final release. Our website has been completed with a Privacy Policy and User Guide. Our app has been completed, with usability UI changes, hardware connectivity as explained in later sections, and QR code scanning. Our Webots simulation has also been completed and tested, and our physical hardware is at a point where all modularized operation can be shown and has been tested, and connectivity with our app is fully functional. This demo has seen a lot of progress in terms of bringing everything together to finally showcase our product.

1. Project plan update

Our Demo 4 goals are as follows:

- Updated Website - Achieved
- Create user Privacy Policy (uploaded to our website) - Achieved
- Completed User Guide & Leaflet - Achieved
- Updated advertising video - Achieved
- Usability testing of app - Achieved
- Completed Webots Simulation - Achieved
- Updated App UI with Usability changes - Partially Achieved
- QR Scanning for Add Device function on App - Achieved
- App-Hardware Connectivity fully working & tested - Achieved
- Hardware Package Size Testing - Achieved
- Fully built and tested delivery sequence to showcase - Partially Achieved

We are fully on track for our website, app and Webots simulation. The only exception here is there were some usability UI changes we didn't get a chance to complete, as explained later in this report. In terms of our hardware, we have completed coding and testing on all individual parts of our device, including the forklift and collapsible platform. However, we did not have time to bring these components together in a way that would more comprehensively show our delivery sequence. This, and other problems we encountered regarding communicating with devices, is explained

further in the Hardware section of this report. A revised Gantt chart can be viewed in our appendix.

The finishing touches to the app were completed by Huacheng and Yizhuo, with Harry managing and testing the hardware connectivity for his Photon. Harry and Hallelujah were the team working on all Hardware-App connectivity for this demo, as well as communication with our physical hardware via sensors for testing. The simulation and advertising video were finished by Neo. The user guide was worked on by everyone, with Chris also formatting a leaflet version for our clients. Amy and Chris continued updating the website, with Amy writing up the privacy policy. Read our privacy policy [here](#) or in the appendix. Usability testing on the app was carried out by Hrichika and Chris. Hrichika was in constant contact with the hardware experts to get our physical components ready for this demo, and oversaw the hardware testing with Harry.

During this demo we have continued managing our tasks using Trello, and have set up GitHub repositories for the individual sections of the project, for example the app and the website. These repos are within a Github organisation, which we have set up for our company DeliverEd. We have kept in constant contact through Microsoft Teams, with whole-team meetings every couple of days. Lots of communication with experts has occurred this demo, with huge focus on finishing up all hardware testing, and the finer points of our user guide.

In terms of budget, our sources of cost are solely in the physical components that we have commissioned – the moving platform, electromagnetic lock, Pi, Arduino, and Photon. This will be detailed further in the budget section of this report.

2. Technical details

2.1. Webots Simulation

In this week Neo has implemented 2 minor features to the DeliverED Webots simulation.

Firstly, the control of the door and lock via command line input now, which demonstrates the capability of forwarding any control signals sent by the Photon server by using a simple socket to simulate. However, the server simulation is not implemented in Webots, since it's already been finished as the physical hardware of RaspberryPi and photon communication in Appleton Tower.

Secondly, as mentioned by Steve, we've added more environment simulations to give a better presentation which

gives the audience a closer connection between simulation and real life. Neo has rendered house and trees, and use pre-built garden view as background textures. Rendered scene is shown below.



Figure 1. User Environment Simulation

2.2. Hardware

Our goal for demo 4 was to have a fully tested, fully built physical hardware system, a goal that we partially achieved. Partially since whilst we have all components individually coded and tested, we did not have the time left to link all components together into one fluent delivery sequence like we had hoped.

Last demo we spoke about the problems we ran into whilst trying to communicate with the Appleton hardware from outside the university, and these problems persisted. The proposed solution of connecting the device to Eduroam and having the technicians claim it and give us the details to communicate with was reported to not work. This situation was unfortunately totally out of our control, and so we decided to focus on perfecting our control of the hardware rather than continuing with these efforts. App-hardware communication was already proven last demo from speaking to Harry's personal Photon. Additional code was written for this photon to handle notifications for the app and other software backend functionalities to prove our system works. These factors combined allow us to be confident that our original design would work well in normal circumstances.

We instead focused heavily on both testing the physical hardware using readings from the various sensors at our disposal as well as finally getting a chance to work with the newly built forklift and collapsible platform. Tuning the forklift proved to be a long and tricky process, as there was lots of slippage to deal with initially. After a while though we achieved a setup that successfully demonstrates the behaviour we want, which can be seen in our demo video. There is an infrared sensor in our secure compartment, depending on the readings of which, we were able to start the motor attached to the forklift to then lower the platform. The platform only lowers when a box has been placed on it and the infrared sensor (s1) senses that the object in front of it is now at a smaller distance (i.e., less than 19 cm). This happens every time a delivery item is dropped onto the platform. The platform stops at about 4 - 5 cm above the bottom of the secure compartment, where we have recently

decided to install another infrared sensor (s2), so that the platform knows when to stop and does not keep driving down into the floor. Such a situation can take place when the compartment is full while the platform is at its lowest point. When this situation takes place, i.e. distance read by s1 is less than 19 cm and that read by s2 is less than 10 cm, we are able to alert the user that their mailbox is full.

2.3. User interface

For this demo we were focused on completing the implementation of our redesign, alongside feedback collected during usability testing (refer to the Evaluation section). We now have core functions, locking/unlocking the secure compartment door, on the home screen (accessible from a dropdown for a device) and have moved more device settings into a deeper layer of navigation.

We conducted our usability testing on Wednesday 24th and Thursday 25th March, from which we gained valuable feedback on our UI and UX. Overall, our testers had a very easy time intuitively navigating our app and understanding what buttons did what. One recurring comment made was that they did not understand what the 'target and arrow' icon meant - we have updated this to a 'thumbtack' to better convey its meaning (where the user currently is). A reoccurring action was tapping a notification to get help with it (if it was an error) instead of looking for the user guide. Implementing this functionality this was unfortunately too big of a task to complete before the deadline - hence why this milestone was only partially achieved.



Figure 2. App Home Screen Implementation

Substantial progress has been made on our website, with the user guide fully complete on it too. Click to view our website and [user guide](#).

2.4. Software

Our Android app uses the barcodescanner component to determine the function of scanning the QR code. Each mailbox has its own corresponding QR code (the 24 character Particle Photon ID), which makes it possible to add equipment by scanning the QR code of our mailbox. When the camera recognizes that a QR code appears, it will automatically fetch the string associated with it (The Photon ID) and display it on the screen. Then the user can click to add a device after confirming, and the corresponding device information will be generated on the home page so that the user can control it.



Figure 3. QR Code Scanner

3. Evaluation

3.1. Webots Simulation Testing

In the past week, Neo has run multiple test for the Webots simulation in order to ensure its robustness and investigate its capacity. Even though its simulation testing, in order to present a real-life scenario, the parcel size and process are strictly following the maximum standard of Royal Mail UK Parcels Size and Weight. The length of UV sanitation differs based on parcel size after research (Hiroki Kitagawa, et al.)

From the experiments we could tell that for the current size of the mailbox (75cm*75cm*100cm), it could take 12 max-size letters, or 5 max-size small parcels, or 1 max-size medium parcels. Blueprints and actual simulations are provided as screenshots. Though the large size parcel cannot be put into our mailbox, according to Royal Mail standard, large parcel has a length of 1.5 meters[13], such large parcels (e.g. television, furniture, etc.) are better to be handled in person, which is not considered as our product initiative.

Type	Total Pieces	Total Volume(L)
Letters	12	132
Small	5	125
Medium	1	129

Table 1. Evaluation of maximum capacity of different size parcels

Type	Volume(L)	Process Time* (s)	Error
Letters	2.2	5 + 10	None
Small	25	7 + 20	None
Medium	129	10 + 30	None
Large	3375	-	Oversize

Table 2. Evaluation of different size parcels (Process Time is denoted as conveying + UV sanitation)

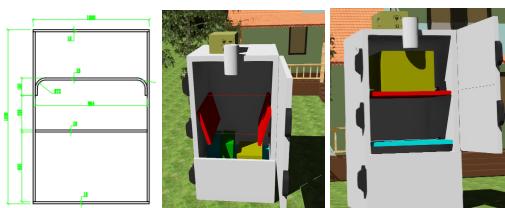


Figure 4. Small Parcel (Left) & Medium Parcel (Right)

3.2. Hardware Testing

With respect to the the electromagnetic lock, we are able to operate it from our microcontroller, as has been discussed in the hardware section. We are also able to read sensor values to check if our door latch is pulled in (=1) or pushed out (=0), or if our solenoid off (=0) or on (=1) and if it is pulled in (=1) or pushed out (=0)[1].

We tested the open/closed state of our solenoid by both operating it with our microcontroller and manipulating it manually, then checking the sensor readings for whether they reflect it being pulled in or pushed out. On average, the readings were accurate 4/5 times. We suspect that the sensor readings are not entirely accurate due to some noise present in them. We ran a similar test after manipulating our latch and the latch sensor returned expected values between 3/5 and 4/5 times, with some noise accounting for 1 or 2 unexpected readings. For each case, we changed states (i.e., between 0 and 1) 5 times[1]. When returning the state of the above components to the app, we look at readings in groups of 5. If 3 or more readings are the same, we report the state that corresponds to the majority reading.

Garry was present at the lab to confirm that our solenoid was working as expected at all points, which means that it was pulled in at our "on" command and pushed out at our "off" command (as was implemented using the microcontroller)[1].

We also tested our secure compartment mechanisms which included a forklift driven by a motor and two infrared sensors. One sensor (s1) is at the top of the compartment (at 33 cm), pointing across it and mounted onto a wall adjacent to the doors. The other sensor (s2) is at the bottom of the compartment, pointing upwards. If s1 returns less than 19 cm (width of the compartment),then we know a parcel has entered the secure compartment. Readings from s2 let us know the distance of the moving platform from the floor.

We ran 30 iterations of the movable platform's upward and downward movement to decide on thresholds of when it should stop. The forklift is about 48 cm high. To allow for the parcel some space to enter the secure compartment and drop into the platform, we stop it at 31-32 cm when going up. We want to stop the platform at a 4-5 cm distance from the floor to avoid it ramming into the sensor s2 when going down.

We ran 5 iterations of dropping a single parcel into the movable platform. It stopped after moving down far enough to clear s1's 'line of vision' a 100% of the times. We ran another 5 iterations with multiple boxes (3), placed one after the other. The forklift moved down as expected a 100% of the times. Upon placing a parcel such that s1 returned a reading of less than 19 cm while the moving platform was at 4 cm from the ground, it did not move down any further, which is the desired behaviour. In this state, we are able to raise a flag of "Mailbox is full".

We also had to allow for a little noise in our infrared sensors. Sensor s1 gives a reading which sometimes varies between

19 and 20 cm while there is no parcel. We take the lower threshold, i.e., 19 cm, to check against. This worked well for our above test cases. Sensor s2 gives a similar varying reading, which is why we allowed a 1 cm interval when deciding the thresholds as discussed previously.

3.3. Software Testing

3.3.1. STRESS TESTING

As we have tested all basic functionalities in last demo, we proceed to the next stage of testing. In this demo, we used Monkey to test the robustness and stability of Android application. Memory usage and coherence between different classes would be considered. Table 3 contains all functionalities in application and testing result.

	Number of Test	Error Rate
Notification		
locked	1000	1.2%
unlocked	1000	0.8%
receivedParcel	1000	0%
full	1000	0%
lowCharge	1000	0%
noCharge	1000	0%
locationChanged	1000	0%
connect	1000	0%
disconnect	1000	0%
paired	1000	2.5%
removed	1000	4.8%
HomePage		
Lock	1000	0%
Unlock	1000	0%
Add Device	1000	0%
Remove Device	1000	0%
Full Detail	1000	0%
DevicePage		
Lock	1000	0%
Unlock	1000	0%
Remove Device	1000	5%
AccountPage		
User Guide	1000	0%
Log Out	1000	2%
NavigationBar		
Home Page	1000	5.3%
Alert Page	1000	7.7%
Navigation Page	1000	0%

Table 3. Stress Test

In the test, we found that some functions are highly dependent on the quality of the network. When the network delay is high or the connection is unstable, those functions trying to send HTTP Post will be blocked. At the beginning of the design, if the function corresponding to a button cannot be finished due to network reasons, it will cause the button to be temporarily inaccessible. This is to prevent excessive touches from causing the entire application to become unresponsive. In specific use, although the user cannot touch the functions that are being used, he can touch functions that have not yet been used, such as the navigation bar.

The results of the stress test show that the application performs well when it does not involve frequent page switching, but if frequent page switching is performed, some functions will occupy a considerable amount of memory. This is because the App uses a polling method to update the

data, and the data on the entire page will re-send the HTTP command to Particle Photon every time it is re-entered. When the data is obtained, the page will not be refreshed immediately, but will be automatically refreshed after the user leaves the page or the page is static for a period of time. Before entering the new interface, the application will also try to obtain updated data.

3.3.2. USABILITY TESTING

For our usability testing, we had 5 participants, 2 of whom were native English speakers while 3 were non-native English speakers. While 3 of them were from within the Systems Design Project course, 2 of them were from outside of the School of Informatics. All of them were students at the University of Edinburgh. Maintaining a balanced mix of both native and non-native English speakers as well as students with and without a technical background helped us shed some light onto how different people would interact with our app. All of them found our terminology intuitive and the app mostly easy to use. We noted their interactions to note any improvements that our app might need in future development cycles. Our key findings were discussed in section 2.3, "User Interface", of this demo. Our gatherings have been summarized in further detail under the "Usability Testing" section of the appendix. You can interact with our online app demo [here](#).

4. Budget

Our budget has not changed much since Demo 3, except for the addition of the costs of the second lock. Our budget for this demo is shown in Table 4. Our budgets for each previous demo has been added to the "Appendix" (Tables 5, 6 and 7). Our budget changed as we started implementing our physical hardware and made certain choices, such as substituting a scissor lift with a forklift for the movable platform to save space, etc. Refer to "Real Build" in Appendix for real product considerations.

Items	#	Cost(£)
Metal Work [Lock]	2	20.00
Standard Deadbolt Lock	2	40.00
Solenoid	2	50.00
Electronics And Wiring [Lock]	-	10.00
Motor [Fork Lift]	1	35.00
Lego Set [Fork Lift]	1	15.00
Motor Board [Fork Lift]	1	10.00
Basic Sensors	-	10.00
Advanced Sensors	-	30.00
Encoder Board [Fork Lift]	1	10.00
Miscellaneous [Fork Lift]	-	10.00
Particle Photon	1	18.67
Technician time (3 hrs) [Fork Lift]	-	-
Total		258.67

Table 4. Budget

5. Video

Watch our draft pitch video [here](#) (SharePoint).

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Appendix

More Hardware Figures

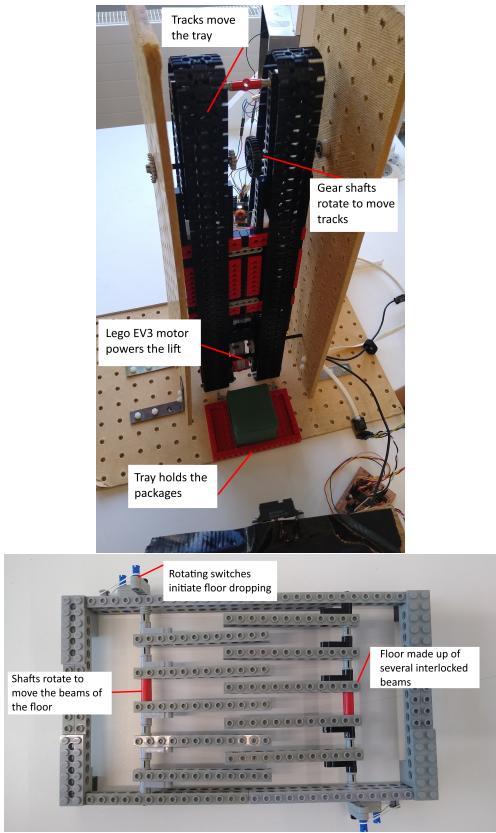


Figure 5. Forklift (top) & Collapsible Door (bottom)

UI Evaluation[1]

1. **Visibility of system status:** On the home screen, the user can see at a glance if their devices are in a healthy status or not by the circles exclamation point indicator next to them. The user can click the dropdown button on a device to see the 3 most important statuses: locked/unlocked, battery life and capacity.
2. **Match between system and the real world:** The vocabulary used in the app is simple and should not take a tech-savvy user to understand what information is being presented or what action a button will take.
3. **User control and freedom:** At any opportunity the user has to edit anything, there are confirmation and cancel buttons either on the same screen or in a pop up modal. Important actions will have an exclamation point beside them.
4. **Consistency and standards:** There is no ambiguity in the language used for actions throughout the app. Actions can only be performed from their designated page, e.g. editing your device name can only be done by navigating to that device's information.

5. **Error prevention:** Errors from the physical device will come through on the notifications screen. They are easy to identify by the big exclamation point icon and universal exclamation point beside the text. In addition, they will be highlighted red. All notifications will come through the phone's native notifications as well. Errors within the app will appear as a toast notification at the bottom of the screen. All errors will have meaningful descriptions.

6. **Recognition rather than recall:** With our simple design that has few screens to navigate the user should not have to recall where to find information or actions.
7. **Flexibility and efficiency of use:** We have all our core information and functionality on the home screen so that a novice user can easily perform tasks. On the home screen, each device has a button that takes the user to a new screen where they can perform more actions. Here they can edit the device name, if they are the owner, control access to the device or remove the device.
8. **Aesthetic and minimalist design:** Our interface is simple, with large text and buttons. There is no clutter and we make the most of the screen's real estate.
9. **Help users recognize, diagnose, and recover from errors:** As mentioned earlier, error messages are identifiable from the large exclamation point and red highlighting, with a meaningful description that will also suggest looking at the help screen.
10. **Help and documentation:** As mentioned above, there is a help screen with quick links to how to complete common tasks and solve common errors. It also has buttons to see the full user guide online or download it as a PDF, as well as an 'Email us!' button.

Market Requirement[2]

In 2016, August Home Inc. reported that nearly 11 million U.S. home owners had their package stolen within the past year. They reported that majority of the packages delivered to the customers' homes were stolen (74%) during the day, when the customers were not out, and it increased to 81% during the holidays. [16]

In 2019 C+R Research conducted a survey of 2,000 consumers in the U.S. who had shopped online at least once in the past 12 months. They found that 36% had experienced a package theft at least once. They report that the average cost of replacing a stolen item is \$109. The average amount spent by consumers to prevent package theft was \$191, through camera and motion light installations, putting up fences and gates, etc. [3]

Another survey of 562 participants from 49 states in the U.S. revealed that nearly 23.8% of the respondents had experienced package theft.[9]

It has also been reported that 12 million in Britain have fallen victims to package theft.[6]

It is evident from the statistics that there is a market need for a product that is able to safeguard parcels from getting stolen or otherwise damaged after delivery, while the consumer is not at home. Through our smart mailbox, we hope to provide an effective solution for the existing issue.

Due to lockdown measures and restrictions, the primary mode of purchase has shifted to online shopping. However, the popularity of online retailing was already on the rise before Covid-19.[14]

We have also included a sanitisation feature in our product so that consumers can avoid contamination through deliveries. Coronavirus appears to be able to survive on cardboard for 24 hours and for up to 3 days on plastic surfaces.[10] Our sanitisation feature will not only help protect our customers during the pandemic but also from other viruses, such as the flu virus. It is advised that deliveries be made contact free and be disinfected whenever possible.[18] 64% of consumers say that they are worried about their own health while 82% say that they are fearful for the health of others.[7] Our smart mailbox is able to address this concern through its UV sanitiser.

Market Competitors [1]

Here we look at some of the existing market solutions for safeguarding delivered packages when the customer is unable to collect it firsthand. We discuss below how our product stands out from these identified competitors.

1. **myRenzbox:** [15] It is targeted at commercial and residential buildings where it needs to be provided for the tenants and dwellers, by the owners. DeliverEd Home, on the other hand, targets a slightly different demographic and has been designed keeping home owners in mind, which means that it is perfectly suitable for individual purchase and personal use. This also means that our design is much more compact as compared to myRenzBox and can be installed into smaller spaces. The sanitisation feature of our product is another differentiating factor, which is not included in myRenzbox. As discussed under "Market Requirement", there is a constant public health concern at the moment and our UV sanitisation feature will help customers to protect themselves and their family from contamination.
2. **Yale Smart Delivery Box:** [11] A key difference between our products is that there is no secure compartment in their design. The parcel drop-off and collection area are the same. This makes already dropped off parcels susceptible to theft by delivery people with ill-intentions. This was a key consideration in our design for DeliverEd Home, where we have a secure compartment for parcel storage, which is not accessible from the drop-off compartment, other than parcels being dropped down. This means that the customer's parcels will not be accessible to anyone other than them or their trusted ones. The Yale box is unlocked using a keypad attached to it, which is an optional feature. This brings in the hassle of creating, remembering and

sharing a pass-code so that people can retrieve parcels from the mailbox. In contrast, DeliverEd Home can be unlocked remotely, using our app, while having a backup lock and key mechanism. This means that you can give your trusted ones access to your parcels in the secure compartment without having to share a pass-code. This is useful in situations such as when you may have perishables delivered that you can't collect in time. The Yale box remains unlocked until a delivery is made and then auto-locks. The problem here would be that anyone can drop off anything. On the other hand, the drop off area for DeliverEd Home is secured using an electromagnetic lock which we plan on operating using our app. You can keep it open for the duration that you expect a delivery. Securing it was considered so that no random person can pull a prank and drop off unexpected items into your mailbox. Yale's design also does not consider accessibility issues. For example, in most cases, one would have to bend down to retrieve parcels from it. DeliverEd Home takes this into consideration and allows you to customise its installation to a preferred height. The sanitation option is, again, a differentiating factor between our product and Yale's, where they don't provide one, unlike us.

3. **Amazon Lockers:** [12] This is a "go and collect" service which may or may not be available in an area close to you, whereas with DeliverEd Home, you are able to store your parcels at your own address. So, you don't have to worry about the inconvenience of having to travel to collect your parcels. With Amazon Lockers, you have 3 calendar days to pick up your parcels, but with DeliverEd Home, you don't have to worry about how long you are away. You can store your parcels in our mailbox for as long as you need to. Another important consideration is that only items dispatched by Amazon are eligible for delivery to and collection from a Locker. With DeliverEd Home you can opt for any courier service of your choice. And lastly, just as with the above two, you have an option to sanitise your parcels inside our mailbox, which you don't with the Amazon Locker.

Real Build

In this section we will outline some of the materials we could consider using for the real product:

1. **The walls:** For the walls of the mailbox, we can use stainless steel. This will prove to be both sturdy and weather resistant. It is corrosion and erosion resistant, and it will not be easy to cut through. We can also paint it, giving customers an option to customise their mailbox. Stainless steel is also less likely to be affected by exposure to UV light, considering we are planning on providing the option of UV sanitisation. The price related to this can be ascertained after meeting with our potential production partners.

2. **Movable Platform:** We can build the movable platform using stainless steel as well. We will probably have to use more powerful motors as compared to the ones we are using in the workshop. The price related to this can be ascertained after meeting with our potential production partners.
3. **Handymen for installation:** We suggest 2 people for 2 hours for installing the smart mailbox according to the customers' preference. The average hourly rate of a handyman is £11.71 [5]. So the total installation fee will be £46.84. (Note that this is excluding the bracket for installing the mailbox onto the wall.)
4. **UV Sterilizer LED:** We expect there to be 2 such LEDs (110 V, US) on 2 opposite walls (the ones adjacent to the access doors). The total comes to £24.02 (£12.01 each) [4].
5. **Locks:** All materials for the lock are expected to remain the same, although upon a future round of testing (hypothetically) if we find that the locks are not sturdy enough to withstand brute force, we might have to look at certain improvements, although the core mechanisms stay the same. The cost for building the current electromagnetic locks have been included in the budget.
6. **Bascule trap door / collapsible platform:** This platform separates the drop-off area and the secure compartment. We can use RSPro struts, which are £41 per metre and angle joints for RSPro struts, which are £5 each. [17]
7. **Particle Photon:** The price of a particle photon has been noted in our budget in Table 4.

Ways to break the system

1. **Take out the battery:** One could potentially hinder the functioning of the mailbox by taking out the battery. But although this would disconnect the electromagnetic locks, we still have fail-proofs in place that immediately bolts the access doors. But now the lock needs to be opened by a key, where one might try to pick the lock.
Solution: this is all contingent upon the fact that the person/attacker is able to detach the battery. In our design, the battery is located inside the secure compartment. Note that we are considering using the real mailbox using stainless steel. In such a case, the attacker would have to cut through the exterior of the mailbox. Keeping the fact that this product is aimed at home owners in mind, who probably live in neighbourhoods, it can be assumed to some degree that such an attacker won't go unnoticed. They would also require to have access to or carry workshop tools capable enough to cut through the tough exterior of our mailbox. Although we cannot entirely rule out this possibility entirely, we think our design safeguards

our power source well. We will of course want to conduct further testing on the material with which the mailbox is built to ensure it can withstand such attacks reasonably well.

2. **Cutting the mailbox out:** An attacker might think of cutting out the mailbox entirely.
Solution: Since we intend on screwing the mailbox onto a wall of the customer's house, it would be really difficult for anyone to cut it out. The discussions had above about the difficulties of actually cutting through the exterior of the mailbox still stand.
3. **Cutting through the collapsible gate:** An attacker who gains access to the drop off area might want to hold the collapsible gates down to try and break it or cut through it.
Solution: If the access door to the drop off area is open for too long (say more than 5 minutes), we intend on sending an alert through the app. We understand that just a notification cannot entirely prevent such a break in, but it can help us call in either neighbours or the police (depending on the value of the products in your mailbox) should we suspect any threat to our mailbox's security. In the future, we should test how much force it takes to break the collapsible platform.
4. **Someone gaining access to the App through a clients phone:** A person might resort to trying to access the phone to gain access to the app to open the door.
Solution: added authentication though Google sign-in provides a level of security security. We could also have Bio metric authentication in the final product as part of the sign-in to have a better authentication method in the case of this happening.
5. **QR code of device scanned by a user other than the owner:** Another user might scan the QR code of the device and adds it resulting in the device receiving requests from both(all) users.
Solution: Notifications of other users trying to access the device included in the final product as well as a strict ownership model incorporated into the architecture in the final development cycle that prevents more than one user being able to send requests to a device.
6. **Requests being sent to the mailbox by a malicious agent:** A malicious agent might launch attack on the system and gain access to the device.
Solution: Encryption of messages sent to the device and those received as well.

Usability Testing

Overview:

In the "Usability Testing - Notes", with different participants, we outline the tasks that we asked each of them to perform, the difficulty score, of between 1 and 10, that they gave to each task (1 being extremely easy and 10 being

extremely difficult), and added comments to reflect any of their notable actions while interacting with the app. Where there are no comments added, it reflects that the participant completed the task as expected without any concerns.

Method:

For the Usability Testing, we contacted the participants through university's email. We sent them a summary of our study along with our 'Participant Information Sheet' and 'Consent Form', the latter of which the participants signed and returned to us. The testing was conducted as a recorded video call with each of the participants, where they were given access to our app's user interface through a rendering on Figma [8]. We described our project to them and how the app ties with the hardware. They were then asked to perform certain tasks using the app and rate how difficult it was for them to complete the tasks. A difficulty of 1 corresponds to 'extremely easy' whereas a difficulty of 10 corresponds to 'extremely difficult'. We also noted some useful comments while analysing the participant's interaction with our app. At the end we asked them some general questions and documented their feedback. These are presented in the "Usability Testing - Notes".

Items	#	Cost(£)
Lift Motor	1	27.05
6mm+8mm Bright Steel Round Bar	1	15.00
MDF (per 8ft x 6ft x 12mm sheet)	1	11.00
12mm Thk T6 Aluminium Plate	1	10.00
3D printed material (5p per gram)	1	2.50
ON Semi PN2222ATA NPN Transistor	4	0.80
ON Semi 2N4403TA PNP Transistor	2	0.16
Nichicon 1F Electrolytic Capacitor	1	0.75
Vishay 50V 1A, Diode 1N4001-E3/54	4	0.80
Custom PCB	1	2.00
Steel Plates	6	45.00
UV Sterilizer LED	2	18.30
Door Spindle	1	8.40
Magnetic Lock	1	7.00
6mm Springs	4	12.00
Particle Photon	1	14.34
Total		175.10

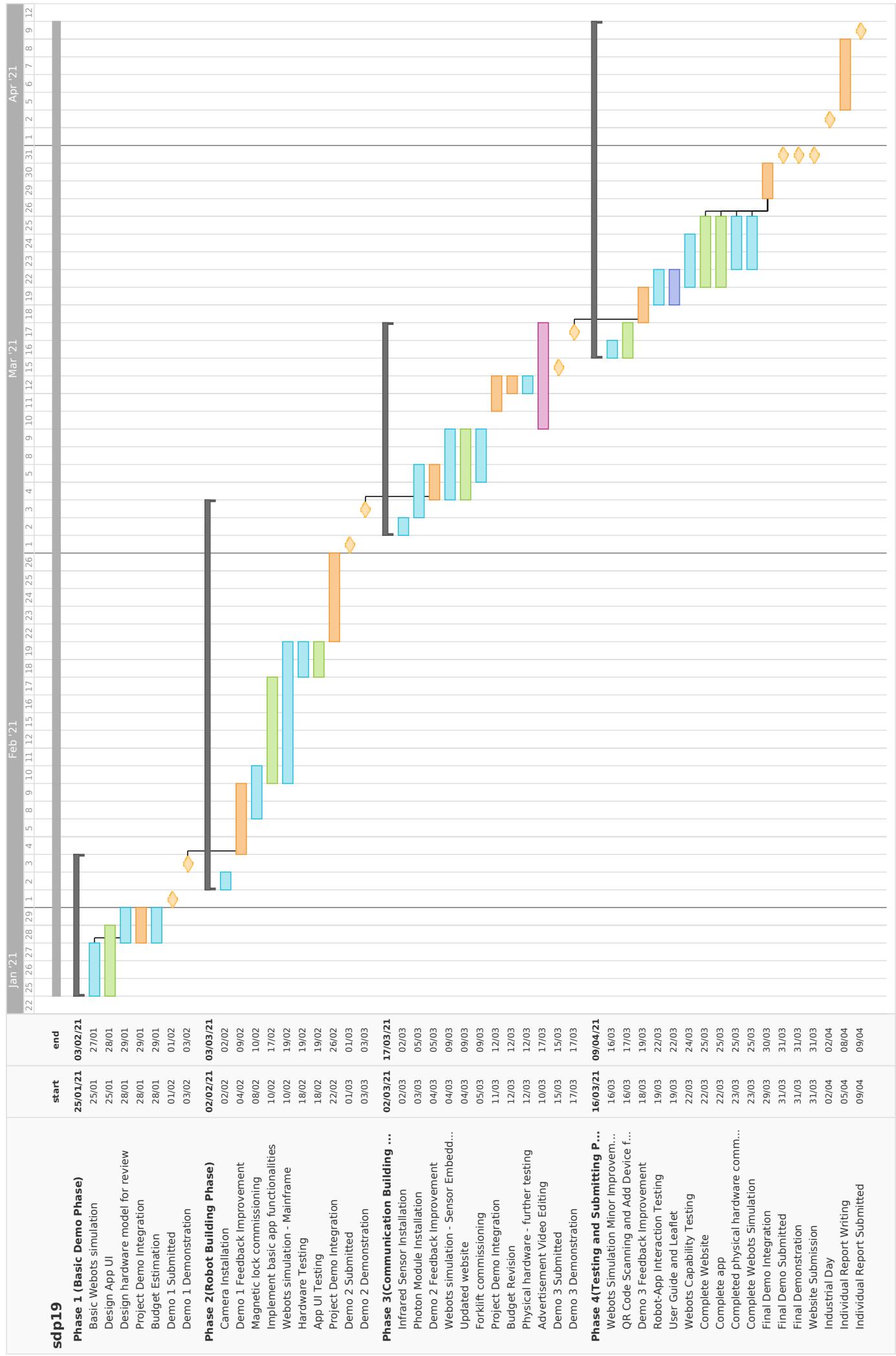
Table 5. Demo-1 Budget

Items	#	Cost(£)
Metal Work [Lock]	1	10.00
Standard Deadbolt Lock	1	20.00
Solenoid	1	25.00
Electronics And Wiring [Lock]	-	5.00
Motor [Fork Lift]	1	35.00
Lego Set [Fork Lift]	1	15.00
Motor Board [Fork Lift]	1	10.00
Basic Sensors	-	10.00
Advanced Sensors	-	30.00
Encoder Board [Fork Lift]	1	10.00
Miscellaneous [Fork Lift]	-	10.00
Particle Photon	1	18.67
Raspberry Pi	1	30.00
Technician time (3 hrs) [Fork Lift]	-	-
Total		228.67

Table 7. Demo-3 Budget

Items	#	Cost(£)
Metal Work [Lock]	1	10.00
Standard Deadbolt Lock	1	20.00
Solenoid	1	25.00
Electronics And Wiring [Lock]	-	5.00
Motors [Fork Lift]	-	2.50
Lego [Fork Lift]	-	15.00
Miscellaneous [Fork Lift]	-	10.00
Basic Sensors	-	10.00
Advanced Sensors	-	30.00
Motor And Encoder Boards	1	10.00
Steel Plates	6	45.00
UV Sterilizer LED	2	18.30
Door Spindle	1	8.40
Magnetic Lock	1	7.00
6mm Springs	4	12.00
Particle Photon	1	14.34

Table 6. Demo-2 Budget



Participant 1

Participant information:

- Native English Speaker
- From within Systems Design Project
- From within the School of Informatics

	Task	Difficulty*	Comments
1.	Login and view your account.	6-7	Participant did not see the icon for “Your profile” (with a person’s face) straight away. Had difficulty initially figuring it out.
2.	Let’s say you’ve successfully added your friends’ mailboxes, Jane and John. Can you determine the status of Jane’s mailbox delivery door, battery life and storage capacity?	1	
3.	Close the dropdown now. Let’s say you’ve now bought your own mailbox and have had it successfully installed and powered on. Can you add your new device via the QR code on the mailbox?	1	
4.	Unlock and lock your new device.	1	
5.	Let’s say Jane and John have added your mailbox to their accounts. Can you edit your device name and remove Jane from the device then save those settings?	2-3	Participant found the order in which things need to be done a bit confusing (that is related to how we have implemented the app prototype for the demo).
6.	Now let’s remove your device.	1	
7.	Now try and view all your notifications, then just notifications from John’s mailbox.	1	
8.	As you can see some notifications look a bit scary, how would you find help for these?	1	Initially wanted to click on the notification itself rather than the FAQ icon (the question mark).
9.	Log out of your account.	1	

Some general questions:

Question	Participant’s comments
Was the text easy to read and differentiate from the background?	yes
Were the accompanying icons clear for what they represented?	Yes but confusion about the “target” button’s role
Any general feedback	“really nice idea”
Was the vocabulary / pictures used intuitive and easy to understand	yes

Participant 2

Participant information:

- Non-native English Speaker
- From within Systems Design Project
- From within the School of Informatics

	Task	Difficulty*	Comments
1.	Login and view your account.	1	
2.	Let's say you've successfully added your friends' mailboxes, Jane and John. Can you determine the status of Jane's mailbox delivery door, battery life and storage capacity?	1	
3.	Close the dropdown now. Let's say you've now bought your own mailbox and have had it successfully installed and powered on. Can you add your new device via the QR code on the mailbox?	2	
4.	Unlock and lock your new device.	1	
5.	Let's say Jane and John have added your mailbox to their accounts. Can you edit your device name and remove Jane from the device then save those settings?	1	Initially, participant removed own device from app by mistake, instead of removing Jane. Would prefer "Save" and "Discard", on the 'Device' page, to be right below the names in "Accessible by".
6.	Now let's remove your device.	1	
7.	Now try and view all your notifications, then just notifications from John's mailbox.	1	
8.	As you can see some notifications look a bit scary, how would you find help for these?	2	Initially wanted to click on the notification itself rather than the FAQ icon (the question mark).
9.	Log out of your account.	1	

Some general questions:

Question	Participant's comments
Was the text easy to read and differentiate from the background?	yes
Were the accompanying icons clear for what they represented?	Yes but confusion about the "target" button's role
Any general feedback	"looks great"; would like adding/removing a person outlined in the user guide or included in FAQ
Was the vocabulary / pictures used intuitive and easy to understand	yes

Participant 3

Participant information:

- Native English Speaker
- Not part of Systems Design Project
- From outside the School of Informatics

	Task	Difficulty*	Comments
1.	Login and view your account.	2	
2.	Let's say you've successfully added your friends' mailboxes, Jane and John. Can you determine the status of Jane's mailbox delivery door, battery life and storage capacity?	2	
3.	Close the dropdown now. Let's say you've now bought your own mailbox and have had it successfully installed and powered on. Can you add your new device via the QR code on the mailbox?	1-2	
4.	Unlock and lock your new device.	1	
5.	Let's say Jane and John have added your mailbox to their accounts. Can you edit your device name and remove Jane from the device then save those settings?	3	Participant was a little confused about what the task entailed, but upon clarifying that they were meant to change the name of the device and not their account name, they were able to complete the task smoothly.
6.	Now let's remove your device.	1	
7.	Now try and view all your notifications, then just notifications from John's mailbox.	1	
8.	As you can see some notifications look a bit scary, how would you find help for these?	3	Initially wanted to click on the notification itself rather than the FAQ icon (the question mark).
9.	Log out of your account.	1	

Some general questions:

Question	Participant's comments
Was the text easy to read and differentiate from the background?	yes
Were the accompanying icons clear for what they represented?	yes, "it was pretty self-explanatory"
Any general feedback	"I thought that it worked really well."
Was the vocabulary / pictures used intuitive and easy to understand	yes

Participant 4

Participant information:

- Non-native English Speaker
- Not part of Systems Design Project
- From outside the School of Informatics

	Task	Difficulty*	Comments
1.	Login and view your account.	2	
2.	Let's say you've successfully added your friends' mailboxes, Jane and John. Can you determine the status of Jane's mailbox delivery door, battery life and storage capacity?	1	
3.	Close the dropdown now. Let's say you've now bought your own mailbox and have had it successfully installed and powered on. Can you add your new device via the QR code on the mailbox?	1	
4.	Unlock and lock your new device.	1	
5.	Let's say Jane and John have added your mailbox to their accounts. Can you edit your device name and remove Jane from the device then save those settings?	3	Participant couldn't find "Full device information and settings" button on Home screen at first, and would like it to be bigger. They gravitated towards "Remove device" button, on the 'Device' page, to remove Jane instead of "Save" and would prefer "Save" and "Discard" to be right below the names in "Accessible by".
6.	Now let's remove your device.	1	
7.	Now try and view all your notifications, then just notifications from John's mailbox.	1	
8.	As you can see some notifications look a bit scary, how would you find help for these?	1	Participant went to the FAQ section (clicked on the icon with the question mark) right away.
9.	Log out of your account.	1	

Some general questions:

Question	Participant's comments
Was the text easy to read and differentiate from the background?	Mostly yes, but would like the "Full device information and settings" button on Home screen to be larger with a darker background or something that made it obvious that it was a button to interact with.
Were the accompanying icons clear for what they represented?	yes
Any general feedback	Having an FAQ page along with the user guide was found to be particularly helpful.
Was the vocabulary / pictures used intuitive and easy to understand	yes

Participant 5

Participant information:

- Non-native English Speaker
- From within Systems Design Project
- From within the School of Informatics

	Task	Difficulty*	Comments
1.	Login and view your account.	1	
2.	Let's say you've successfully added your friends' mailboxes, Jane and John. Can you determine the status of Jane's mailbox delivery door, battery life and storage capacity?	1	
3.	Close the dropdown now. Let's say you've now bought your own mailbox and have had it successfully installed and powered on. Can you add your new device via the QR code on the mailbox?	1	
4.	Unlock and lock your new device.	1	
5.	Let's say Jane and John have added your mailbox to their accounts. Can you edit your device name and remove Jane from the device then save those settings?	1	
6.	Now let's remove your device.	1	
7.	Now try and view all your notifications, then just notifications from John's mailbox.	2	
8.	As you can see some notifications look a bit scary, how would you find help for these?	2	Initially wanted to click on the notification itself rather than the FAQ icon (the question mark).
9.	Log out of your account.	2	

Some general questions:

Question	Participant's comments
Was the text easy to read and differentiate from the background?	yes
Were the accompanying icons clear for what they represented?	yes
Any general feedback	Not much to talk about in terms of other problems as they found it all right.
Was the vocabulary / pictures used intuitive and easy to understand	yes

***Difficulty rated on a scale of 1 – 10, 1 very easy and 10 very hard.**

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Last updated: March 26, 2021

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Collecting and Using Your Personal Data

Types of Data Collected

Personal Data

While using our app services, we will ask you to sign in using your Google account. This provides us with certain personally identifiable information that can be used to contact or identify you. This is also our only point of collecting information. This information consists of:

- Email address
- First name and last name
- Usage Data

Usage Data

Usage Data is collected automatically when using our services.

Usage Data may include information such as your device's Internet Protocol address (e.g. IP address), browser type, browser version, the pages of our site or app that you visit, the time and date of your visit, the time spent on those pages, unique device identifiers and other diagnostic data.

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- **To contact you:** To contact you by email, or other equivalent forms of electronic communication, such as a mobile application's push notifications regarding updates or informative communications related to the functionalities, products, or contracted services, including the security updates, when necessary or reasonable for their implementation.
- **To manage your requests:** To attend and manage your requests and queries to us.
- **For other purposes:** We may use your information for other purposes, such as data analysis, identifying usage trends, determining the effectiveness of our promotional campaigns and to evaluate and improve our service, products, services, marketing, and your experience.

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Law enforcement

Under certain circumstances, we may be required to disclose your data if required to do so by law or in response to valid requests by public authorities (e.g. a court or a government agency).

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Links to Other Websites

Our service may contain links to other websites that are not operated by us, for example submitting comments on Industry day. If you click on a third-party link, you will be directed to that third party's site. We strongly advise you to review the Privacy Policy of every site you visit. We have no control over and assume no responsibility for the content, privacy policies or practices of any third-party sites or services.

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We will let you know via email and/or a prominent notice on our app and website, prior to the change becoming effective and update the "Last updated" date at the top of this Privacy Policy. You are advised to review this Privacy Policy periodically for any changes. Changes to this Privacy Policy are effective when they are posted on this page.

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