Traffic Light Aura Preliminary design

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1. Introduction

During and post-pandemic, nations around the world have put a greater emphasis on introducing sanitising solutions to mitigate the transmission of COVID-19. This has been seen by the introduction of sanitisation stations in businesses and public areas and increased frequency of cleaning in general. These measures have been effective to an extent, but while businesses can have staff cleaning amongst their other duties, public spaces with irregular staff maintenance are areas often neglected.

Hi-touch areas are especially areas of concern. People commuting throughout New Zealand and overseas are forced to touch the same unsanitised surfaces, specifically for our interests traffic light crossing buttons. Pedestrians who wish to cross the roads safely, as well as those who have a visual or other disability will be forced to touch the same buttons as others with no sanitisation between uses. This makes them an easy point of transmission for COVID-19 as well as other pathogens.

There is a clear need for sanitization in this area and a product intended to satisfy this need would provide a great investment opportunity. This is why our team developed the T.L. Aura, a sanitising solution that can be affixed to existing traffic light crossing buttons and sterilise the buttons after every use. Using sterilising UV-C light in its design, the TL Aura is able to provide a robust and effective sanitising solution without altering the familiar user interaction . All of this while preserving the accessible functions that allow people such as the visually impaired to safely cross the road day-to-day.

Fig 1: Example of standard traffic light crossing button.

2. Specifications

The initial product was specified as an assistive device designed for the post COVID market. The specifications were explored further during client meetings leading to the following outline:

- Assistive devices were given a broad definition by the client and could range from a small device for assisting in personal care to a large device used to assist packing shipping containers in warehouses.

- The device should look to address a problem created or exacerbated by the covid pandemic but should be able to remain relevant and marketable once the effects of COVID die down.

- Ultimately, the goal of the product was to turn a profit rather than address one problem in particular.

Given the broad nature of the specifications, the team’s method of design focused on researching a wide range of options, presenting these for feedback, and refining them based on the client’s perceived levels of interest.

3. Methodology

The purpose of the initial meeting was to explore the initial project specifications and also gauge the client's interest in particular areas of investment. Discussions from this meeting allowed us to develop the product specifications listed above. The team also used the first meeting to gain an understanding of how involved the client would like to be in the design process and what style of communication best suited them. This information was used to guide the frequency of client meetings and how ideas were presented. Since the project specifications gathered from the first meeting were quite broad, the team decided that the best approach would be to present a wide range of concepts. The client’s feedback on each design would then be used to eliminate or refine each area of focus.

Following the first client meeting, the team researched sectors that had been most affected by the COVID pandemic. Sectors that had already been addressed using robotic solutions were discounted. The team then developed seven concepts, each with different market applications and levels of complexity.

The scope of the second meeting was to present the team’s market research and range of ideas and examine if any concepts stood out to the client (whether it be an aspect of a design or an area of application). Due to the client’s preference for visual communication, the team presented these ideas in a PowerPoint presentation with concept drawings for each design. This proved effective and the client was able to visualise each solution and immediately provide feedback on the complications or promise of each idea. Moreover, the client expressed interest in solutions to high touch surfaces as there was a gap in the market and the concept seemed cost effective and simple to implement. Based on this, the team moved forward in developing designs for three high touch surface solutions.

The goal of the third meeting was to present three ideas for client feedback then select a single concept which the team could research further and refine into a solid preliminary design. When preparing for the meeting, the team put most of their focus on the infrared button design as it seemed the most effective and simplest design of the three solutions. However, the client raised concerns with aspects of all three designs. A notable question that was raised was how the design of the contactless traffic light button would account for the significant change in user experience as well as cope with dirt and grime. Based on the feedback from this meeting, the team spent a lot of time deeply researching and refining the options - leading to the development of a more simplistic yet safe UV-C cleaning system that would leave the current user experience unaltered.

4. Preliminary Design

4.1 Design Overview

As mentioned above, the team decided on a UV-C cleaning device for crossing buttons. This idea provides a couple options for development and implementation. The first is to design an entirely new crossing button design with a built in UV-C cleaner, that could replace the current design. The second is to retrofit a smaller cleaning device to the pre-existing crossing buttons. As the client had expressed an interest in profitability of utilising the current button boxes, we decided to focus on designing a cleaner that could be retrofitted to the existing buttons.

A crucial step in our design process was to get an example of the current crossing button to base our retrofit around. From this, we discovered that the inside of the buttons is mostly free space and that we could easily fit the electronic components for our cleaner on either the front plate, between the button and the tactile transducer, or on the back plate which only had holes for the boxes mounting. On the exterior of the button box , we would be able to fit the cleaner just above the button using the existing mounting holes. A sketch of the crossing button's exterior can be seen below in figure 2..

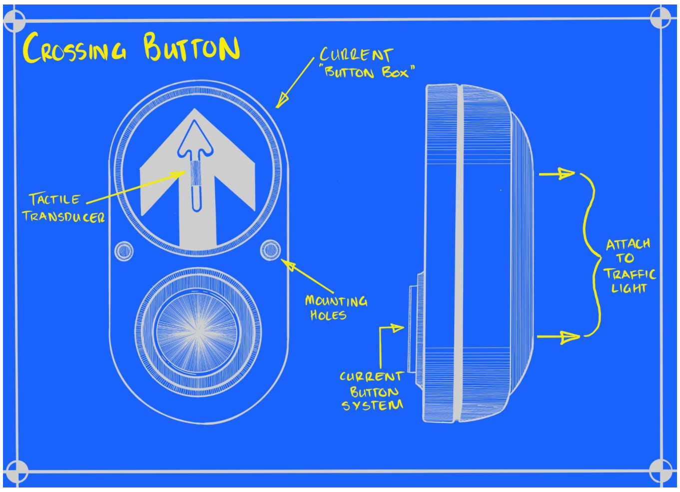


Fig 2: Existing button design.

Working from the dimensions of the box, we came up with the design seen in figure 3. The hood of the light sits above the button and will be made of the same metallic material as the outer casing, which is proven strong and resilient. The hood has three main purposes. The first is to angle the UV-C LED over the button so that the maximum intensity of the light is aimed at the centre of the button. The second purpose of the hood is to enclose the UV-C LED controlling direction of the UV light it gives off, preventing users from staring directly into the light source. The third and final purpose of the hood is to act in the same way as the current metal bars that most crossing buttons have, being to provide a support for differently abled people using the tactile transducer.

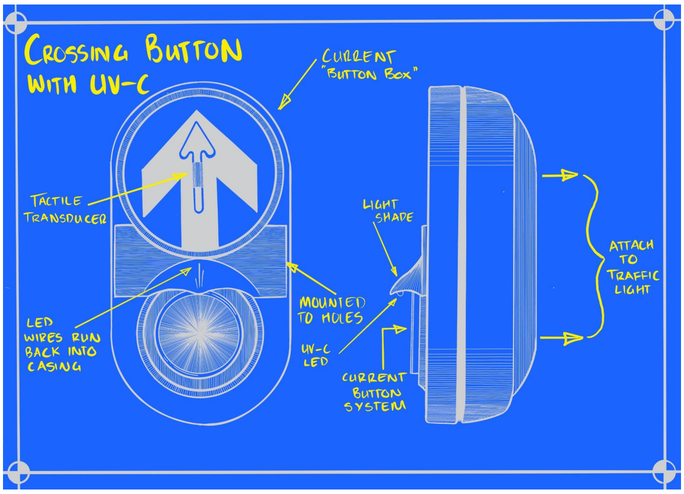


Fig 3: Updated hooded design.

For the retrofit we would need to drill a hole in the front plate for the LED wires to run through. This hole would need to be painted in a rust/corrosion proof paint and sealed to prevent moisture from entering the box containing the electronics. Inside the box we would mount the electronics used to control the cleaning cycle and connect to the power from the traffic light pole. It is important that these electronics are built to last and are as robust as the existing electronics. Robustness in general is of utmost importance when designing the UV-C cleaner. It needs to be people proof and able to withstand the stresses of constant human interaction and use. These aspects will be considered in greater detail as the design progresses.

4.1 Designing the Cleaning Cycle

The feasibility of the design hinged on whether the cleaning cycle could be designed in a way that would be compact, effective against COVID and safe for use around humans. The first design decision was to choose a UV-C light source. UV-C light sources fall under two main categories: bulbs and LEDs. LEDs were the clear choice between the two because they are incredibly compact and widely available as they can be focused in a chosen direction. Additionally, they can be designed to select specific wavelengths of light – allowing them to be optimised for use as a germicide. Bulbs on the other hand were bulky, hard to focus and often produced ozone as an unwanted by-product during use – making them unfit for purpose. Research into the effectiveness of UV-C showed that a dose of 5mJ/cm2 of UV-C light is enough to kill 99.7% of live coronavirus on surfaces. Past this point, there are diminishing returns with either very high intensity light or long exposure periods needed to reach higher levels of disinfection.

Human safety was taken into consideration when deciding how this dosage will be administered. Just as the sun can cause damage to human skin and eyes, prolonged exposure to high intensity UV-C light can have adverse effects on humans, such as skin redness and temporary eye irritation. While the shape of the hood was designed to prevent users from looking at the UV-C source, user's hands would still be exposed to the UV-C used for cleaning. Since the outer skin on most of the human body is sufficient to absorb UV-C radiation, the use of low intensity UV-C LEDs would not pose any immediate risk to users. Despite the low risk, the American Conference of Governmental Industrial Hygienists (ACGIH) has published guidelines that recommend limiting daily UV-C exposure to 6mJ/cm2.

In order to provide the necessary dose while staying within the ACGIH's exposure guidelines, the cleaning cycle was designed to deliver the dose over the course of 42 seconds. The timing of when the cleaning cycle would occur was designed specifically to limit UV-C exposure. Based on the design, the only case where users will be exposed to the light is if a user presses the button between 10 and 52 seconds after the last user. Due to the rarity of such an occurrence, the UV-C exposure is expected to be close to 0mJ/cm2 per interaction. Should a user press the button so soon after a previous user, the system is designed to minimise exposure. The time between a user's hand entering the cleaning zone and pressing the button (which disables the UV-C) is estimated to be under 4 seconds leading to a low dose of 0.48 mJ/cm2. This calculation assumes the highest possible exposure where the user's hand is covering the entire surface of the button. The less of the button is covered, the lower the exposure dose will be.

5. Initial Business Case

Because the T.L Aura is designed to be fitted to traffic light buttons, this product is intended to be marketed to regional and city councils. With the current pandemic pushing public health and safety being a primary concern, the T.L Aura can be marketed to these councils as a necessary step in reducing the risk of COVID transmission. In the future, it is possible to produce a range of T.L Aura products that use the core technology to provide a diverse range of sanitising solutions. In this case, the customer base would expand to include private companies and individual consumers. However, our current cost estimate focuses on the sale of the T.L Aura as a cleaning solution for traffic light buttons.

To begin with we can trial the product on the New Zealand markets. All traffic light buttons use the same general design in NZ so we can use the same design in implementation. If successful on the NZ market then we can explore markets overseas, the most obvious of which is Australia. They have joint standards with NZ and similar for others. This means we could implement a pipeline to the Australian market with little redesign.

The initial cost analysis focuses mainly on the estimated component cost vs. sale price for each product unit. This unit was defined as the UVC source, metal light shade and control electronics and is intended to be fitted onto a pre-existing traffic light button box. There is the option for the unit and traffic light button box to be sold as a single package in the future.. Additionally, the prices of the electrical and hardware components used to build the unit was based on individual component sale prices. This price is an overestimate as the bulk orders required for large scale production will result in a significant reduction in cost per component.Given this estimation (Fig 4), selling a single unit at $100 would result in a 65% profit (Fig 5).

Unit Cost	
UVC LED	$13
Microcontroller	$8
Metal Hood	$9
Additional Costs	$5
Total	$35

Fig 4: Table of cost estimations.

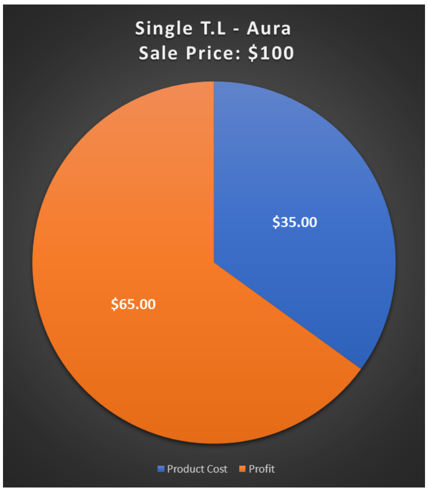


Fig 5: Pie chart of costs vs. profit.

Based on the production costs and profit of a single unit, the cost vs profit was predicted for an initial wave of sales in various locations. In addition, the estimate was deliberately conservative in assuming only one crossing at 70% of all traffic light operated intersections. In reality, there can easily be as many as four crossings and eight buttons at any given traffic light, resulting in higher sales and profit. Once the initial wave of installation is over, sales will continue as new crossings are built and old button boxes are replaced.

	Wellington	**Christchurch**	**Auckland**	**NZ**	**AUS**
Traffic Light Operated Intersections	73	131	427	1748	11000
Number of Crossing (At least 1 crossing at 70% of Intersections)	51	91	298	1223	7700
Number of Buttons (2 per Crossing)	102	182	596	2446	15400
Unit Production Cost (NZD)	$35	$35	$35	$35	$35
Unit Sale Price (NZD)	$100	$100	$100	$100	$100
Total Production Cost (NZD)	**$3,570**	**$6,370**	**$20,860**	**$85,610**	**$539,000**
Total Revenue (NZD)	$10,200	$18,200	$59,600	$244,600	$1,540,000
Total Profit (NZD)	**$6,630**	**$11,830**	**$38,740**	**$158,990**	**$1,001,000**

Fig 6: Expanded breakdown of potential profits.

6. Team Management

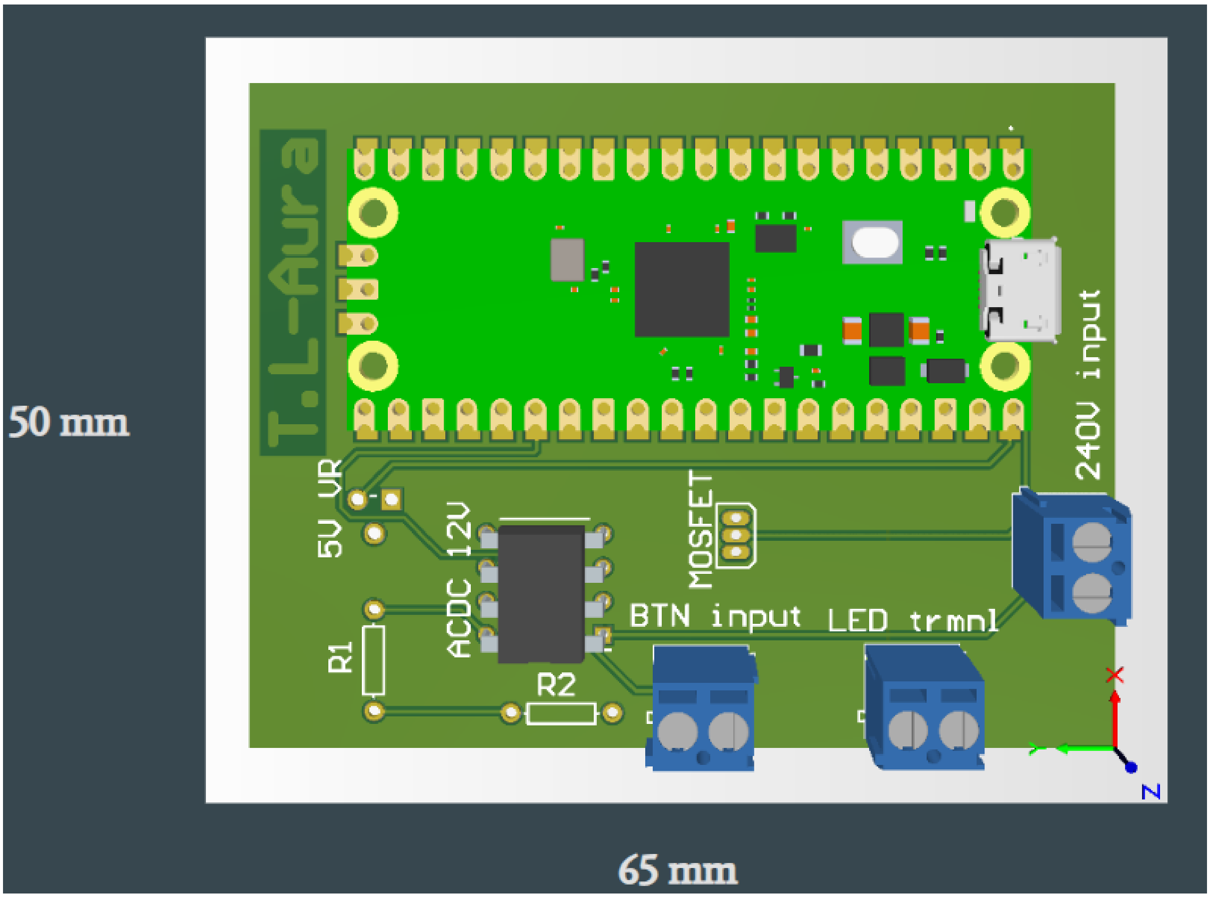
The team has been successful throughout this project, with good client engagement and feedback which has produced a solid preliminary design. To achieve these results we worked together as a team and played into each other's strengths.

The team leader, Aaron Claydon was in charge of delegating workloads, coordinating team meetings as well as keeping everyone on the same page in preparation for client meetings. Additionally, he oversaw the progress of the project to keep everyone moving forward, and maintained order during meetings. Griffin Almand was in charge of taking minutes during client meetings, sending follow up emails to the client, and drawing blueprints of concepts to aid in client engagement. Sharon McTaggart was responsible for researching the data behind UV-C light and how it compares to other cleaning methods. Furthermore, her understanding of the UV-C light was key to developing the preliminary design. In addition to this, Sharon managed the style of slides and delivery of the presentation. Jonathan Haydon took the initiative and managed our outreach efforts. This included contacting traffic light suppliers, procuring a traffic light button box, and contacting the council about traffic light data. Hau Shian researched the feasibility of implementing a contactless solution using infrared sensors which ended up not being pursued due to a few constraints. He was also in charge of our initial costs and pricings analysis.

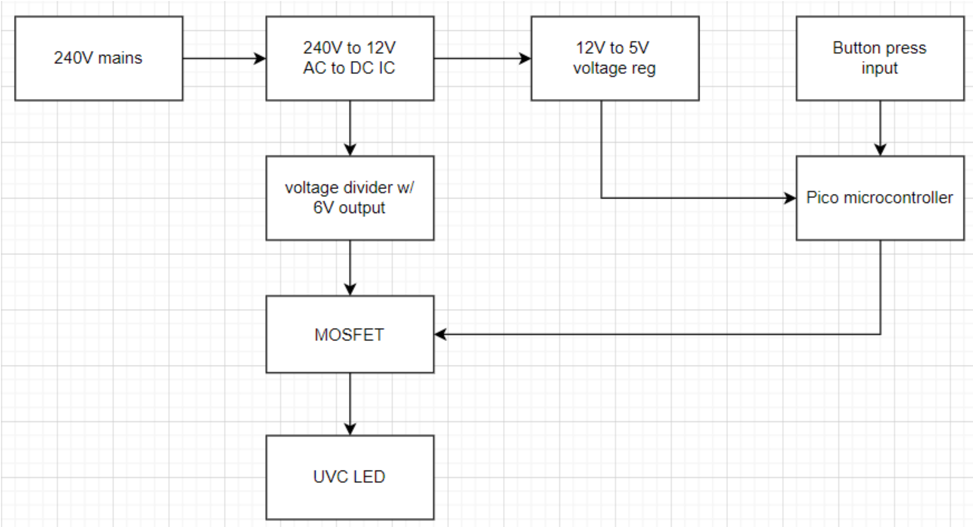
During each team meeting, the team leader would keep track of the main action points in order to make sure they were achieved. At the start of each meeting the action points made in the previous meeting would be reviewed. The team would then brainstorm ideas and solutions to the problems presented in the last team or client meeting. When discussions started to become less relevant the team leader would bring the conversation back to the action points, tick off the achieved ones, then refocus the team on the next one. Towards the end of each meeting, the team would discuss action points for the next meeting and the team leader would allocate tasks to be completed before the next meeting. Aaron would log them so that the team could get back into the work from where they left off.

When preparing content for the client, the team would prepare a broad range of questions to gauge the clients preferences. These types of questions ranged from how they would like to receive updates, to asking for their insight to an idea. Once the team had a list of questions, we would practise them with “Client Griffin" to see how the questions faired against a tough client. For our first two meetings this was a relatively successful way to prepare. This was because it allowed the team to refine how we transitioned from speaker to speaker and cut out any questions that lead to deadends. These practice sessions also helped the team figure out each other's conversational strengths and weaknesses, so that we could compensate for one another.

Throughout this design process the team worked solidly together around each other's schedules. This was evident right from the start and allowed us to make great progress early on. As the project got tougher each member helped lift the quality of the others work which added to the positivity of the team. The team leader wishes to thank the client for their time and feedback as well as each member for their contributions.



The pcb design uses the Pi Pico micro controller. This was chosen because of how cheap it was and how expandible it is. It has a large array of inputs and outputs allowing it to drive external functions such as the UVC LED and it can gather and store timing data on button usage. Its also Jtagg compatible allowing us to flash software to large quantities of the T.L Aura devices. We also incorporated screw terminals to make the installation easier.
The micro controlled is 50mm wide and 65mm long.



The T.L Aura takes 240V from mains at the top of the pole and runs it down to the AC to DC Converter. Then 12V from the AC to DC converter is put into the 5V voltage regulator which in turn powers the micro controller. The microcontroller takes button inputs and then outputs a signal to the MOSFET to turn on the UVC led. The UVC led is powered by 6V from a voltage divider connected to the AC DC converter. The LED requires 7V to 5V.

Here is the component list

Electronics		
	Pi Pico	$6.23
	AC-DC Converter	$2.90
	Voltage Regulator	$1.11
	LED	$14.00
	Resistors	$0.58
	Screw Terminals	$4.62
	MOSFET	$1.94
	PCB	$2.00
Hardware		
	Metal Hood	$5.00
	Bolts	$3.10
Additional		
	Wire	$0.50
	Solder	$0.50
	Sealant	$0.71
TOTAL		**$43.19**