5 Appendix A: User Interface and Appearance Design

The purpose of the user interface (UI) and appearance design introduces how our product CANnect interacts with the users and makes sure that users can easily understand how to use our product through the UI with no difficulties. The concept and theory behind the user interface design will also be explained to support our UI design.

As a scope of this appendix, we start with the graphical representation to illustrate the device appearance and the schematics of the CANnect Reader and mobile app UI. Our proposed UI will be supported with the user analysis and technical analysis. The user analysis is performed to support the schematics in the user perspective while the technical analysis entails 7 concepts of UI interaction proposed by Don Norman in The Design of Everyday Things. Engineering standard is introduced to ensure that our proposed UI follows the standard. Finally, the analytical and empirical usability testing are proposed to ensure the bug free and high-quality UI.

5.1 Graphical Representation

The two main subsystems of CANnect are the CANnect reader and the supporting software application. The reader and application are designed to be simple and intuitive. With user analysis, constraints and engineering standards in mind, the finalized concept designs for both are detailed below and shown in Figure 5-1, and Figure 5-2 respectively.

5.1.1 CANnect Reader Appearance

During the alpha-phase, the reader will have limited user interface beyond the LED lights available on the Arduino Uno and shields that indicate that it is sending and receiving data. This lack of user interface is acceptable as the only users that will operate them are the developers that have a complete understanding of the system.

In preparation for the beta-phase however, the reader will undergo development to improve its user interface for potential customers. Because we want our reader to be used during a normal operation of a car, our reader must be compact and will not interfere with the driver's ability to operate their vehicle. This will take the form of enclosing the reader in a plastic shell that is small enough not to impede the driver's legs and feet.

The CANnect reader will feature two LEDs that indicate the status of the reader. Each LED informs the user of the states of the reader. The power LED turns on when the reader is powered on and is not in sleep mode. If the reader does not receive power, the power LED turns off. The Bluetooth LED starts blinking on and off at a one second interval to indicate it is searching for a device to pair. If the Bluetooth LED stays constant, it means that the reader is actively paired to a device. Grips are added for better handling of the reader and preventing accidental slippage. The cube-shaped encasing, protects the CAN Bus controller module, Bluetooth module, and electrical components inside, and rounded edges offer protection should the device drop on its edge. The proposed design for the beta and production phase prototype are shown in Figure 5-1.

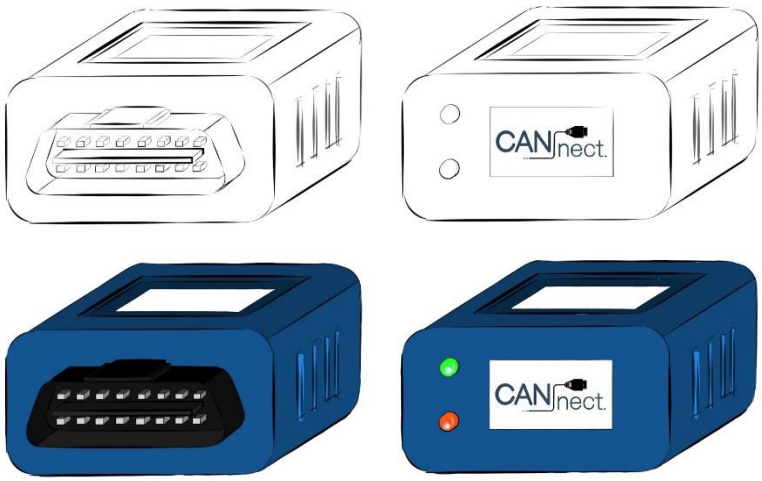

Figure 5-1: Device sketch and concept color mapping of front view (left) and back view (right) of CANnect reader including grip, company labels and indicator lights

5.1.2 Mobile App UI

The following Figure 5-2 shows the graphical representation of the mobile app UI. The Main Menu consists of 4 buttons and the users can easily tap one of them to go further on the next screen. The "Press to Connect/Disconnect" button and the connection status are also placed in the same screen. The settings can be the screen where the users can modify the app configuration however they want and the diagnostics screen is where the user who wants to run the diagnostics test on the selected PID from the menu. The user can press the button "Press to Run Test" and the diagnostics result will be in the table form. The dashboard provides the visualization with the list of parameters in the tabs, and finally we propose to have a map feature with the GPS toggle button ON/OFF.

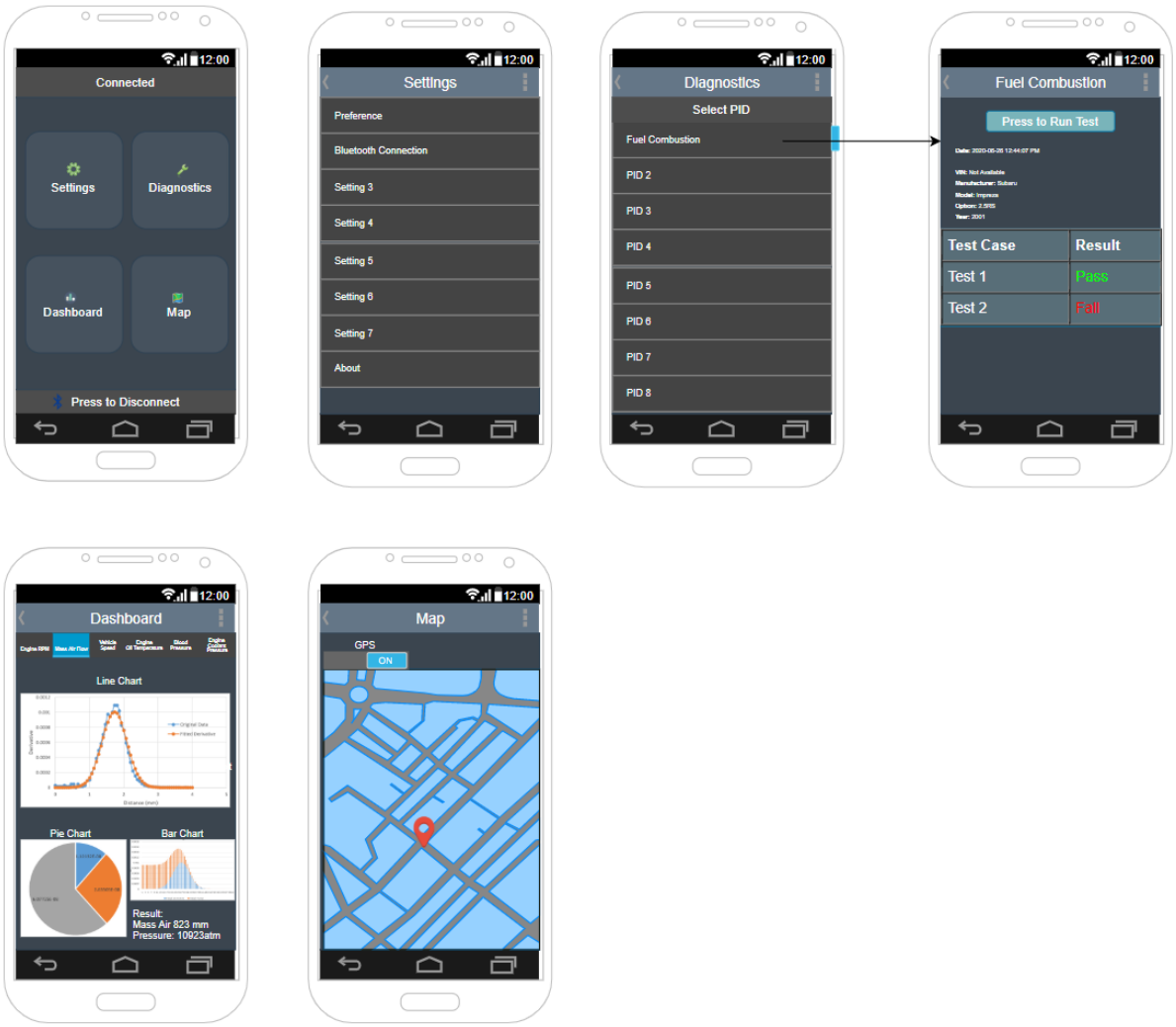

Figure 5-2: Mockups of App Front-end

5.2 User Analysis

The user analysis provides an explanation of how to use our product from the interaction with the hardware and the mobile app UI while the analysis is performed from the perspective of users. Our target audience are users who are car enthusiasts, and tend to have a higher knowledge of cars than the average person, but also users who want to analyze or conduct maintenance of their vehicles. The open source aspect of CANtech opens up the opportunity to work with car manufactures to offer maintenance support for their customers, or promote development research through the use of our product. It is also meant to foster a community of users with an interest in or area expertise in vehicles, looking to expand on or develop applications based on our CANnect product.

The CANnect reader features a standard OBD-II connector, indicator lights showing that the device is turned on and that Bluetooth connection is working, and grips on either side of the reader. The user should know the location of the OBD-II standard connector on their vehicle as well as compatibility with their vehicle before use. The first-use interaction with the reader involves the user simply connecting the CANnect reader to the OBD-II port in their vehicle and establishing a Bluetooth connection with a compatible smartphone device.

For the software application, the text information from each item in the UI informs the user what action they can make. As you can see from the Figure 5-3, the text content of “Press to Connect” from the button with the Bluetooth symbol in the Main Menu is self-explanatory to the user that they would know pressing this will establish the Bluetooth connection. The same principle applies to all any other text content from each item such as the 4 buttons from the Main Menu, list of items in the menu, and finally title from the header.

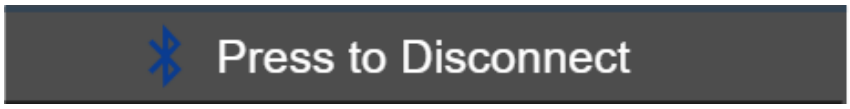

Figure 5-3: Bluetooth Connection Button on Main Menu

5.3 Technical Analysis

The technical analysis will support our UI and appearance design based on the “Seven Elements of UI Interaction” from Don Norman’s Principal [1]. This analysis is performed to support our design from the technical perspective following Don Norman’s Principal.

5.3.1 Discoverability

The concept states that **“It is possible to determine what actions are possible and the current state of the device**”.

The CANnect reader follows the concept of Discoverability since the two LED indicate the current status of the reader device. The power LED represents the current status of power and it can indiates the next possible action if you want to turn ON or OFF. Similarly for the Bluetooth LED, blinking LED or LED that stays ON continuously indicates the different status as searching for the device to be paired or the status of established connection respectively. Again, each status determines the next possible actions since if the LED is blinking, you will have to pair the Android device within the Bluetooth range or if the LED stays constant, you can start interact with the mobile UI as the Bluetooth connection establishes.

As for the mobile app UI, there are primarily two functionalities in our UI that follow the concept of Discoverability. Firstly, each screen has a title name; for example, “Dashboard” can inform the user of the current state of the application. Without this title, the user will be confused with the current state of where they are and they may go back and forth to identify their current state. From the Main Menu, the Bluetooth connection status is shown to inform the user if the device is connected with Bluetooth or not, which is also the current status of the device. Secondly, the list of items provides the user what actions are available to be made. For example from the dashboard, the list of tabs are shown so that the user is informed of what options are available for actions as to visualize and this also applies to the list of items in the settings and diagnostics menus.

5.3.2 Feedback

The concept of Feedback “**There is full and continuous information about the results of actions and the current state of the product or service. After an action has been executed, it is easy to determine the new state**.” is also followed.

The concept of Feedback applied on CANnect reader is similar to the Discoverability in that both power and Bluetooth LED is the full and continuous information as a result of actions made. Powering the Reader will result in a new state as power ON, which is easy to be interpreted by the LED light up. Action of connecting the Bluetooth from the mobile app UI after bringing the Android device near the Reader will result in a new state that the connection is established. Again, this new status is easy to be interpreted by the Bluetooth LED that stays constantly ON.

As for the mobile app UI, from the Main Menu, the Bluetooth connection status is the full and continuous information as a result of the action the user makes and the connection status is the information that notifies the user the current status of the device as also mentioned in the Discoverability concept. Once the user presses the "Press to Disconnect" or "Press to Connect" button, the connection status is shown as "Disconnected" or "Connected" respectively, and this result is easy for the user to determine the new status. Similarly for the toggle button on the map screen, tapping this button will toggle to ON or OFF, which is the continuous information as a result of the action made and informs the user the current status of the map. The resulting status after the executed action is also to be determined as a new state since it only toggles from OFF to ON or ON to OFF. If the status is ON, the user can know their location on the map but if the status is OFF, they cannot know their location.

5.3.3 Conceptual Model

The Conceptual Model states that "**The design projects all the information needed to create a good conceptual model of the system, leading to understanding and a feeling of control. The conceptual model enhances both discoverability and evaluation of results.**".

The design of the CANnect reader is very intuitive. The OBD-II connector is a specific standard across vehicles that will be familiar to our users. As soon as the Reader device is plugged in and the Power LED lights up as ON, blinking Bluetooth LED will search for the device to be paired and the user should be able to establish the connection from the mobile app UI. Once the Bluetooth LED stays constantly ON, the user now can interact with the mobile app UI and they take the desired actions from the Main Menu. This whole process of the user interacting with the both Reader and mobile UI is our conceptual model which makes the user feel control of the entire system. Also, this model enhances the enhances the Discoverability concept since the user activity flow from Reader to mobile app UI simultaneously follows the concept of Discoverability (each object in both UI follows this concept presented above) while evaluating the resulting states throughout this activity flow.

5.3.4 Affordances

The concept of Affordances states that "**The proper affordances exist to make the desired actions possible**".

CANnect reader has male connector as can be seen in the design schematics from the figure 10-1 that should fit well with the car with the female port. This allows the user to perform the desired action, which is powering the reader ON. We propose that our reader follows the concept of Affordances as there is no any hindrance in the reader shape design.

The overall mobile app UI system also follows this concept since there is no hindrance or contraction of features that exists to prevent the user's actions on the UI and the resulting state on the UI will always be reached. For example, any button, toggle button, list of tabs, and list of items in a menu shown in Figure 5-2 always provides the possible actions to the user. To support this, the location and layout of the item such as button and the font size of the text provides enough information to the user that they can immediately know where the action can be made and they can interpret what resulting states the actions will bring from the text. As an one example, the location and the font size of text from the button "Press to Disconnect" as shown in Figure 5-3 can let the user know where this button is and what action is available from this button.

5.3.5 Signifiers

This concept states that "**Effective use of signifiers ensures discoverability and that the feedback is well communicated and intelligible.**".

Our signifiers in the Reader are both the power and Bluetooth LEDs. The user will be able to learn quickly that the power LED will be the status of power ON/OFF and this signifier ensures the concept of Discoverability and Feedback presented above. Bluetooth LED is also a signifier that the user will be able to learn quickly represents the status of Bluetooth connection and again this follows the both concept of Discoverability and Feedback aforementioned above.

The overall mobile UI follows this concept, especially the Main Menu. One example could be that from Figure 5-4, the Bluetooth symbol which is commonly known among people indicates that the action is associated with the Bluetooth so that the user can identify that pressing this button will result in the connection with Bluetooth. This ensures the aforementioned concept of Discoverability since the Bluetooth signifier is integrated in the button. Also, 4 categories of buttons in the same screen also have signifiers as they have each associated commonly known symbols. For example, the settings button uses the symbol of gear, the diagnostics button uses the wrench symbol and so on as signifiers.

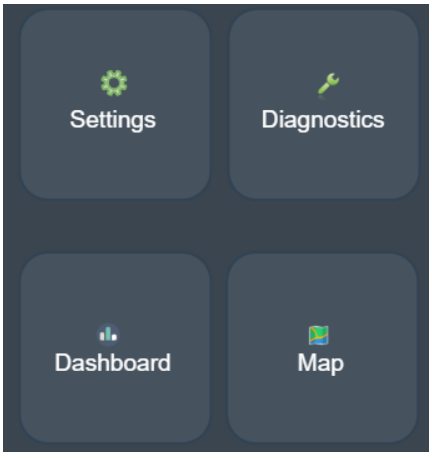

Figure 5-4: Categories of Button on Main Menu

5.3.6 Mappings

This concept states that "**The relationship between controls and their actions follows the principles of good mapping, enhanced as much as possible through spatial layout and temporal contiguity.**".

Our CANnect reader schematic design is referenced in the specification document. For the mapping of internal modules, pin connections are clearly defined with 1 to 1, input to output mapping. For the open source use of the hardware module, various general purpose pins on the modules can be reformatted to introduce a new functionality the user may want to add. Similarly, user interaction with the CANnect reader involves one action: plug in the reader and the device is powered on. Connect the smartphone to the reader via Bluetooth, and the vehicle system data can now be accessed by the user on the mobile app. Send a request to run a specific diagnostic test and receive results of the specified test on the application dashboard.

All the screens in our mobile UI start with the title on the top with the "go back" functionality signified as the left arrow button on the left side of the title and then come with the content below. The user can always make sure that they are on the correct screen by looking at the title and if not they can immediately go back by pressing the left arrow button. If the screen is what they are looking for, they can look for the content after the title and this time flow is minimal and the user experience is efficient since we believe that people will look things from top to bottom and this is also mentioned by the P. Laja [2] that people read in "F-patterns", meaning that people read things from top to bottom. This also means that people read things from left to right, so we placed some items on the left side to make the user experience efficient. For example, we placed the text content in a list of menu left hand side.

5.3.7 Constraints

Constraints states that "**Providing physical, logical, semantic, and cultural constraints guides actions and eases interpretation.**".

The CANnect reader dimensions are based on the size constraints of the internal modules, OBD-II standard connector and other electrical components being used. The average sizing data of the CANnect reader components are shown in Table 5-1. The encasing is thus determined to be 50 x 30 x 26 mm, with the modules arranged according to these length, height and width constrictions, and a 2mm plastic thickness on each side of the reader. A schematic of the CANnect reader views is shown in Figure 5-5.

Device/ Component	**Size (L x W x H)**
MCP2515_CAN	41.00 x 24.00 x 14.00 mm
ESP32	26.00 x 48.00 x 11.50 mm
OBD-II Standard Connector	15.30 x 41.20 x 19.05 mm

Table 5-1: The average size of modules and components of the CANnect reader [6][7][8]

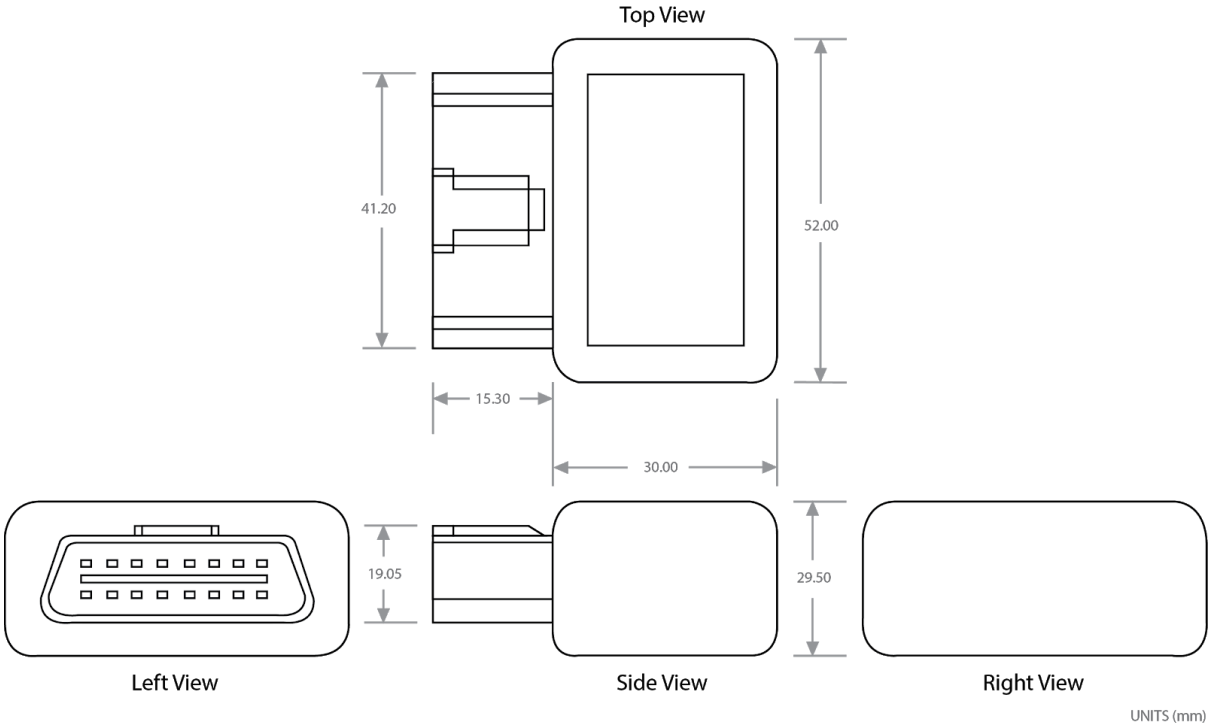

Figure 5-5: Proposed Reader Shell Diagram

For the mobile app UI, there is a high constraint on the system since the only actions they can do are as follows:

- Press the button
- Select the item from the menu or tabs
- Press “Go back” button to go back
- Scroll the items from the menu

The app UI is intended for read-only interaction with the car, so there should not be too many freedom of actions on the UI to make users confused. We believe that the high constraint on the read-only interface makes the users guides the next possible actions smooth and the interpretation will be easy.

5.4 Engineering Standards

Our product *CANnect* follows the following engineering standards for our proposed user interface.

5.4.1 ISO 9241-11:2018

CANnect reader follows this standard that defines a framework for understanding the concept of usability of an interactive system used by people [3]. CANnect reader follows all the items in the usability list defined in this standard but we especially would like to highlight that our device follows the usability in that the system or product can be used by the targeted audience of users with high satisfaction [3]. CANnect reader falls under this concept since our target audience is those who have already knowledge in related automotive technologies and we ensure the high usability of our

product, which was analyzed in the user analysis and technical analysis. We ensure our product is safe, useful in the context of use to connect to the car, effective, and efficient.

5.4.2 ISO/IEC TR 11580:2007

Our mobile app UI follows this standard and this code defines the format of name and properties of UI objects, actions, and attributes, and they are standardized as a basis [4]. Our each object in the UI follows this standard to ensure that each item in our schematic is properly implemented. Specifically, our UI object may or may not be interactive since some objects are static; for example, diagnostic results as a table form in the specific PID screen is read-only and non-interactive and the button object is interactive, which all meet the standard.

Each pressable button and tappable item within the menu is considered “Action” in the standard, so the system can accept the user request from their actions. Selection of items within the menu is considered “Selection” that identifies the object and is intended for the subsequent actions. Every action the user can take will alter the “state”; for example, pressing the Bluetooth button will bring the device to be the connected state, and this is also considered “activation” of Bluetooth connection. Finally, each object in the screen has a “label” that depicts their actions or attribute using the language-dependent information [4].

5.5 Analytical Usability Testing

Our team at CANtech will be performing the outlined testing procedures for both the CANnect reader and the Mobile App.

5.5.1 CANnect Reader

Manual testing of the CANnect reader will be performed with respect to the states of the LEDs. When the reader is connected to the OBD-II port of a compatible vehicle, the LED turns on, indicating access to the vehicle’s power supply, and the LED turns off when the reader is not connected to the vehicle. Further, the LED for Bluetooth connection, given the power LED is on, should either blink repeatedly to indicate the reader is in pairing mode, or remain solid to indicate a valid Bluetooth connection has been established. The currents, voltages, and overall function of each module will be individually verified, to ensure the correct data is being transmitted to the mobile application and at an appropriate speed.

5.5.2 Mobile App UI

We will be using Espresso, the automated testing framework for the Android applications and this will be able to test the user interface. According to A. Kanwa [5], compared to the regular QA procedure; feature development, deployment to device, manual testing, bug fixing for wrong implementations, deployment to device and so on, Espresso will be able to automate the testing procedure and reduce the overhead of manual testing. Figure 10-4 shows the proposed Espresso program to automatically test the UI. The program starts from the Main Menu and tests each feature from settings to map with bluetooth ON. The program will iterate the process again with the bluetooth OFF to test the functionalities while the connection is OFF. The following proposed automation program can be

implemented using Espresso testing framework in Java on the Android Studio.

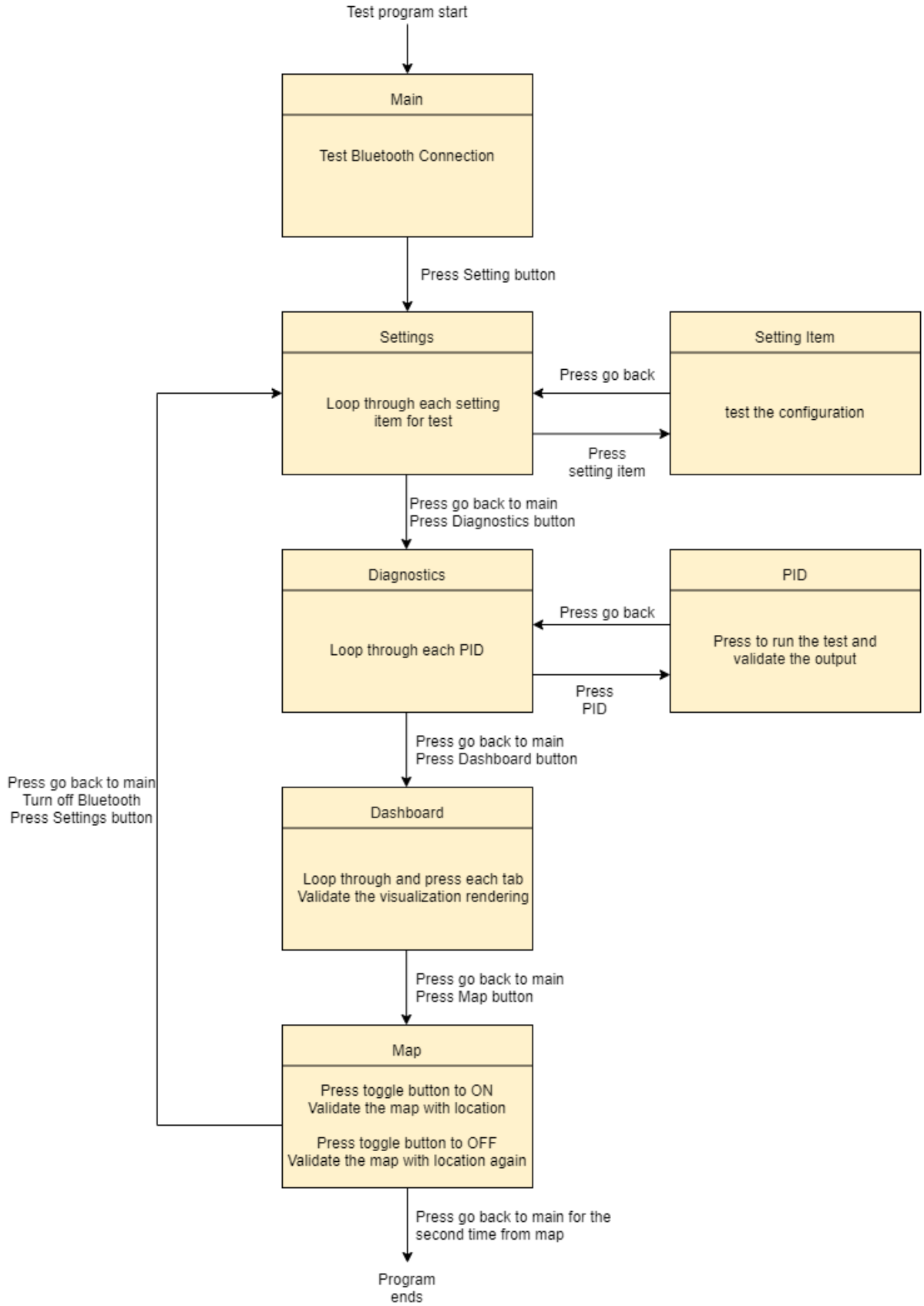

Figure 5-6: Flow Chart of Espresso UI Testing Program

5.5.3 Empirical Usability Testing

The empirical usability testing can be conducted by our internal members and the end users. We will conduct an end user testing by requesting feedback using a survey form from the survey participants. The survey can be conducted by either our internal team members or the audience who voluntarily participated in our survey. An example of a survey feedback form will be used to conduct an end user testing as demonstrated in section below. This survey form will be able to get the feedback from the end users and ensure the error free of our UI system, and note that there is no risk in using this app since our app is a read-only system. As a disclaimer, the device should only be connected to vehicles using OBD-II supporting the CAN Bus standard protocol. Combining the reader with external connectors or altering the reader is not recommended, and can affect the overall performance of the reader. However, hardware designs are open source and can be customized by the users with experience working with similar systems.

5.5.3.1 Example of Survey

Please rate the following information on a scale of 1 to 5, with 5 being “strongly agree” and 1 being “strongly disagree”.

CANnect Reader

1. Design Feedback Questions:
2. Did you experience any issues connecting the reader to your vehicle?
3. Did you experience any issues connecting the reader to your smartphone?
4. How would you rate the reliability of our reader on a scale of 1 to 5?
5. How would you rate the overall safety of our reader on a scale of 1 to 5?
6. How would you rate the overall performance of the reader on a scale of 1 to 5?
7. How would you rate the overall design of the reader on a scale of 1 to 5?

Mobile App

Layout Questions: How comfortable with the following layout?

1. Overall layout design
2. Buttons, tabs, toggle button
3. List of items in the tabs and scrollable menu
4. Settings
5. Diagnostics
6. Dashboard
7. Map

Please explain and elaborate your answer:

_____

Content Questions: How suitable did you find with the following content?

1. Bluetooth connection feature
2. Each setting configuration
3. Each diagnostics PID
4. Testing process in Diagnostics
5. Dashboard Item (Parameter)
6. Type of Visualization in Dashboard
7. Map

Please explain and elaborate your answer:

_____

Please report if there is any bug in the UI:

_____

From the above survey form, we can quantify the result for both CANnect reader, and the mobile app UI and data analytics can be performed to analyze each feature in the UI.

5.6 Conclusion

To conclude, we have proposed our UI in schematics for both CANnect reader device and mobile app interface and conducted analysis in the user and technical perspective to support our proposed schematics while we ensure that the engineering standards are followed. Also, the analytical and empirical usability testing is proposed to ensure our proposed UI design is bug free and maintain the high-quality system. As the current status of the proposed design of our UI, CANnect reader is only proposed in Schematics and we haven't actually made the product yet, so we will continue refining the schematics as we progress on the actual implementation of design as a future work.

As for the mobile app UI, although we presented the settings screen as a list of setting items in a menu, since each item of setting configuration is not defined, we are yet to define the UI for each specific setting interface. Therefore, as a future work, we will further propose UI for each setting item when our research on the design progresses. Also, we identified that having a map feature is useful to have since we can correlate the geographic information with the parameters associated with the car, but the current UI on the map does not give any insight yet. Hence, we will also research further on the map UI if we can further elaborate it as a future work.

5.7 References

[1] D. A. Norman, The Design of Everyday Things, Revised ed., New York, New York: Basic Books, 2013.

[2] P. Laja, "10 Useful Findings About How People View Websites," 23 Feb 2020. [Online]. Available: https://cxl.com/blog/10-useful-findings-about-how-people-view-websites/. [Accessed 13 July 2020].

[3] “ISO 9241-11:2018(en), Ergonomics of human-system interaction — Part 11: Usability: Definitions and concepts.” https://www.iso.org/obp/ui/#iso:std:iso:9241:-11:ed-2:v1:en (accessed Jul. 15, 2020).

[4] International Organization for Standardization & International Electrotechnical Commission, "ISO/IEC TR 11580:2007(en) Information technology — Framework for describing user interface objects, actions and attributes," International Organization for Standardization, 2007. [Online]. Available: https://www.iso.org/obp/ui/#iso:std:iso-iec:tr:11580:ed-1:v1:en. [Accessed 13 July 2020].

[5] A. Kanwal, "Espresso Android UI Testing," Medium, 22 April 2018. [Online]. Available: https://medium.com/@aleesha/espresso-android-ui-testing-c6d696956dc9. [Accessed 13 July 2020].

[6] “MCP2515 CAN Bus Interface Module,” 16-Jun-2020. [Online]. Available: https://protosupplies.com/product/mcp2515-can-bus-interface-module/. [Accessed: 16-Jul-2020].

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[8] “OBD-II Connector,” *DEV-09911 - SparkFun Electronics*. [Online]. Available: https://www.sparkfun.com/products/9911. [Accessed: 16-Jul-2020].