Milestone One Concept Memo

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Automatic Luggage Assistant (ALA)

IED Section: 6

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Problem Statement

Traveling is a difficult task to accommodate. Flights are no exception to this scenario and are arguably the most difficult form of long distance traveling to accommodate with comfort. The typical traveler already spends a significant amount of money on purchasing flight tickets alone not to mention food, checked baggage, and sometimes even seat preference. With this truth in mind, flight passengers are almost always inclined to find ways to save even more money. What many people turn to is traveling lighter, or cutting out easy costs.

Travelers are looking for flights with included carry-ons, carrying heavy backpacks themselves, or traveling with others to transport more belongings. To travel cheap is becoming an increasingly physical task. There is a huge sacrifice of comfort in order to perform our flying needs. With this ever increasing physical demand there is a larger barrier formed for elderly people, those with physical challenges, and even flyers with small children. These are just a few examples of potential flyers who have to cut comfort from their budget in order to make a flight, yet end up placing more burden on their already hectic travel plans.

Traveling should be a time of relaxation, there should not be a hurdle to overcome to begin feeling relaxed. For airline, and airport administrations, this is an issue that should be addressed as it disincentivizes potential travelers from making the decision to fly. Our proposed solution to this problem is a small and lightweight luggage carrier that automatically follows the user around.

Our solution, which we call ALA, will address the problem of users finding great struggle with carrying multiple backpacks and carry-ons with them in airports. Other than resolving this issue, we expect many more benefits with our design. Primarily is the lack of the need to purchase new baggage. The ALA device will be compatible with carry-on sized luggage and personal items that most travelers already have. In addition, we envision the unit being rented out at the airports. This means that flyers will be able to easily afford the ALA units and airports/airlines are able to make a profit off of them as well. Furthermore we expect this to incentivize travelers to explore the airports themselves and visit shops and restaurants more frequently. With ALA removing the challenge of carrying luggage for long walks across the airport, we anticipate travelers being open to seeing what other luxuries an airport has to offer such as lounges and restaurants.

Customer Requirements

Although ALA devices are helpful for all types of airport travelers they are particularly helpful for travelers with physical disabilities who have a more difficult time carrying around heavy luggage. Parents traveling with children would also find ALA helpful, as well as elderly travelers. Specified below is a table listing requirements and specification for both airports and travelers.

Table 1: Customer Requirements and Technical Specifications for Airports

Customer Requirement	Technical Specification	Target Value / Range of Values
Affordable	Unit Price	\$550-\$700
Safe	Speed	3mi/h-4mi/h
	Distance from receiver	2ft-3ft
Storable	Folded Size	3.5ft x 2.33ft x 0.7ft
Durable	Lifespan	5 years
Reliable	Capacity	150lb-200lb

Table 2: Customer Requirements and Technical Specifications for Travelers

Customer Requirement	Technical Specification	Target Value / Range of Values
Affordable	Rent Price	\$7.50-\$10.00
Safe	Speed	3mi/h-4mi/h
	Distance from receiver	2ft-3ft
Spacious	Unfolded Size	3.5ft x 2.33ft x 3.41ft
Efficient	Battery Life	8 miles
Reliable	Capacity	150lb-200lb

Concepts and Benchmarking

Benchmarking

There are two major kinds of automatic luggage assistant in the market. The team did some research on three of them.

Figure 1: Cowarobot Auto-follow Smart luggage

The first kind of product in the market aims at private use. These products are improved from normal suitcases. An automatic-follow feature is added to the suitcase allowing it to follow the customers around wherever they go.

Cowarobot developed one of such suitcases, called Auto-follow Smart Luggage (Figure 1). It costs 700 dollars, which is a lot more expensive than a normal suitcase. It knows where the customers are and sends an alert when the customers are 6 feet away. It comes with a 92Wh battery which allows the product to travel a maximum distance of 12 miles. Furthermore, customers can charge their phones using the product while it follows the customers around.

Figure 2: FLEET Autonomous Baggage Robot

Figure 3: SITA’s Baggage Robot

The second kind of product in the market aims at public use. These products are mainly owned by airports. These products do not fully implement the auto-follow feature, but instead follow a fixed routine.

FLEET Autonomous Baggage Robot (Figure 2) aims at aiding travellers checking in luggage. Travellers can use a touch screen to identify their airline and the robot will transport the luggage to the corresponding baggage belt. It can handle about 450 bags per hour.

SITA’s Baggage Robot (Figure 3) is similar to FLEET but has some more functions. It can carry up to 2 luggage with a maximum load of 32 kg. It can also help to check-i and transport the luggage onto the correct flight. However, SITA’s robot is able to work in all areas of the airport, so it is capable of detecting the surrounding environment and avoiding colliding with other people or objects.

Table 3: Concept Selection Matrix

Design	Cowarobot Auto-follow Smart Luggage	FLEET Autonomous Baggage Robot	SITA’s Baggage Robot
Price	-1	1	1
Capacity	-1	1	0
Portable	1	-1	0
Power	-1	1	1
Safety	1	0	0
Sum of +1	2	3	2
Sum of -1	3	1	0
Sum of 0	0	1	3
Net Score	-1	2	2
Rank	2	1	1

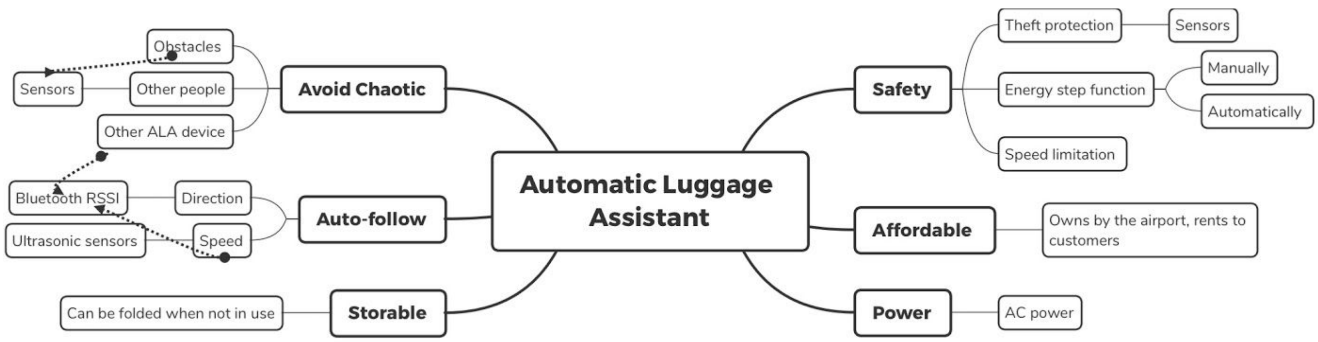
Compared to a normal mid-tier suitcase which costs around 100 dollars, an auto-follow smart suitcase costs about 7 times the price of a normal one, which means most of the customers are not able to afford such a suitcase. Furthermore, the battery inside the smart suitcase utilizes a lot of space and also limits the capacity of the suitcase. The FLEET robot has a suitable capacity and is free to use as an airport facility, however, has limited features. It can only follow a fixed routine for check-in from the specific service counter to the baggage load area. The SITA's Baggage Robot is similar to the FLEET robot but is more developed. SITA's robot is able to work in all areas of the airport due to the auto-drive function. But the function device also limits its capacity and the size that is too large to work in the busy area after security check. And like FLEET, the SITA's robot also has the crucial problem that it's only used for baggage check-in.If customers still have a lot of belongings after security check or they need assistance for baggage claim, they are not able to use the product.

The team plans to improve the above two designs and develop an automatic luggage assistant which is owned by the airport and is capable of following the customers around.

Mind Maps

Figure 4: Mind Maps

The team considers six aspects which are crucial to the design of our product.



- First of all, ALA should fully implement the auto-follow function, which means it should be able to determine the direction and speed by itself.
- Private suitcases which have auto-follow functions are expensive for customers, so the team aims at selling the products to the airports and airports can rent the service to customers.
- Airports are usually crowded. ALA should not add more pressure to the heavy traffic at the airport. A speed limit is set to ensure the product is controllable. Under emergency situations such as getting into a huge crowd of people, ALA should be able to stop automatically or manually. What's more, since the ALA will carry the luggage while following the customers, customers cannot see if their luggage is safe on ALA. Thus, a sensor should be used to detect if anyone other than the customer attempts to get the luggage.
- Situations in airports can be very complex. The ALA device may collide with an obstacle, other people or other ALA devices. Because of that, ALA should be able automatically avoid these cases.
- Spaces in airports are limited. Normal luggage carts can be stored easily and take very little space. ALA should also satisfy this requirement. It can be folded when not in use.
- Power supply is crucial to electrical products like ALA. Moving with heavy suitcases carried costs a lot of energy and the product should not suddenly run out of battery halfway. A sustainable, rechargeable and safe battery should be used on ALA so it can support all of the operations as well as be friendly to the environment.

Proposed Solution

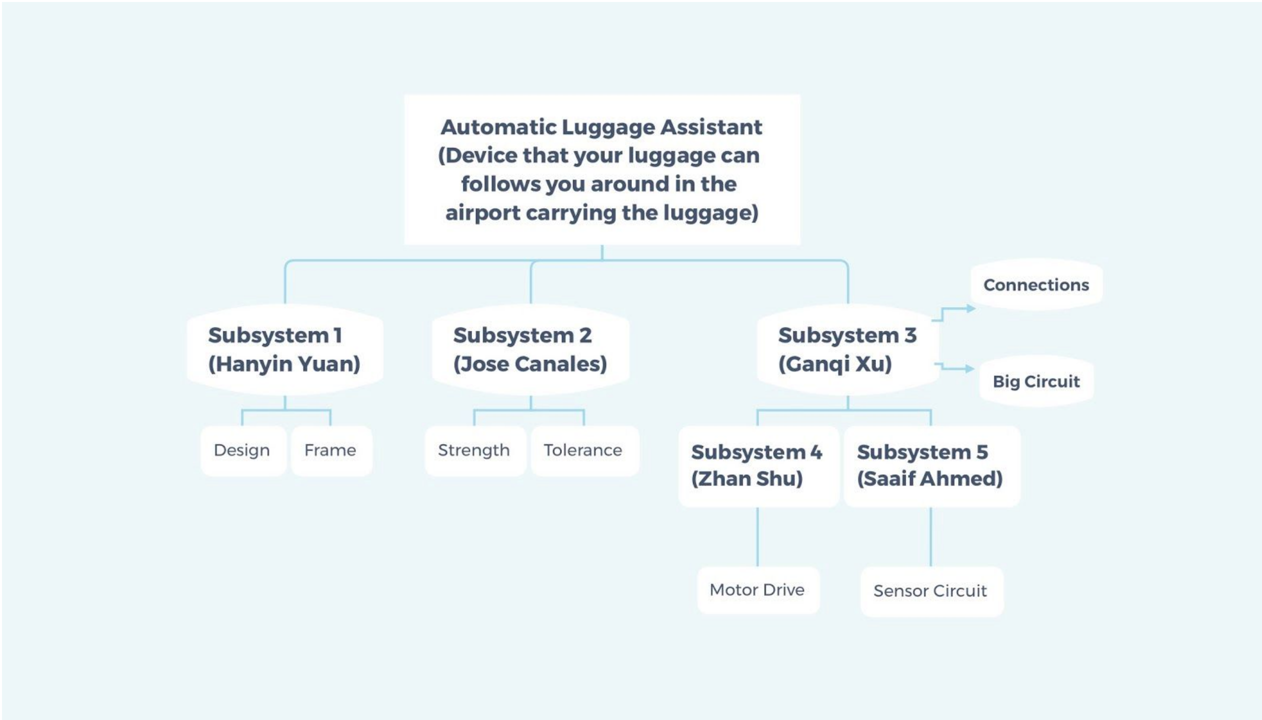


Figure 5: Subsystem Hierarchy Diagram

- **Subsystem 1--- Model and Frame:**

The overall design of the luggage cart looks like figure 6. After the team does some research on the luggage, there are four different sizes. The smallest one is 18 inches and the largest one is 30 inches. The most standard checked bag can measure(length+width+height) on the outside is 62 inches. This includes the handles and wheels. Due to the size and weight limits for checked bags, the length, width, and height of the automatic luggage assistant should be 3.5ft(43inches)*2.33ft(28inches)*3.41ft(41inches). The minimum load of the cart is 150lb because each passenger can carry two baggage(140lb) and sometimes they may have one more bag with them.

The basic idea for the design is the ALA should not occupy too much space and it can easily move. The luggage assistant should be open from two sides to slide the luggage inside and should have some space for advertising. The sensors should be placed on both sides which are the blue part below. The panels can fold when the cart is not in use and the design is intended to use space as economically as possible(figure 7).

Figure 6: Overall sketch

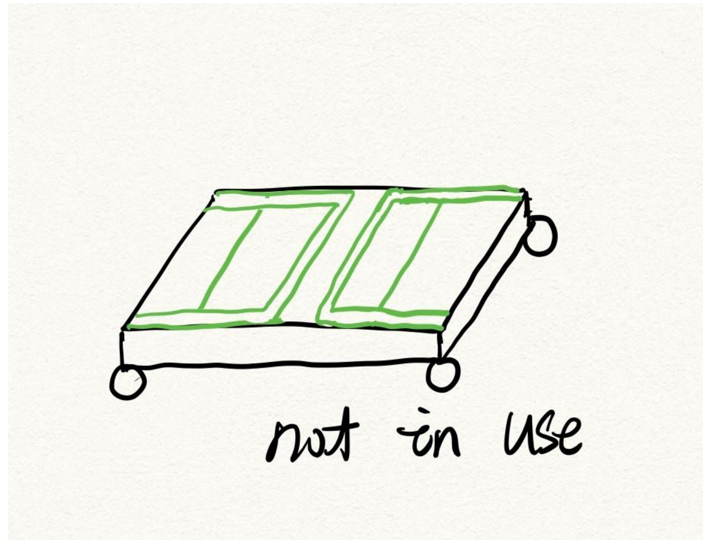
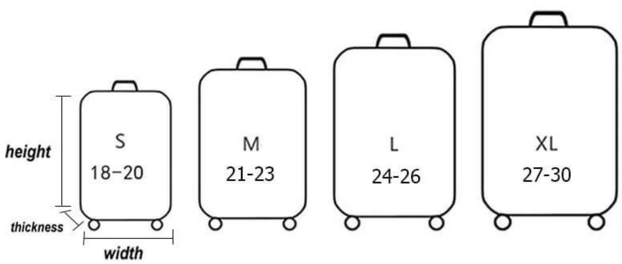


Figure 7: Overall sketch when the cart is folded



size	Suitable Size
S	18-20 Inch
M	21-23 Inch
L	24-26 Inch
XL	27-30 Inch

height	width	thickness	Recommended size	weight
48-53 cm	32-35 cm	20-23 cm	S 61*51cm	0.16G
56-61 cm	37-40 cm	23-25 cm	M 67*60cm	0.23G
63-67 cm	42-47 cm	26-27 cm	L 75*66cm	0.28G
69-75 cm	48-52 cm	27-31 cm	XL 86*70cm	0.36G

Note: height does not include wheels

Class of service	Maximum weight per bag
United Economy®	50 lbs. (23 kg)
United Business®; United First® United Polaris® business class	70 lbs. (32 kg)

Figure 9: Different size of luggage

Figure 8: Maximum weight for passenger

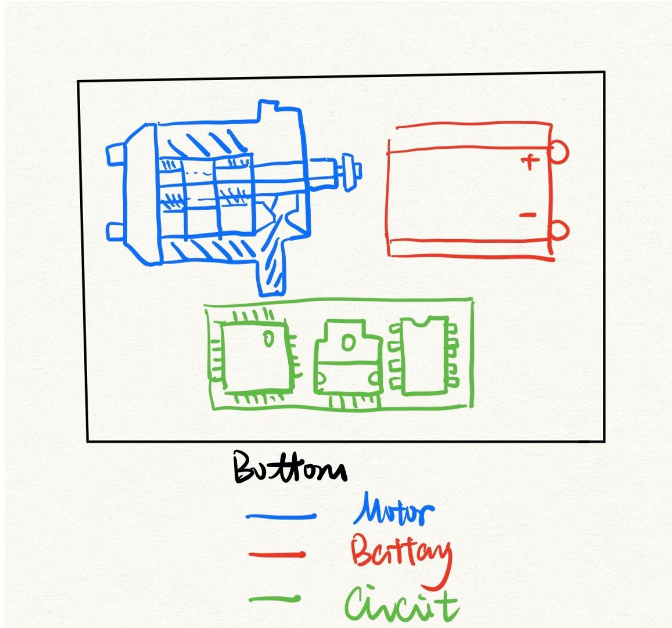


Figure 10: Inside of the bottom of the ALA.

The above diagram is roughly drawing about the motor, battery, and the circuit. These three parts will be inside the bottom of the carts. The team will do the actual sketches and models in the future.

- **Subsystem 2--- Material and Strength Calculations:**

Table 4: Material Comparison

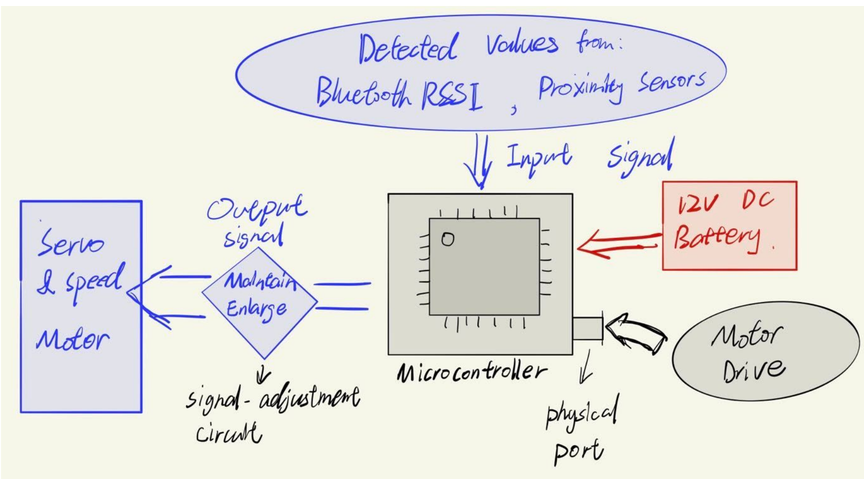
Material	Steel	Aluminum
Price	1	0
Weight	0	1
Durability	1	0
Strength	1	0
Total	3	1

Based on an analysis of material options, steel and aluminum were the best options. When comparing properties of both steel and aluminum our team decided to use steel as the material for our physical frame due to its cheaper price and high strength. Our team will conduct an analysis and simulation of strength and capacity of steel frame designs under different load cases in order to determine the most efficient frame design and maximum capacity of the physical frame as well as durability of the device as a whole. Maximum capacity of the frame will be compared with maximum weight capacity of motors and wheels in order to determine overall capacity of the device.

- **Subsystem 3--- General Circuit:**

The inside circuit has the main function to interact with the outside signals and send feedback to control the motion of the device. The basic circuit structure is built up by Bluetooth signal detector, Proximity sensor, speed-controlled motors, Microcontroller, and other required components(including power source and physical ports).

The whole circuit is powered by a 12V DC Li-ion battery (capacity in 20AH to 50 AH). While in working (after the Microcontroller send out a start signal), the detected values of Bluetooth RSSI and Proximity sensors result will be the analog input signal that sent to C8051 microcontroller and analyzed by Motor drive program, the program will immediately give out a feedback signal to go through a buffer and amplifier to maintain and enlarge the values, so the output values can be used to adjust the servo-motors & speed-motors with suitable direction and speed.



The Motor drive program is downloaded to Microcontroller through the physical ports on device

Servo-motors: a paired motors for setting heading direction

Speed-motors: a paired motors for setting device speed

Figure 11: General Circuit Structure

- **Subsystem 4 --- Motor Drive**

The device gets inputs from ultrasonic sensors and Bluetooth. Based on the inputs, the program should assign pulse width to servo motors and speed motors. ALA should be able to maintain a fixed distance from the user and it can avoid obstacles. There are three ultrasonic sensors and one Bluetooth receiver on the device. The Bluetooth signal keeps track of the user. The front sensor detects the front environment and slows down if there are any obstacles in the way. Left and right sensors are used to detect if there are any other people on the left or right side of the device. As they move closer to the device, it will slow down and turn a bit in the opposite direction. The left and right sensors are also used to determine direction. Specifically, if the left distance is smaller than the right distance, it turns left. If the right distance is smaller than the left distance, it turns right. The pulse width assigned to the motors is calculated using proportional control. Basically, two separate linear equations are assigned to the pulse width of motor and servo. Depending on the reading of the sensors and Bluetooth, the device is able to slow down if the target gets closer and speed up if the target gets further. Similarly, the device is able to turn gradually when the target turns. Using proportional control, the device is able to respond linearly depending on the surrounding environment.

- **Subsystem 5 --- Sensor Circuit**

The ALA device will utilize Bluetooth sensors in order to perform position and location tracking. The sensors themselves have an inherent method of determining distance between transmitter and receiver. This is known as RSSI or Received Signal Strength Indication. In short, the strength of the signal is received and outputted onto a logarithmic scale.

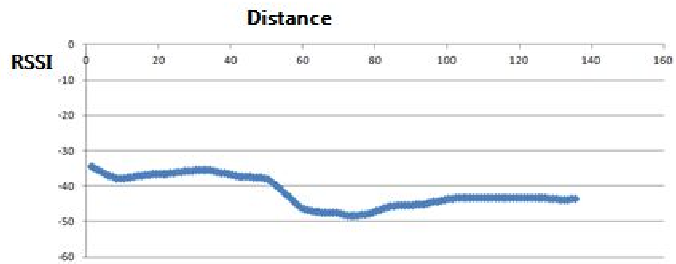


Figure 12: Proximity and RSSI

As shown in the figure above the RSSI values are able to correlate with distance between bluetooth devices. The sensors will send their input to the overarching circuit and the motor drive circuit. There are a few things to note. Based on the bluetooth sensor, a different RSSI value may be calculated. The bluetooth transmitter must be calibrated for the receiver associated with it. However when the device is calibrated we are able to use techniques such as finding the mode, and noise filtration to accurately determine distance within a 1 meter range between transmitter and receiver.

1 meter is still quite a large range for the ALA unit to follow behind. Therefore once the ALA unit is within 1 meter, it will switch to ultrasonic detection. These sensors are very accurate at small distances. Within 1 meter, the reasonable assumption is made that no large objects will be in the way of the user. We can use the speed of sound in order to determine how far the device is as stated in Elec Freaks Manual on the HC-SR04 ultrasonic sensor.

Project Plan

Table 5: Gantt Chart

Project Name	Status	Owner	Start	End	8-Jun-20	9-Jun-20	10-Jun-20	11-Jun-20	12-Jun-20	13-Jun-20	14-Jun-20	15-Jun-20	16-Jun-20	17-Jun-20	18-Jun-20	19-Jun-20	20-Jun-20	21-Jun-20	22-Jun-20	23-Jun-20	24-Jun-20
Team Standards Agreement	100%	Saaif, Jose, Ganqi, Hanyin, Zhan	6/12/2020	6/12/2020																	
Brainstorming and choose the	100%	Saaif, Jose, Ganqi, Hanyin, Zhan	6/12/2020	6/19/2020																	
Research	100%	Saaif, Jose, Ganqi, Hanyin, Zhan	6/19/2020	6/24/2020																	
Define Subsystems	100%	Saaif, Jose, Ganqi, Hanyin, Zhan	6/19/2020	6/20/2020																	
Propose possible solutions	100%	Saaif, Jose, Ganqi, Hanyin, Zhan	6/20/2020	7/8/2020																	
Create M1 presentation slide	100%	Saaif, Jose, Ganqi, Hanyin, Zhan	7/8/2020	7/10/2020																	
Rehearse M1 presentation	100%	Saaif, Jose, Ganqi, Hanyin, Zhan	7/10/2020	7/10/2020																	
Present M1 presentation	100%	Saaif, Jose, Ganqi, Hanyin, Zhan	7/10/2020	7/10/2020																	
Create M1 memo	30%	Saaif, Jose, Ganqi, Hanyin, Zhan	7/10/2020	7/14/2020																	
Adjust and make improvements to subsystems	0%	Saaif, Jose, Ganqi, Hanyin, Zhan	7/10/2020	7/14/2020																	
Work through subsystem 1: strength, materials, calculations	0%	Jose	7/14/2020	7/24/2020																	
Work through subsystem 1: sketches, CAD	0%	Hanyin	7/14/2020	7/24/2020																	
Work through subsystem 1: Bluetooth	0%	Saaif	7/14/2020	7/24/2020																	
Work through subsystem 1: sensor and motor circuit	0%	Ganqi	7/14/2020	7/24/2020																	
Work through subsystem 1: Coding	0%	Zhan	7/14/2020	7/24/2020																	
Combine Subsystems	0%	Saaif, Jose, Ganqi, Hanyin, Zhan	7/24/2020	7/31/2020																	

Materials

Table 6: Parts List

Need/Function	Part Type	Part Name	Price (Estimated)	Retailer
Physical Frame	Metal Frame	Plain Steel	$135	Home Depot
Mobility	Wheels	Uline Flat Free Pneumatic Wheel - 300lb capacity	$31	Uline
Locating	Sensor	SMS-BTA	$100	Vernier
Power source	DC battery	12V 30AH Lithium Ion Battery	$100	Lithium Battery Company
Moving device	Motor	BLDC MOTOR	$120	NANOTEC
Processing	Micro-Controller	C8051	$99	SILICON
Sensor	Bluetooth Sensor	HC-05	$7	Banggood
Sensor	Ultrasonic Sensor	HC-SR04	$4	Sparkfun
TOTAL			$477	

References

Cowarobot Auto-follow Smart Luggage.

<https://www.amazon.com/Cowarobot-Auto-follow-Luggage-Suitcase-Charging/dp/B07P4D5JR1>

FLEET autonomous baggage robot.

<https://www.businesstraveller.com/business-travel/2019/07/14/robots-to-aid-passengers-checkin g-in-luggage-at-dallas-fort-worth/>

SITA's Baggage Robot.

<https://www.sita.aero/pressroom/news-releases/sitas-baggage-robot-lends-passengers-a-hand-a t-geneva-airport>

Travel luggage

<https://encompassrl.com/products/travel-luggage-protective-cover-basic-art-dark-ripples

https://www.united.com/web/en-us/content/travel/baggage/checked-baggage.aspx?POS=US>

Tires

<https://www.uline.com/Product/Detail/H-5454/Casters-and-Wheels/Uline-Flat-Free-Pneumatic-W heel-300-lb-Capacity-10?pricode=WA9542&gadtype=pla&id=H-5454&gclid=CjwKCAjwr7X4BRA4 EiwAUXjbt80CrAcMXZVIJunnhQts9oCqKEkoD1itTRIdeN5CSBJ7q1SPPLyfWRoC1jYQAvD_BwE &gclsrc=aw.ds>

Steel

<https://www.homedepot.com/p/Everbilt-48-in-x-1-1-4-in-x-1-16-in-Plain-Steel-Square-Tube-8012 97/204325636>

Proximity and RSSI

<https://www.bluetooth.com/blog/proximity-and-rssi>

Elec Freaks - HCSR04

<https://cdn.sparkfun.com/datasheets/Sensors/Proximity/HCSR04.pdf>