Product Design: Hoverfly

for Scoot Airlines

Curbing excessive hand carry baggage

SUTD DAI Team 4 Scoot²

Delphine Sim Yingting (1006986)
Tan Hun Chong (1006643)
Cyan Koh Shi-An (1007230)
Lim Sophie (1007487)
Lim Ying Xuan (1006960)
Tan Ze Lin (1007054)

Table of Contents

List of Figures/Tables

1) Design Brief

Problem Statement

Scoot has employed our team to solve their problem of oversized and overweight hand carry baggage. Based on our user interview with them, three pain points were addressed by Scoot - the decline of on-time performance, the growing concern of workplace health & safety issues, and the increase of negative passenger experience. Due to the use of self-check-in kiosks and the lack of a physical staff at the Scoot check-in area to ensure the proper tagging of excessive hand carry baggage, it has created an influx of passengers disregarding the baggage specifications. Thus, after all passengers have boarded the flight, Scoot air-stewardesses and stewards would have to physically sort through and figure out how to stowaway any odd-sized or oversized carry-ons. Moreover, back injuries among cabin crew are common from closing overhead compartments that are filled with heavy oversized hand carry baggage. Despite the air-stewardesses' and stewards' best efforts, a decent number of passenger baggage would have to be sent to the cargo bay of the aeroplane due to the lack of storage space. This causes passenger disputes, usually because of their unwillingness to check-in their carry-ons. The combined delays in attempting to store such bulky baggage, tagging and stowing the baggage in the cargo bay, along with resolving passenger disputes, often results in a decline of on-time performance.

Our point of contact, Allison, a Senior Specialist of the Ground Operations team provided us some insights on the existing infrastructure. Currently, travellers can either weigh their baggage on the digital weighing scales or measure baggage dimensions using the bag check units. However, such physical machines are proving to be inefficient and underutilized. Allison believes that the implementation of a digital solution, like the CAS Smart Baggage scale in Incheon International Airport, would help to resolve both the issue of late detection of excessive hand carry baggage, and frequent customer disputes. This improves the overall travelling experience and on-time performance for both passengers and air crew.

From all these preliminary findings, we decided to finalise on the problem statement - **design a means to prevent late detection of excessive hand carry baggage so as to reduce disruptions in boarding procedures**.

Design Specification

The design specifications are categorised according to the demands and wishes that the final product must satisfy.

Demands

1) Visibility of Status (Aesthetics)	The final product must be able to display information to the users, for instance - a screen panel that displays the dimensions, such as the weight, length, and width, of the baggage or the number of baggage(s) being analysed.
2) Accuracy (Function)	The final product must be able to accurately check and compare the baggage's weight and dimensions to Scoot's Baggage Allowance policy and provide an unerring verdict if this baggage should be tagged as excessive.
3) Portability (Function)	The final product should be lightweight and have wheels that can operate on different terrains in order to accommodate for the frequent changing of boarding gates and the different physical capabilities of the person operating the final product.

4) Affordability (Cost)	The final product should utilise materials and components that are relatively cheap and easily replaceable, allowing for easy maintenance. Furthermore, the design of the final product should not be complex, allowing for it to be easily mass-produced so that it can be implemented for all flights and at other airports.

Wishes

1) Precision (Function)	The final product must be able to measure and record the exact weight and dimensions of the luggage, serving as a data collection point for future data analysis. Such data could be used to support research conducted to better understand passenger baggage patterns and habits and resolve the issue of excessive hand carry baggage.
2) Digitalisation (Aesthetics)	In comparison to an analog display, the interface of digital displays is much simpler and straight-forward, allowing the interpretation of the values to be easier, thereby reducing the time taken to resolve conflicts with passengers. Furthermore, Allison suggested the machine could take inspiration from the CAS Smart Baggage scale in Incheon International Airport which is completely digitalised.
3) Ease of Operation (Function)	Controls on the final product should be user-friendly and intuitive such that the ground staff, regardless of their experiences with operating machines, are able to operate it correctly on their first try without prior training.
4) Speed (Function)	The final product should be able to measure and display the weight and measurements of the baggage instantaneously to avoid further delays in flight boarding.

2) Concept development

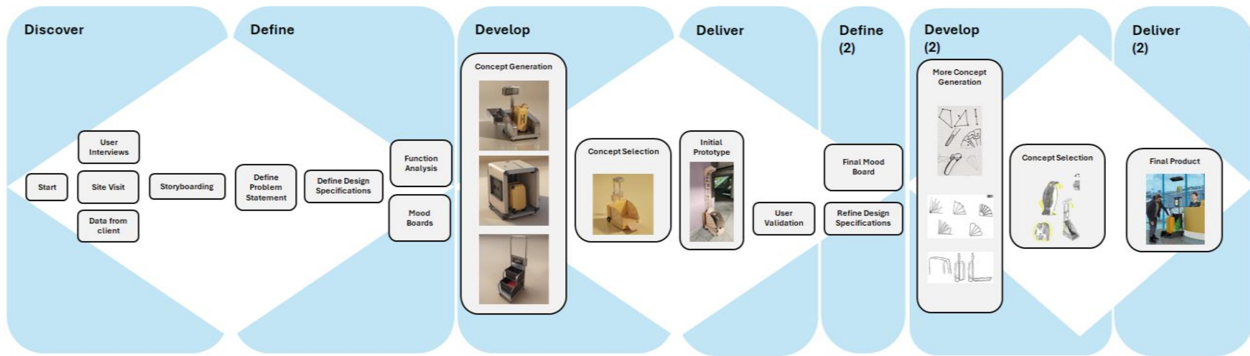


Figure 1: An overview of the design process. A higher quality version is available in the appendix.

Function Analysis

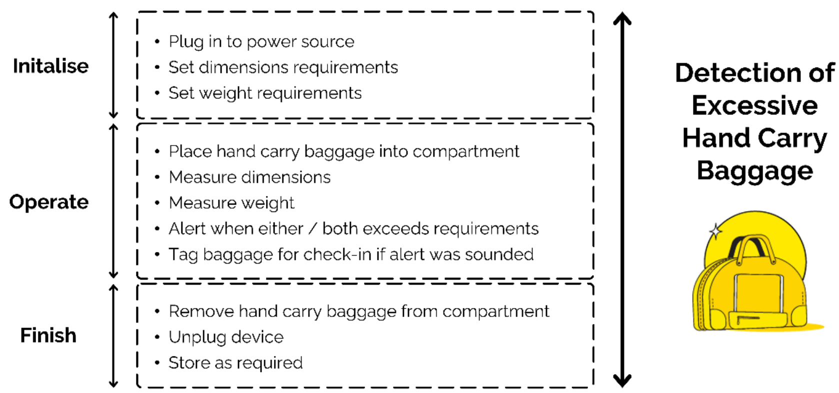


Figure 2: Function Analysis Diagram of the Detection of Excessive Hand Carry Baggage

To analyse the product's function in detecting excessive hand carry baggage, we broke down the process into three parts: initialization, operation, and finish.

During initialization, the product will be brought to the required location – Scoot's boarding gate, plugged into a power point and set up for usage. Since Scoot and ScootPlus have different baggage allowances, the settings of the product should be adjusted accordingly too.

During the operation phase, the hand carry baggage will be placed into the compartment that will measure the baggage dimensions and weight. The screen of the product will display the exact baggage dimensions and weight and will directly display an alert if the dimension and/or weight exceeds the baggage allowance. Once alerted, the ground crew stationed near the product will then tag the baggage with a baggage release tag for check in to the cargo bay.

After all travellers have boarded the plane, the product can now be kept. In the finishing phase, the crew will empty and clean up the compartment, unplug and store the product away for future usage or move it to the next location.

Mood Boards / Inspiration Images

Figure 3: 6 Different Mood Boards made by each group member

As part of the double diamond design process "define", mood boards were created to facilitate the brainstorming process of themes and visual or physical aspects that might be included into our final product. Across the board, majority of the group members unanimously chose yellow as the main colour, and amongst the keywords could find the common group of descriptors associated with describing the experience - user-friendly, accurate and seamless. We then did quick sketches to see possible form of our product such as side views, top-down view with inspiration from our mood boards.

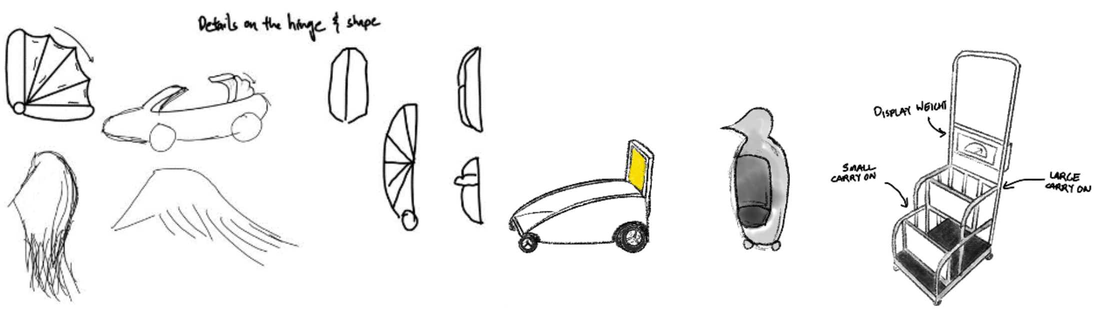


Figure 4: Mood board Conceptual Sketches

Concept Generation

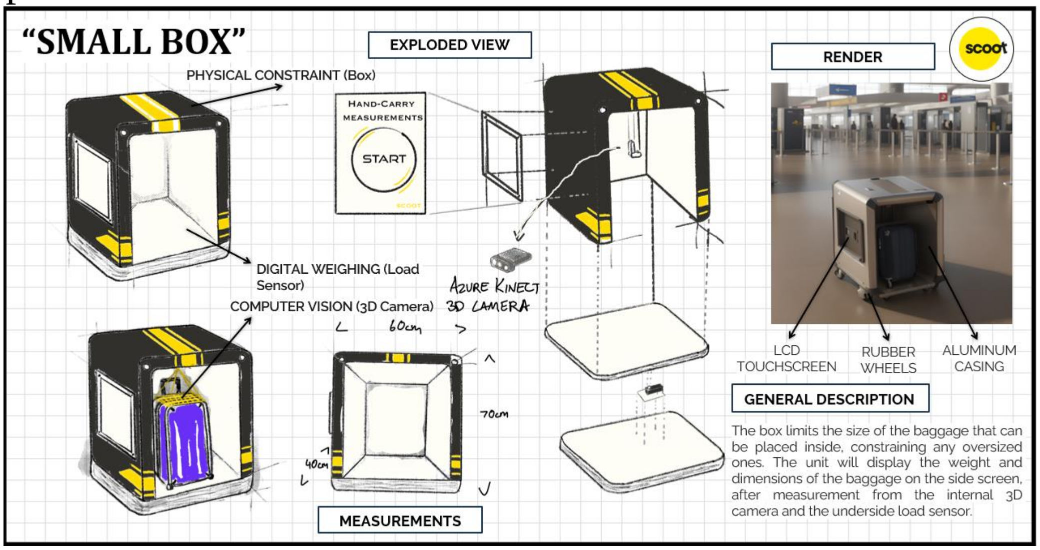


Figure 5: Concept Generation #1
(Left: Initial Sketch with Photoshop, Right: Sketch Rendering on Vizcom AI)

The first concept generated was a singular box unit. The baggage would be placed within the box and an Azure Kinect camera would measure and record the dimension of the baggage. A digital weighing scale at the base would simultaneously measure and record the weight. These dimensions and weight would then be displayed on a screen on the side of the box. To allow for portability, there are wheels at the bottom of the box that can be locked when stationary. In addition, for easy storage, the shape of the box makes it ideal to keep it in the crooks or have things be stacked on top of it. The advantages of this design lie in how compact and versatile it is. The boxy shape also makes the product sturdier and more durable. However, it lacks handles which makes it difficult to manoeuvre the box. Moreover, the camera would be exposed within the box to allow for accurate measurement of the baggage, should travellers not be careful when inserting their baggage, potential rough handling may damage the cameras. It is also not very convenient to place baggage in as it lies very low.

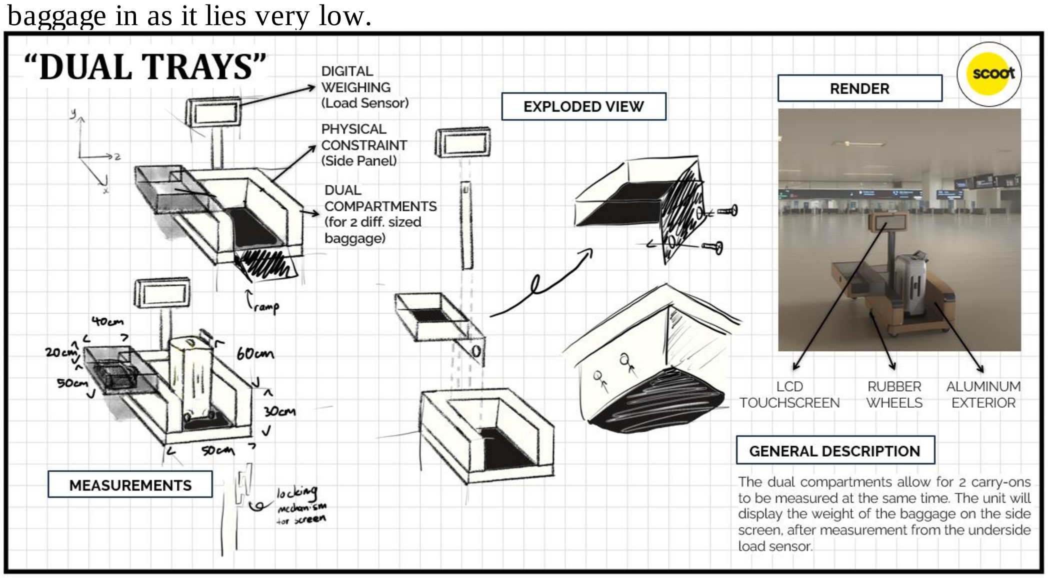


Figure 6: Concept Generation #2
(Left: Initial Sketch with Photoshop, Right: Sketch Rendering on Vizcom AI)

The second concept generated had two separate compartments to allow for two separate baggage to be measured simultaneously – one for the overhead and one for under seat bags as they have different limits. The measurement of these pieces of baggage would be taken through the physical constraint of the containers - if it is unable to fit within the weighing container it exceeds the baggage allowance. The weight is taken through a digital weighing scale and the value is displayed on a LED-screen. To allow for easy transportation, there are wheels at the bottom of the equipment. While this design is intuitive and straightforward, it does not provide the exact measurement of the baggage and it may be bulky to move around due to its extending parts. Furthermore, the second measuring compartment is attached to the side of the machine, sticking out and making it a potential safety hazard and inconvenient to store.

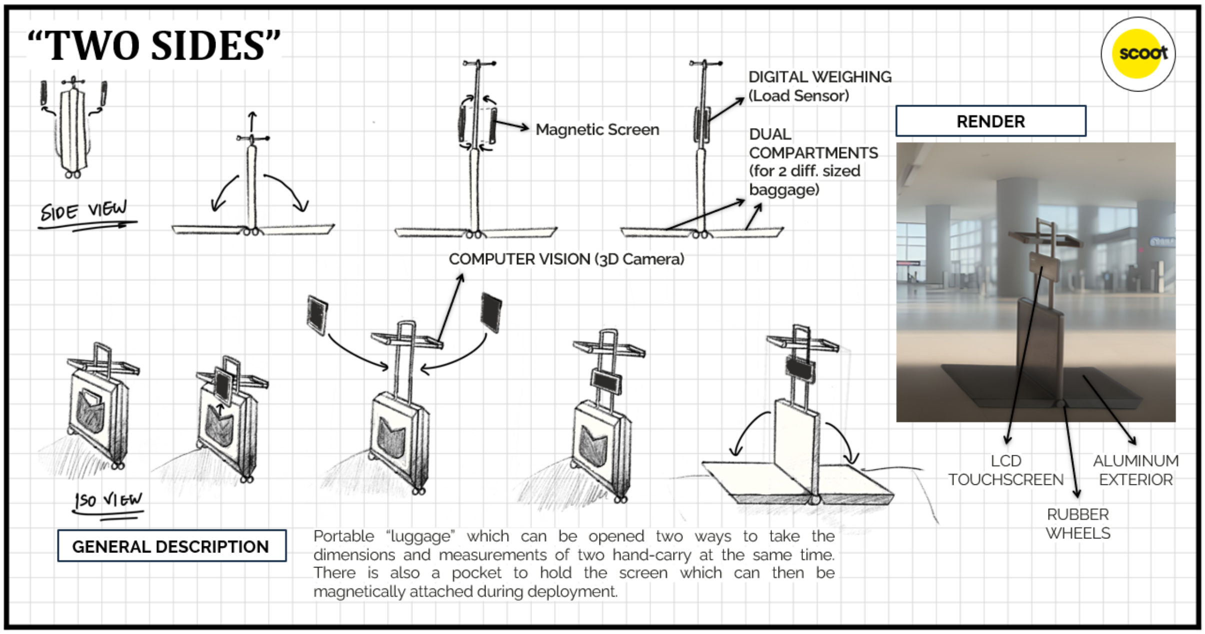


Figure 7: Concept Generation #3
(Left: Initial Sketch with Photoshop, Right: Sketch Rendering on Vizcom AI)

The third concept allows for 2 separate measurements to be taken at the same time to maximise the efficiency of this measurement counter and to speed up the process. It is portable as it folds up into a luggage like structure to be wheeled around. This concept makes use of the digital weighing scale as well as a 3D camera that can be pulled up to record the dimensions of the luggage placed on the product. Two magnetic screens can then be attached to display the results. Some limitations of this concept is the set-up space it requires due to its unique two way structure. At the boarding gate where there sometimes can be limited space, this concept serves as a problem and might worsen the crowd rather than efficiently disperse them.

Concept Selection

	C1: SMALL BOX	C2: DUAL TRAYS	C3: TWO SIDES
Visibility of Status	1	1	1
Accuracy	0	1	2
Portability	2	2	0
Affordability	1	2	0
Precision	0	0	1
Digitalisation	1	1	1
Ease of Operation	1	1	0
Speed	0	1	1
Total	6	9	6

Figure 8: Concept Evaluation of Concept 1, 2 and 3

Depicted above is the concept evaluation table, resulting in the selected Concept 2. However, since Concept 2 could still be improved upon, the concept was taken back to the ideating stage to fine tune the design and ensure that it meets all the wishes and demands to its best ability.

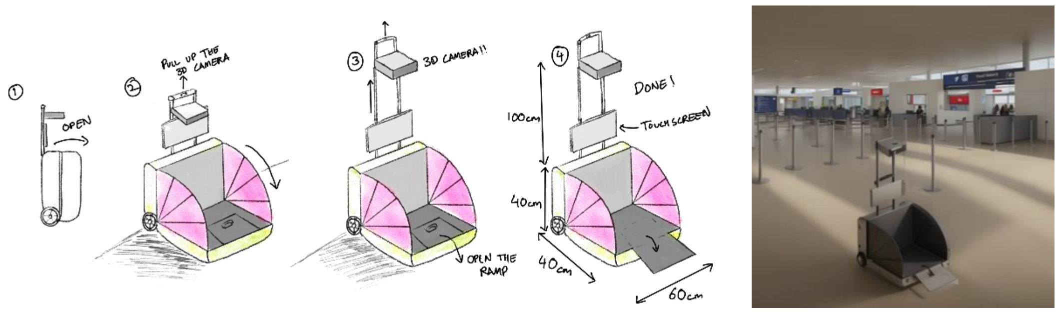


Figure 9: First Iteration of Concept Selection for Prototype
(Left: Initial Sketch with Photoshop, Right: Sketch Rendering on Vizcom AI)

The final concept is the culmination of the best points of all 3 concepts. Like all the three concepts above, the base of the final concept also has a digital weighing scale built in using a load cell sensor, displaying the value of the weight on a screen that is fixed into the space between the two poles. The two poles have a handle built in the middle and are extendible upwards, allowing the machine to be easily manoeuvred and transported around the airport whilst also raising the display screen to a higher height for easy viewing. Combining the dimension measuring method of all three concepts, the final concept measures the dimensions of the baggage through being constrained by the "walls" on its side, but the precise measurement of the baggage is also taken by the depth camera sensor installed at the top of the two poles. The maximum height of the poles would be calculated such that any distortion would be avoided when measuring the baggage dimensions, allowing the recording of data to be accurate and consistent. The bottom of the machine has wheels to make it transportable. To make it compact and convenient, the "walls" on the side have a fan assembly, making the machine collapsible. Thus, when the poles are retracted and the base of the product has been lifted, its size is like a luggage and can be easily stowed away.

Figure 10: Second and Final Iteration of Concept Selection for First Prototype (Left: Physical Prototype, Right: CAD of the first Prototype)

3)Final Design

First Prototype Review

After assembling the first prototype together, it was brought to Scoot to be reviewed and for feedback to be given on what could be improved upon. From the meeting, there were 3 major takeaways - to ensure that the machine is light and thereby easily transportable, durable and utilises materials that are easily repairable and replicable.

The machine must be made of light materials as the machine will be handled by ground staff of different physical capabilities. In the situation where the machine must be carried up or down stairs, or rolled over the airport carpeted floors, the machine needs to be adaptable to its different terrains and be light enough for the ground staff crew to manage it by themselves.

The machine must be durable as it would be put under high-pressure situations frequently. Due to the number of flights done in a day, and the high volume of baggage that would need to be weighed, travellers or ground crew staff who weigh the baggage may not have the luxury to be careful with the weighing process due to the high volume of travellers. As such, it needs to be durable enough to endure several bumps and hits without needing to be repaired.

The machine also must be easily repairable and replicable. As Scoot flies to 67 different countries, it would be ideal if the machine could be at each boarding gate. Additionally, with all things, wear and tear is unavoidable. Thus, it would need to be easily repairable so that it can be back in working condition as soon as possible. The parts of the machine should also be easily sourced to ensure this.

Based on the current design, they liked the fan system as not only was it aesthetically pleasing, but also facilitated the easy storage of the machine. Furthermore, they liked the depth sensor camera as it was precise and accurate, reducing the potential of any traveller disputes. The size of the screen was also favourable as it was easy to view the values of the baggage dimensions and weight. They also requested for there to be some sort of feature that allows the machine to be anchored down to prevent possible theft of the machine.

Final Design: Hoverfly

Figure 11: Final Mood board

Taking into consideration all the feedback as well as previous mood board inspirations, an idea of the final design was drafted. The final product's form is inspired by the shape of a penguin. Furthermore, the feasibility of the fan system in the product also draws inspiration from the collapsibility and compatibility of the Volkswagen van. The main 2 product brand colours are also chosen to be Pure Yellow (#FFE800) and Dark Gray (#262626) to evoke a sense of modernity and vibrancy while maintaining a sleek and professional appearance. Working with these two colours led us to choose the name "Hoverfly" – a friendly insect that is yellow with black stripes.

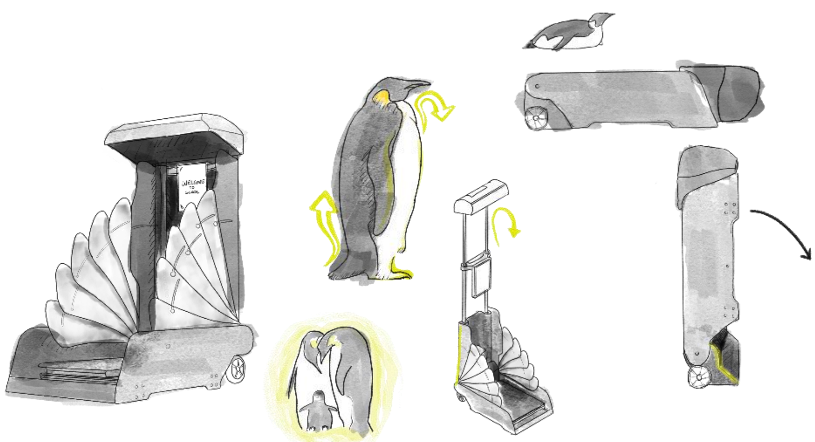


Figure 12: Final Product Sketch

Hoverfly mainly retains the same shape as the first prototype, with the addition of elements inspired by the shape of a penguin from the initial mood boards. Taking inspiration from how penguins tuck their appendages close to their body, Hoverfly simulates this by making the collapsibility of the machine fit into itself, resulting in a compact shape that is easy to manoeuvre and store. Furthermore, the fan system is akin to the appearance of penguin wings. The rounded edges of the cover look similar to the head shape of a penguin as does the base of the machine when folded up.

The final design of Hoverfly also has a proper capped top to protect the depth sensor camera and is fashioned with a handle. The pole system has 3 tiers - the cover of the machine has a handle attached to it to facilitate the extension of the first initial tier, the second tier has a handle attached to it as well along with a space for the screen to be mounted on to and the last tier is fixed into the main body of the machine. At its full height, the machine stands at a height of 3 metres.

The fan system has been improved upon, now including a locking system that prevents the base of the machine from being lifted and collapsed when in operation. To lock the fan system in position, the installed braces would have to be pulled up and straightened. Furthermore, the wheels of the machine are now PU wheels, similar to those seen on scooters, instead of being caster wheels. This allows the machine to be more easily transported around on different floor terrains and are more durable.

The main material that will be used to construct the final product is acrylic sheets along with alloy steel rods that hold the main structure together. This is to ensure that the overall machine weight is as light as possible whilst maintaining its durability.

Rendered Views of the Solution

Figure 113: Renders of Hoverfly
(Left: Ground Crew pulling the Hoverfly into its set-up location, Right: Passenger using Hoverfly at the boarding gate)

Figure 114: Solution Storyboard

Figure 115: Render of Final product

The full functional workflow is depicted in the renders and solution storyboard. From deployment to detection, Hoverfly is designed to be easy-to-use for both passengers and air crew.

Finalised System Diagram (Cyber/Physical boundaries)

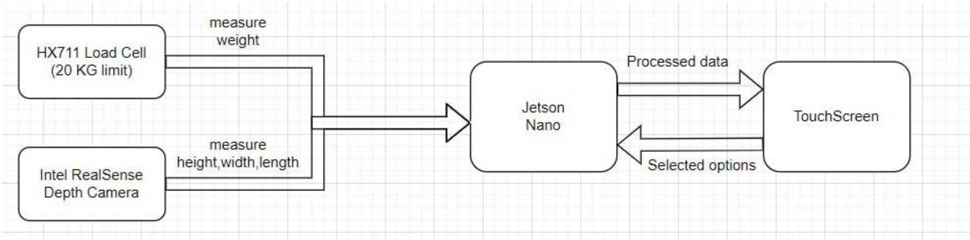


Figure 16: Final System Diagram

For the finalised system diagram, the Jetson Nano is the central control. It runs 3 main files, one to run the flask app to display on the touch screen as well as carry the functions that the flask app would use to retrieve and display the data. Second is to run the HX711 code to read the load readings and store them in a JSON file for retrieval later. Last is the code to run the Intel Realsense camera to take the measurements of the item and to store a set of 3 values: height, width, and length in a JSON file for retrieval later.

From the touch screen, when a button is pressed to “measure” the dimensions and weight of the hand-carry, a function will be called to read the data from both JSON files and process them before they are displayed on the touch screen. The weight data must be converted to reflect the weight accurately as it requires pre calibration.

4)Prototyping

Mechanical Design

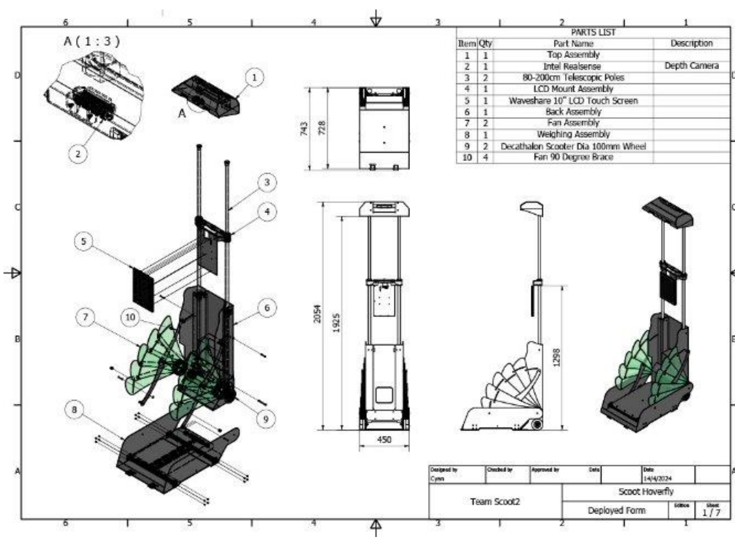


Figure 17: Final System Diagram

The final design is made up of 10 main components, most of them being held together by countersunk screws. The fan assembly and 90-degree braces are held together using book-binding screws that travel in slots between each fan blade, enabling the prototype to be easily foldable and collapsible while still remaining strong when fully deployed.

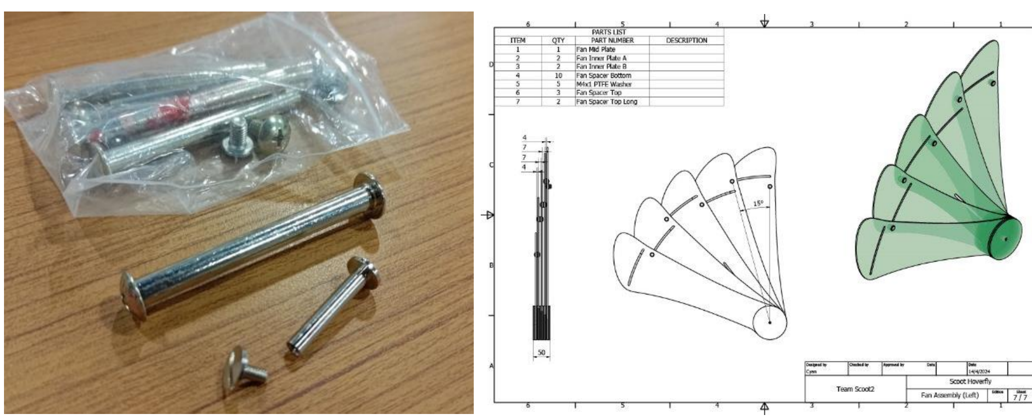


Figure 18: Book-binding/Chicago Screws are used in the construction of joints in the "fan" (Left: Book-binding screws, Right: Technical drawing of the fan assembly)

The fan assembly (Item 7) and its 90-degree braces (Item 10) allows the prototype to be collapsible and provide additional support whilst looking aesthetically pleasing. They ensure that the weighing assembly (Item 8) will remain perpendicular to the back assembly, standardising the field of vision of the depth camera mounted on the top assembly.

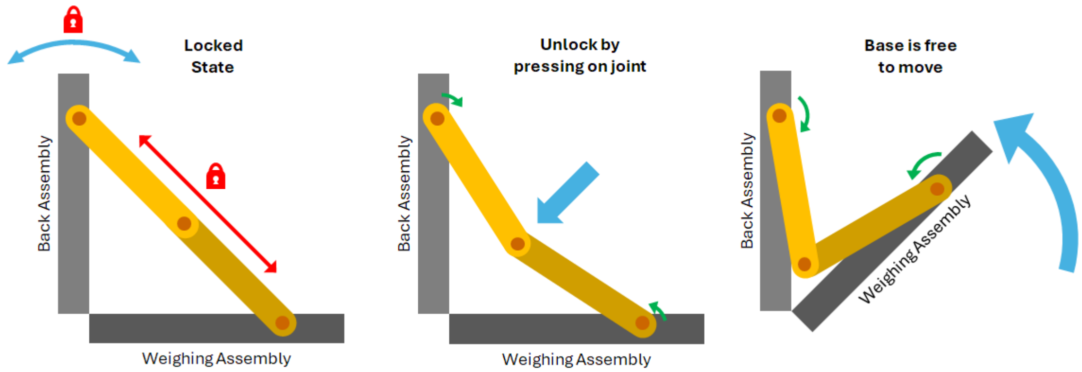


Figure 19: Working mechanism of the 90 degree locking braces.

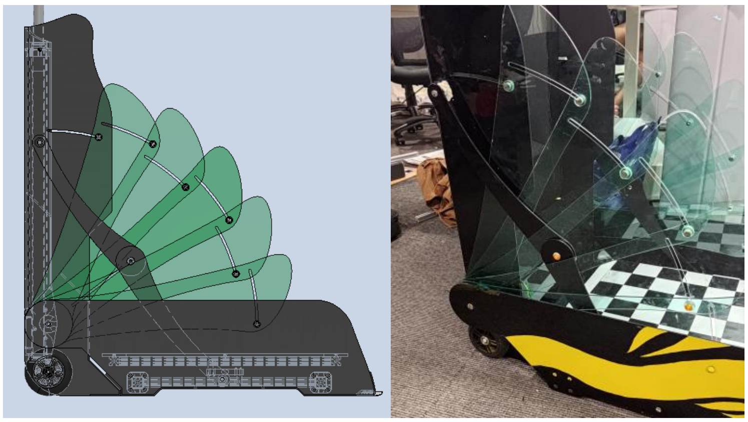


Figure 20: Integration of locking mechanism with the fan assembly.
(Left: Side view of model of mechanism, Right: Physical mechanism in final product)

The top assembly (Item 1) is fitted with a handle. When the prototype is fully collapsed, one can hold on to the handle and wheel it around. This ensures that Scoot's need for an easily portable machine which often needs to be relocated to differing boarding gates is met. Draw latches have also been installed on the main body that latches to the top assembly such that the machine does not accidentally open during relocating or storage.

The telescopic poles (Item 3) enables the prototype to be extended upwards to the maximum height of 3 metres such that the depth sensor camera, which is mounted into the top assembly, can overlook the luggage positioned beneath without obstruction and distortion, ensuring the accuracy of the camera and its measurement. The telescopic poles are locked and released by twisting each pole. This mechanism ensures the ground crew setting it up can comfortably and easily extend the poles without requiring external assistance. These are modified from an existing 80-200 cm telescopic laundry pole.

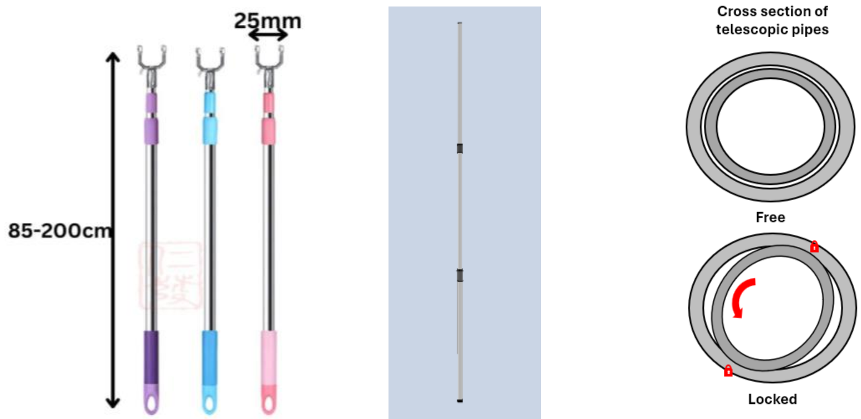


Figure 21: Telescoping pole
(Left: Original product from Lazada[1], Middle: CAD recreation of product, Right: Working principle of the telescopic pipes)

The LCD mount assembly (Item 4) is where the touch screen will be mounted to. The size of it has been carefully considered such that it does not interfere with other components when the prototype is collapsed. When the telescopic poles are fully extended, the screen will be raised to chest-level, ensuring that the machine operators can view the dimensions and weight values displayed comfortably.

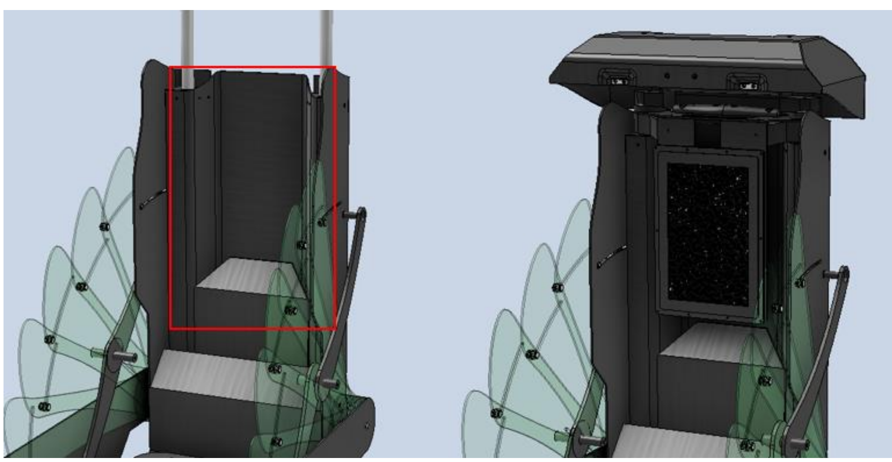


Figure 22: Recessed space in the body allocated for the screen when in the retracted position

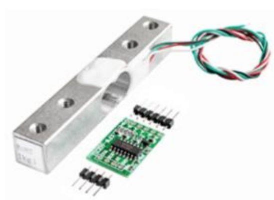
Electronics

The electronics went through many iterations before it reached the final prototype. The main components identified were 1) a microcontroller board 2) a digital load sensor 3) a camera with computer vision. There were many options in the market, and we borrowed electronics to test out to find the most compatible ones. Starting off with a Raspberry Pi 5 as the microcontroller board, a Kinect Azure for the camera and lastly a HX711 load sensor. This proved problematic as the Kinect Azure has very limited documentation online as it is a limited release developmental kit. Thus many other cameras such as the Intel RealSense and StereoPi were explored as they were better documented. Although the StereoPi had better compatibility with Raspberry Pi as it was based on the Raspberry Pi, it was hard to obtain. We thus went with the Intel RealSense which we loaned from a senior.

Figure 23: 3 Models of Computer Vision camera:
(Left: Kinect Azure, Middle: *Intel Realsense,* Right: *StereoPi)*

However, we once again encountered issues with compatibility between the camera and the microcontroller. The Raspberry Pi 5 was relatively new and had limited backwards compatibility with the camera, as such it was unable to download the libraries and recognise the camera. Similarly, the Raspberry Pi 4 was also incompatible with the camera. We eventually tried the Jetson Nano with more documentation of its connection with the Intel RealSense, successfully setting up the camera and the load sensor with the Jetson Nano[2]. For the Jetson Nano, we used a barrel jack connector to power the board as it allows for a higher supply of electricity to be able to power the Intel RealSense as compared to the traditional micro-USB method.

Figure 24: 3 Models of microcontroller boards:
(Left: Raspberry Pi 5, Middle: *Raspberry Pi 4,* Right: *Jetson Nano*



SoC GPIO	Linux GPIO #	Alternate Function	Default Function			Default Function	Alternate Function	Linux GPIO #	SoC GPIO
			3.3 VDC	1	2	5 VDC			
PJ.03	75	GPIO	I2C1_SDA	3	4	5 VDC			
PJ.02	74	GPIO	I2C1_SCL	5	6	GND			
PBB.00	216	AUD_CLK	GPIO	7	8	UART1_TXD	GPIO	48	PG.00
			GND	9	10	UART1_RXD	GPIO	49	PG.01
PG.02	50	UART1_RTS	GPIO	11	12	GPIO	I2S0_SCLK	79	PJ.07
PB.06	14	SPI1_SCK	GPIO	13	14	GND			
PY.02	194		GPIO	15	16	GPIO	SPI1_CS1	232	PDD.00
			3.3 VDC	17	18	GPIO	SPI1_CS0	15	PB.07
PC.00	16	SPI0_MOSI	GPIO	19	20	GND			
PC.01	17	SPI0_MISO	GPIO	21	22	GPIO	SPI1_MISO	13	PB.05
PC.02	18	SPI0_SCK	GPIO	23	24	GPIO	SPI0_CS0	19	PC.03
			GND	25	26	GPIO	SPI0_CS1	20	PC.04
PB.05	13	GPIO	I2C0_SDA	27	28	I2C0_CLK	GPIO	18	PC.02
PS.05	149	CAM_MCLK	GPIO	29	30	GND			
PZ.00	200	CAM_MCLK	GPIO	31	32	GPIO	PWM	168	PV.00
PE.06	38	PWM	GPIO	33	34	GND			
PJ.04	76	I2S0_FS	GPIO	35	36	GPIO	UART1_CTS	51	PG.03
PB.04	12	SPI1_MOSI	GPIO	37	38	GPIO	I2S0_DIN	77	PJ.05
			GND	39	40	GPIO	I2S0_DOUT	78	PJ.06

Figure 25: HX711 Load Sensor (left) and GPIO out pins (right)

Regarding the HX711 load sensor, there were problems initially due to the lack of library available and infrastructure on the Jetson Nano as we used an Ubuntu operating system instead of the more common Windows. To fix this, we coded our own class for the load sensor with functions and attributes to use as intended.

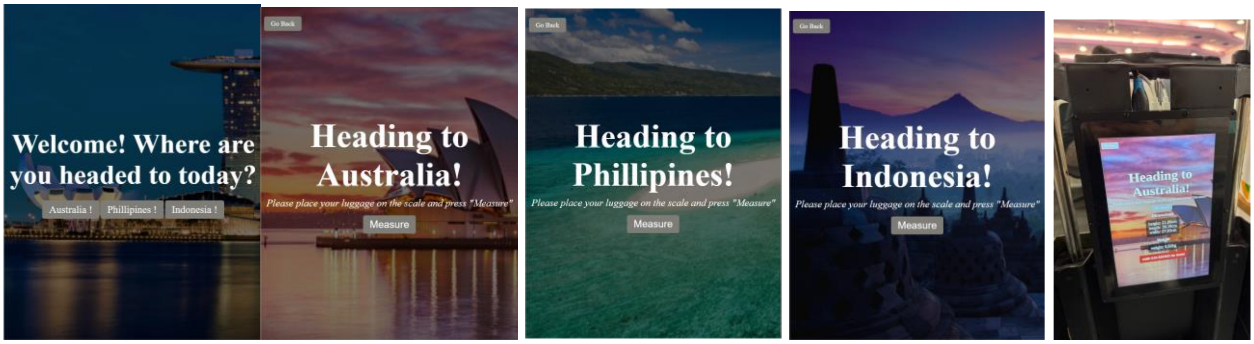


Figure 26: Flask App

For our prototype, we also decided to create a Flask app to have a simple and intuitive interface for the ground crew to operate the equipment. They simply select the country the flight would be travelling to set the background. Next, they will assist the passenger in loading their hand-carry and pressing on "Measure" once it is set down properly. The app will then display the dimensions and weight and indicate if the hand carry passes or exceeds the limitations set by the client.

Testing results

The overall weight of the machine is 10kg, meeting the requirement of it being light. With handles in place, it is also easy to pick up and carry when walking up and down steps. When rolled on different terrains such as gravel, carpeted and smooth floors, the machine can successfully cross over smoothly. When set up, and a luggage is loaded onto it roughly and haphazardly, the fan system that acts as a wall is able to withstand the rough handling and bends slightly under pressure but does not leave behind any scratches. The lock system works successfully and prevents the closing of the base.

The interface of the system is easily readable and easy to navigate, accurately measuring the weight of the object that is placed onto the base. Though the depth sensor camera has been calibrated, the light sensitivity and angle had not been accounted for, resulting in a marginal error of 5cm when taking the measurements of the luggage. In addition, the load sensor is not very consistent in measurements due to the mechanical nature of the load sensor, making it very sensitive to the location which you place the baggage at. When all the electronics are running at the same time together with the app display, there is occasionally a lack of power resulting in the flickering of the screen which must be solved by increasing the power supply.

5)Reflections

Lessons Learnt

Design

Most of the final prototype of the Hoverfly was made of laser-cut and bent acrylic, which was essential to realise its desired form. However, this did lead to some pain-points.

Expected fits and tolerances modelled in CAD software did not match up with the physical prototype by a large margin (up to 20mm), likely due to errors introduced by insufficiently accounting for the change in dimensions when bending acrylic. This led to several instances of gaps in parts that should have been flush, or laser-cut holes in the bent acrylic not lining up with 3D-printed parts.

Figure 27: A 20mm gap introduced after bending acrylic had to be filled in.
(Left: Computer model, Right: Physical prototype)

Acrylic was also significantly heavier than plywood in the final prototype, with each acrylic part weighing approximately 60% more than the equivalent plywood part, despite working with 3mm acrylic compared to 5mm plywood.

The stiffness and strength of acrylic was better than that of plywood, and this worked great for the construction of the fans, where the natural warping of plywood caused interference.

As the team could not source metal axles for the wheels in time, the final prototype features 3D-printed axles in PETG with an infill of 60%. Although they were expected to break quickly, the acrylic panel it was secured to, and the 3D-printed mount ended up flexing more than the axle itself. Thoughtful consideration of the rigidity of the whole system is therefore important.

Figure 28: Bending of the 3D-printed bearing holder (black) when a torque is applied to the wheel perpendicular to its axis.

In future weight-sensitive projects, a combination of extruded aluminium profiles, plywood framing, acrylic forms and 3D-printed parts would work well to achieve a desired combination of rigidity, weight, cost, and form.

Prototyping

We used a HX711 load sensor to measure the weight of the hand carry. This value is retrieved by measuring the tensile stress on the middle portion of the load sensor. As we placed only one load sensor in the middle of the board, this caused a lot of calibration issues as the placement of the object above the load sensor affected the readings depending on if it bends the load sensor forward or backward. The HX711 was also not very consistent with its readings making it hard to ensure accuracy in measurements. A good alternative would be using a pre-assembled digital weighing scale as they have already been properly calibrated, and it demonstrates our concept well. Another alternative would be to have four load sensors in each corner of the weighing base instead and take the sum of the readings.

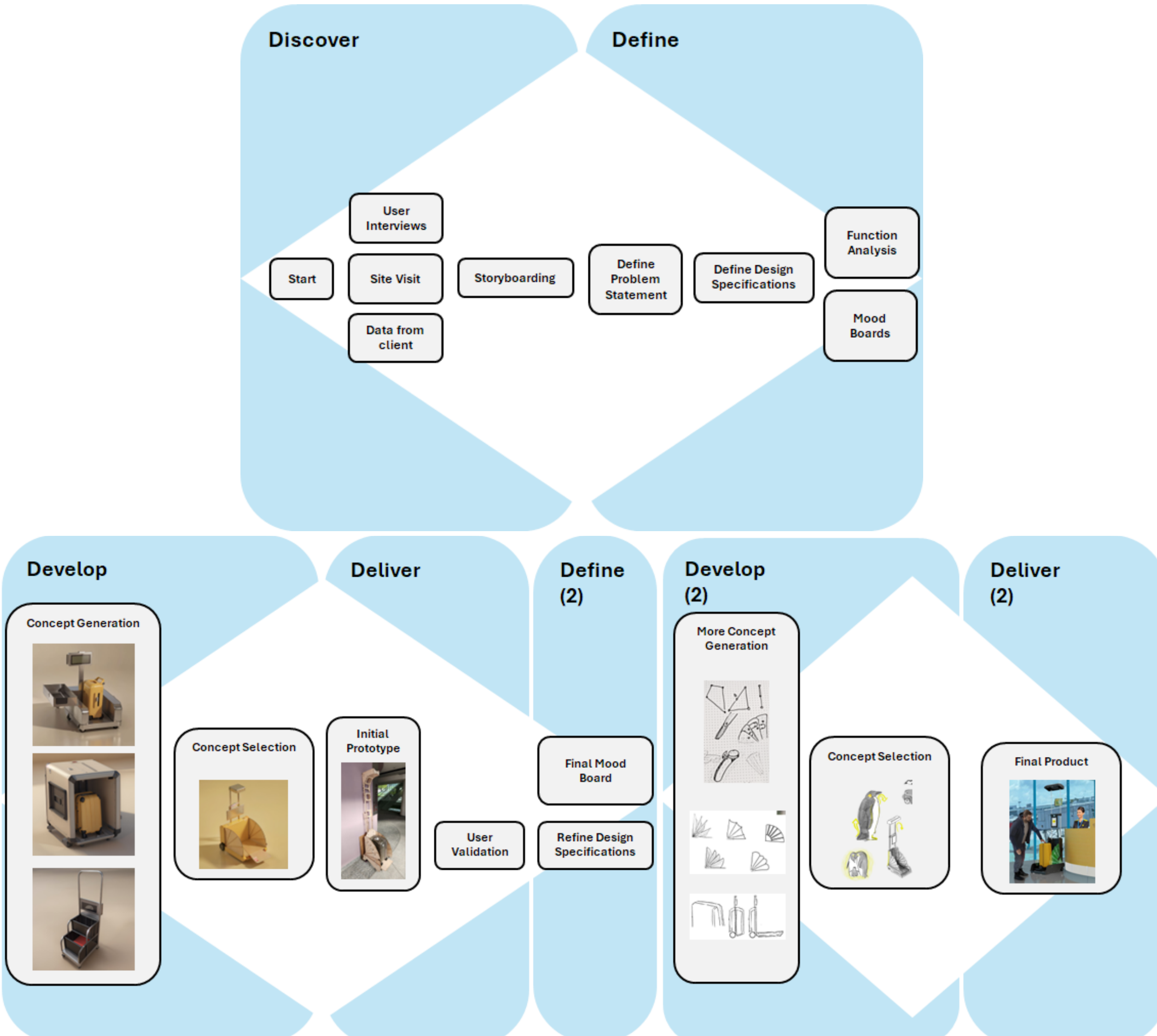
In addition, the camera we used required the checkerboard in order to calibrate to take accurate measurements. This resulted in the use of a chequered base which might not look the best aesthetically and any cosmetic damages to the base would result in calibration issues making the mechanism delicate. With more time, we would be able to better calibrate the camera such that the checkerboard can be removed, and the camera would still work well.

One thing to take note of for the Jetson Nano is the GPIO out pins. The numbers on the board itself does not correlate to the pinout values in code, we retrieved the correct reference pinout values online and "translated" every pinout from their original reference name to the one printed on the board itself.

During prototyping, we faced many problems along the way, and we learned to pivot from our original ideas and try something new until we find one that works. In hindsight, we should have conducted more research as to the compatibility between microcontrollers and depth vision cameras as some pairings work much smoother than others. In addition, we picked up many skills along the way to adapt to the problems that came our way such as cutting data cables apart and soldering them together to lengthen them, picking up a new coding language. Through prototyping, we were able to understand what are some parts that may or may not work as intended theoretically and how we can improve to better suit the client's needs. It works as a proof of concept of our idea, to communicate to our client how the product is able to solve their needs. Most importantly, we learned how it is normal to fail again and again and how to troubleshoot our problems and push through together.

Appendix

Appendix A



Interview Transcripts (excerpts)

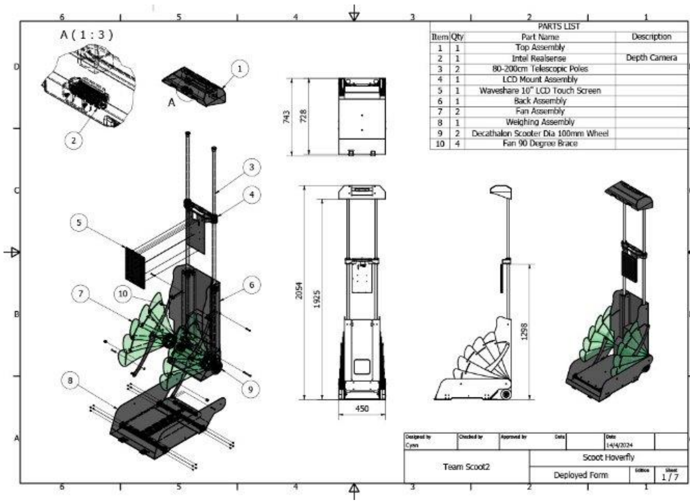
A ⇒ Senior Specialist Ground Operations ***M:*** What is the issue that Scoot is currently facing that requires our assistance? ***A:*** As it stands, our boarding and departure time has been experiencing many delays due to the issue of excessive	X L ⇒ Ground Staff ***M:*** What is the typical experience when dealing with travellers who have excessive baggage? ***X L:*** During our popular flight routes the place can get quite hectic - along with the type of baggage they bring. Typically, most of them disregard the	T ⇒ Cabin Crew T R ⇒ Cabin Crew in Charge ***M:*** How often do you come across excessive baggage? ***T:*** Passengers rarely use the current bag check unit and weighing scale when they're checking in. Even when they do, I'm pretty sure that they often attempt to squeeze their

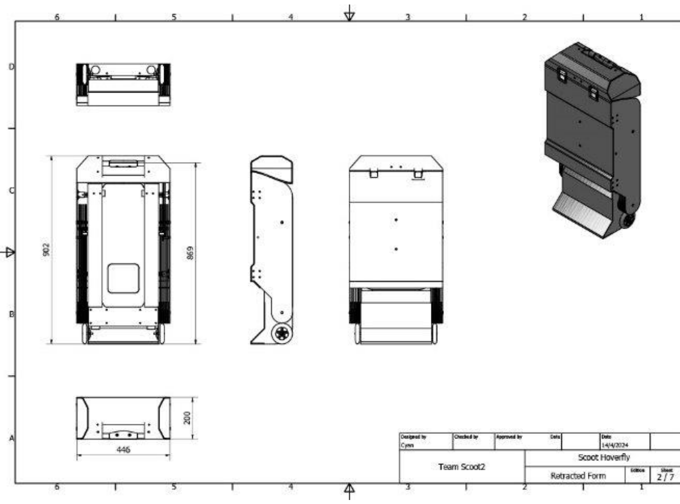
baggaging. Whether travellers are unaware of the baggage allowance or not, it has caused many issues when the crew have to stow away the baggage for takeoff. Due to the limited stowage space, the aircraft crew have to be tactical in how they keep passengers' baggage; it still results in leftover baggage having to be stowed away in the undercarry. Many times travellers will get into arguments with the staff due to their insistence to keep their baggage with them due to personal or medical reasons. We want a solution that helps to detect this excessive baggage early, preferably digitised so that it will deter any traveller arguments.	baggage allowance so it's quite common to see a lot of odd-sized baggage or multiple hand carry items likely bought from duty-free. When it comes to the boarding process, it gets worse when passengers show up late and they have big and odd sized luggage. As we need to tag the bags and wait for the cargo people, it takes up extra time and gets annoying when we need to depart on time.	bags into the box so that later on they can argue with us that their bags fit, despite being clearly odd-sized. Because of this, there have been times where the cabin crew gets injured trying to stow away their baggage. ***M:*** What is the typical experience when dealing with travellers who have excessive baggage? ***T R:*** Passengers on short flights and transit flights tend to save on paying for check-in so they bring everything in their big bags. To accommodate their bags in the overcarry, we must ask those with smaller bags to put it under their seats instead.

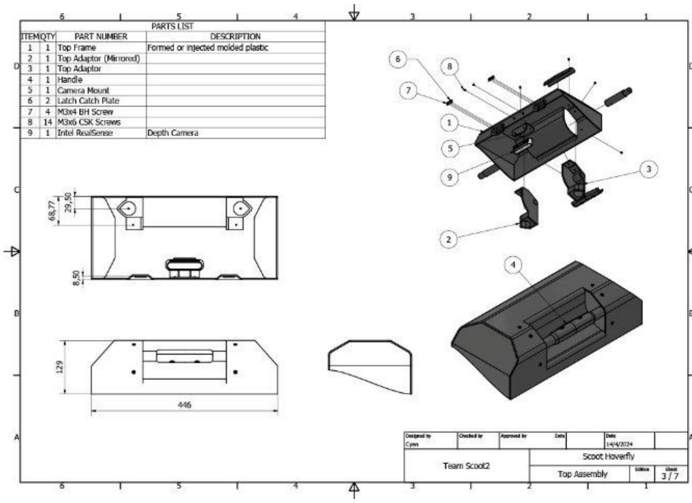
Scoot Carry-On Allowance

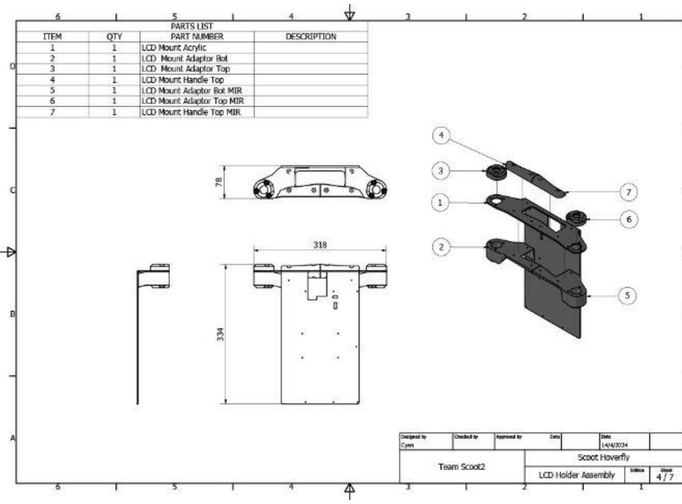
Storyboarding

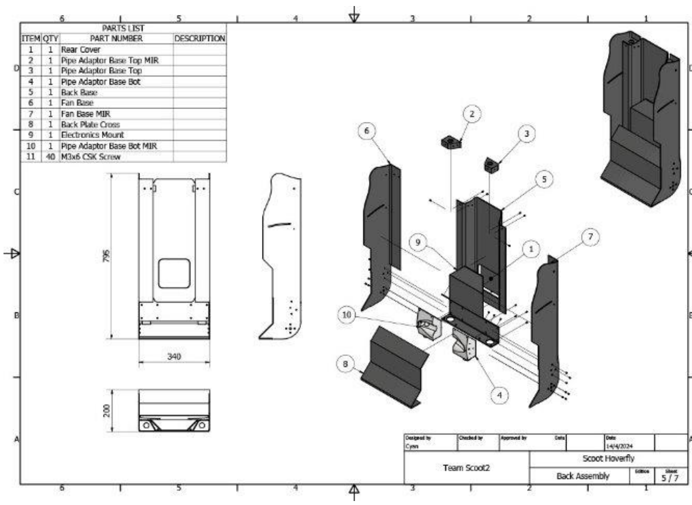
Assembly and part drawings

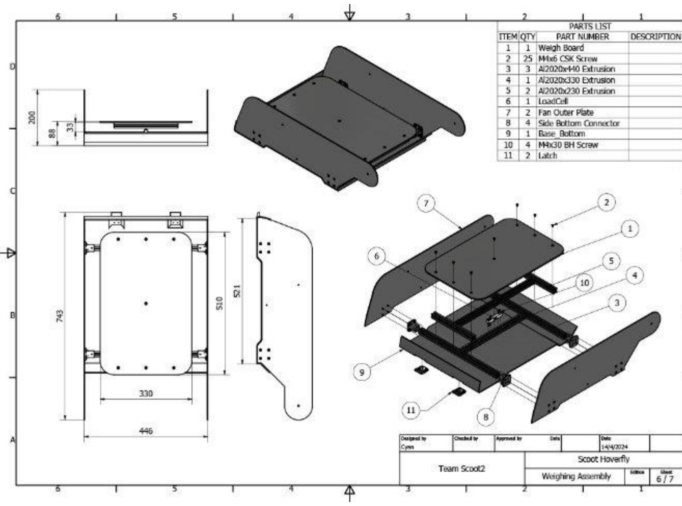


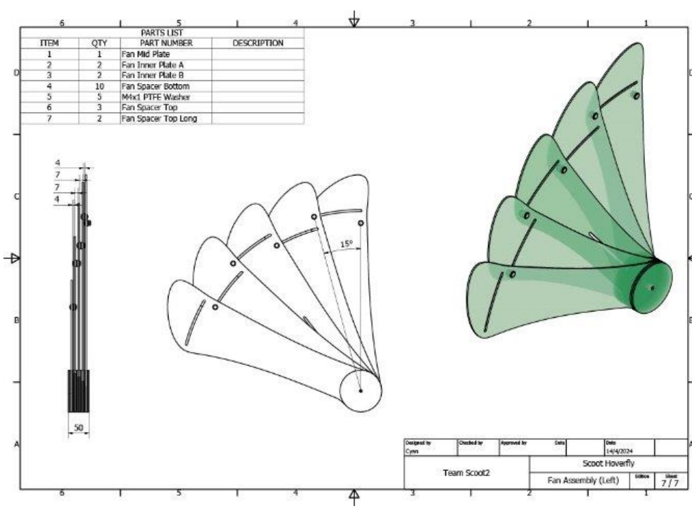




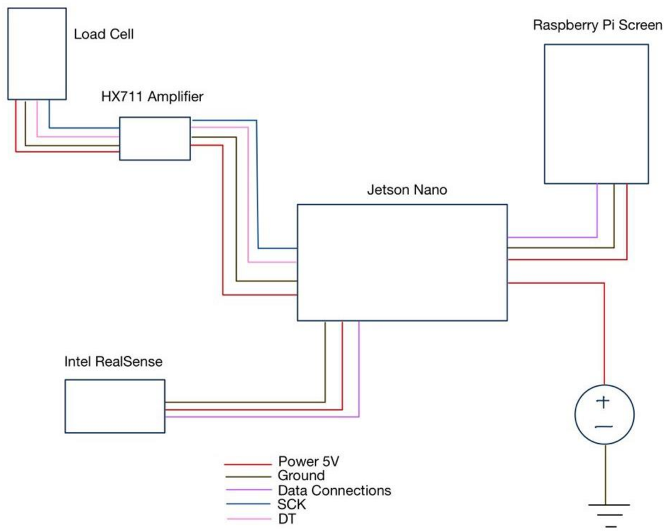








Circuit Diagrams



Programme/Code

Please refer to this link to the GitHub Repository containing all the code that we used for this project from the HX711 load sensor to the Intel Realsense to the Flask App.
https://github.com/hunchongtan/pds_trial

User Testing (Results)

Overall Scoot was quite happy with the end result as many of the features they had requested were accounted for in the final design. There were two handles to make it easier to raise the machine to its optimum height but also to make it easier to bring around and carry. The overall weight of the machine was also light enough to be carried up and down stairs without compromising the durability of the machine. Furthermore, the camera and weight sensor were also operational and decently accurate. The only qualms they had was that the digital interface where travellers log in their details to determine whether the baggage is excessive is a bit slow and could be faster.

References

[1](n.d.). *Telescopic Hanger*. Lazada. https://www.lazada.sg/products/telescopic-hanger-pole-fork-retractable-clothes-support-hooks-i2774536916-s19171011247.html

[2] (n.d.). *IntelRealSense / librealsense*. Github. https://github.com/IntelRealSense/librealsense